Particle identification and multi-particle tracking properties at SAMURAI magnetic spectrometer

Hideaki Otsu (RIKEN Nishina Center)

Expert Meeting for Fragment Separators
at Grand Rapids
on Aug. 31, 2016

Contents today

- SAMURAI overview
  - Recent activities

- Details for Particle Identification property
  - PID at A~132
    - ^{132}Sn (p,n) exp. : SAMURAI17
    - Achievements and Problems
  - J. Yasuda (Kyushu U.)

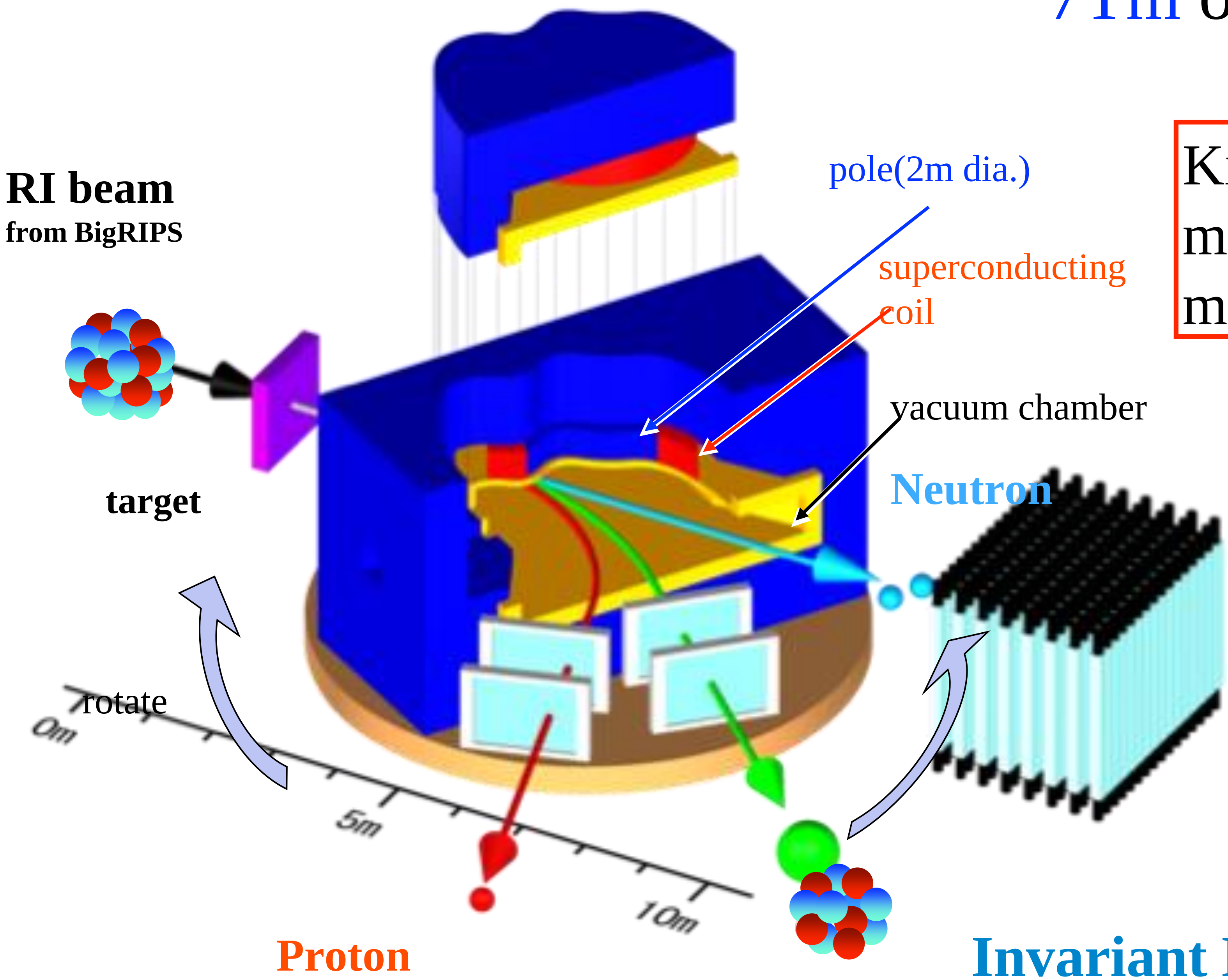
- Details for multi-track property
  - 2 charged particle detection at Focal plane
    - ^{16}C(α,α')^{16}C* $\rightarrow$ ^{4}He+^{12}Be : SAMURAI08
  - S. Koyama (U. Tokyo)

- Summary

SAMURAI
~ Large Acceptance Spectrometer in RIBF ~

Construction ~ 2011
Commissioning : 2012/03
First experiments : 2012/05

Superconducting **A**nalyzer for **MU**lti-particle from **RA**dio **I**sotope Beam with 7Tm of bending power

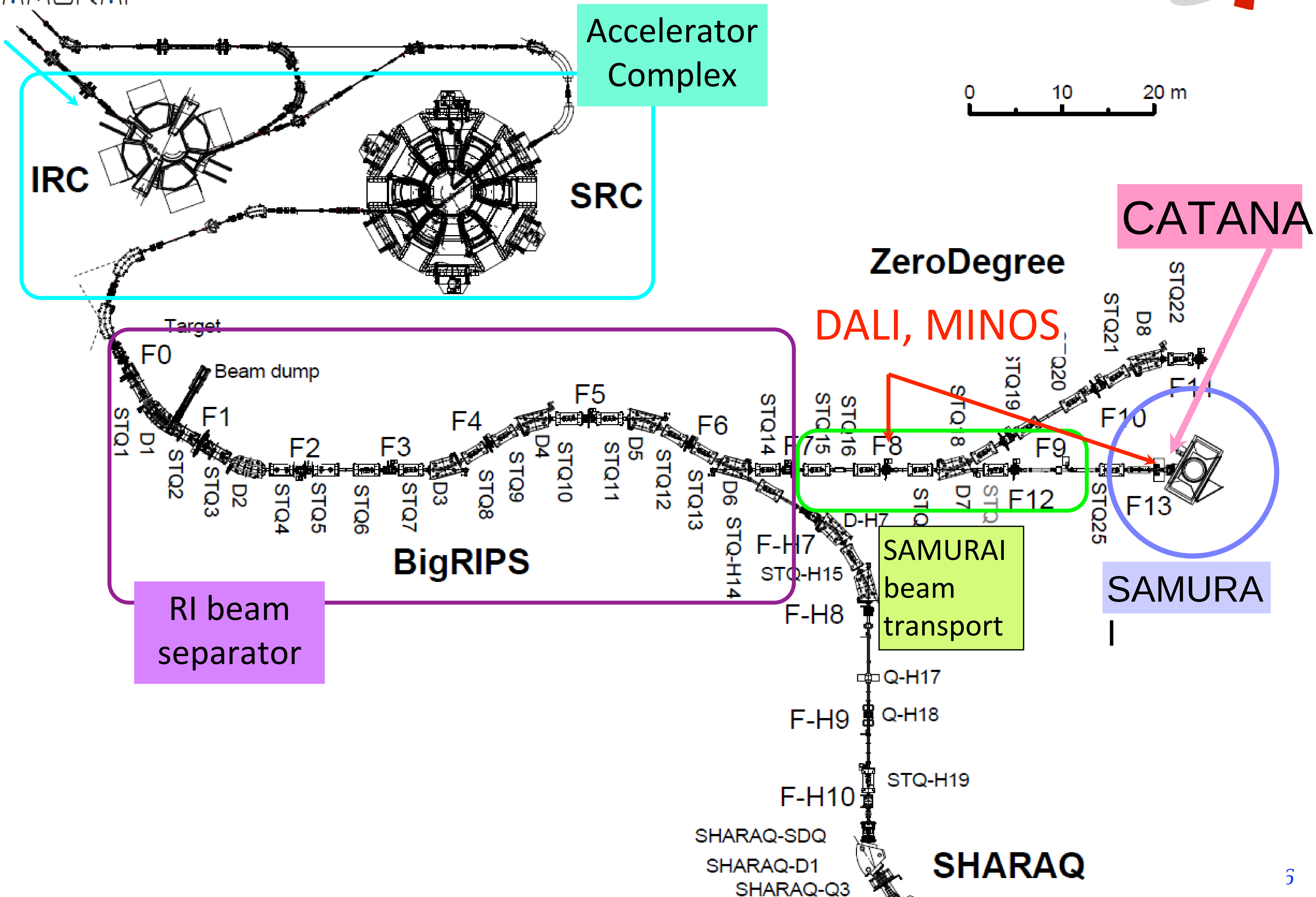


Kinematically complete measurements by detecting multiple particles in coincidence

- Superconducting Magnet
  3T with 2m dia. pole
  (designed resolution 1/700)
  80cm gap (vertical)
- Heavy Ion Detectors
- Proton Detectors
- Neutron Detectors
- Large Vacuum Chamber
- Rotational Stage

Invariant Mass Measurement
Missing Mass Measurement

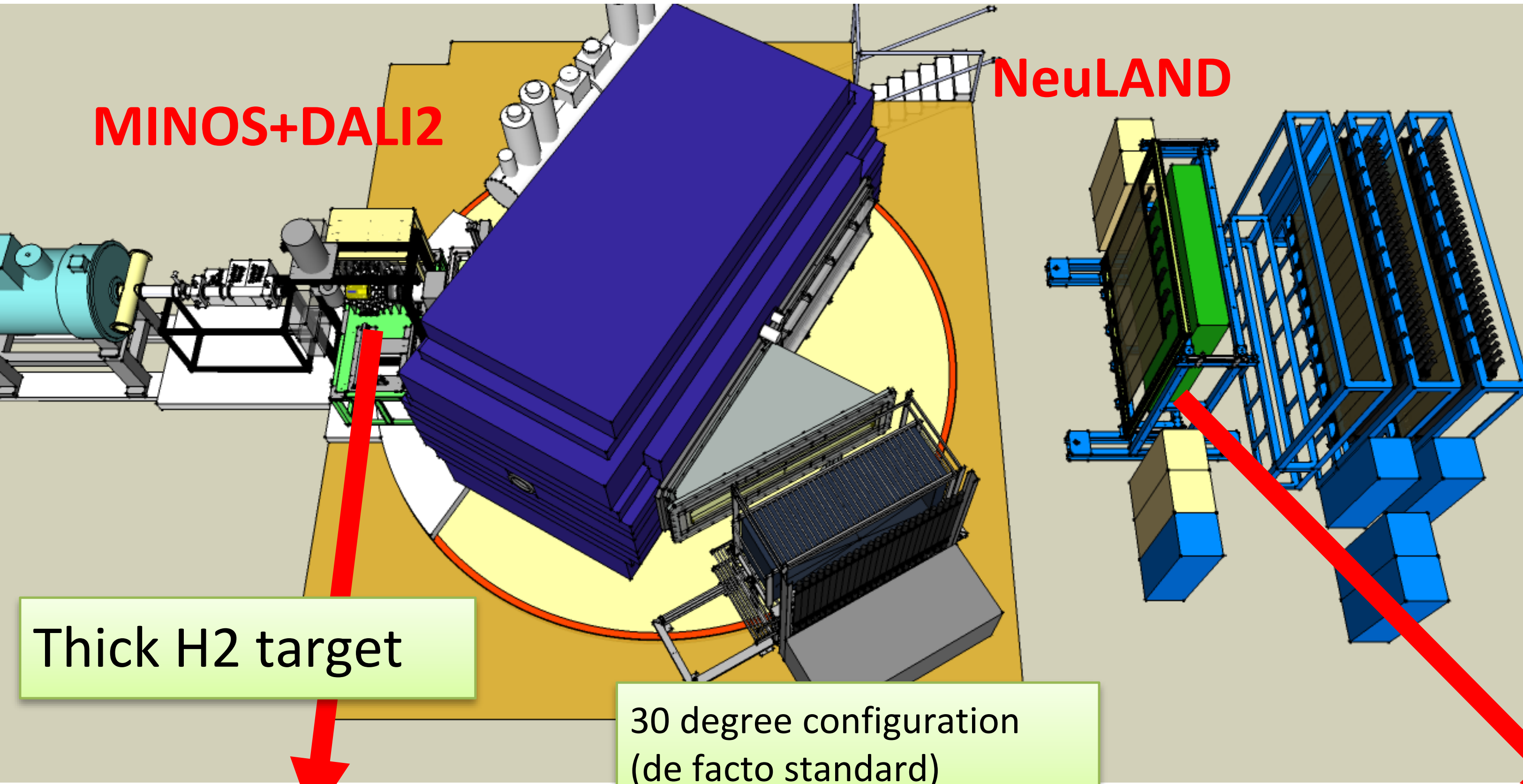
Design Drawing : H. Ueno
Slide: K. Yoneda


Accelerator Complex
IRC
SRC
0 10 20 m
CATANA
ZeroDegree
DALI, MINOS
Target
F0
Beam dump
F1
F2
F3
F4
F5
F6
F7
F8
F9
F10
F11
F12
F13
STQ1
D1
STQ2
STQ3
D2
STQ4
STQ5
STQ6
STQ7
D3
STQ8
STQ9
D4
STQ10
STQ11
D5
STQ12
STQ13
D6
STQ-H14
STQ14
STQ15
STQ16
STQ18
STQ19
Q20
STQ21
D8
STQ22
D7
STQ25
D-H7
F-H7
STQ-H15
F-H8
Q-H17
Q-H18
F-H9
STQ-H19
F-H10
SHARAQ-SDQ
SHARAQ-D1
SHARAQ-Q3
SHARAQ
BigRIPS
RI beam separator
SAMURAI beam transport
SAMURAI

Recent Activities

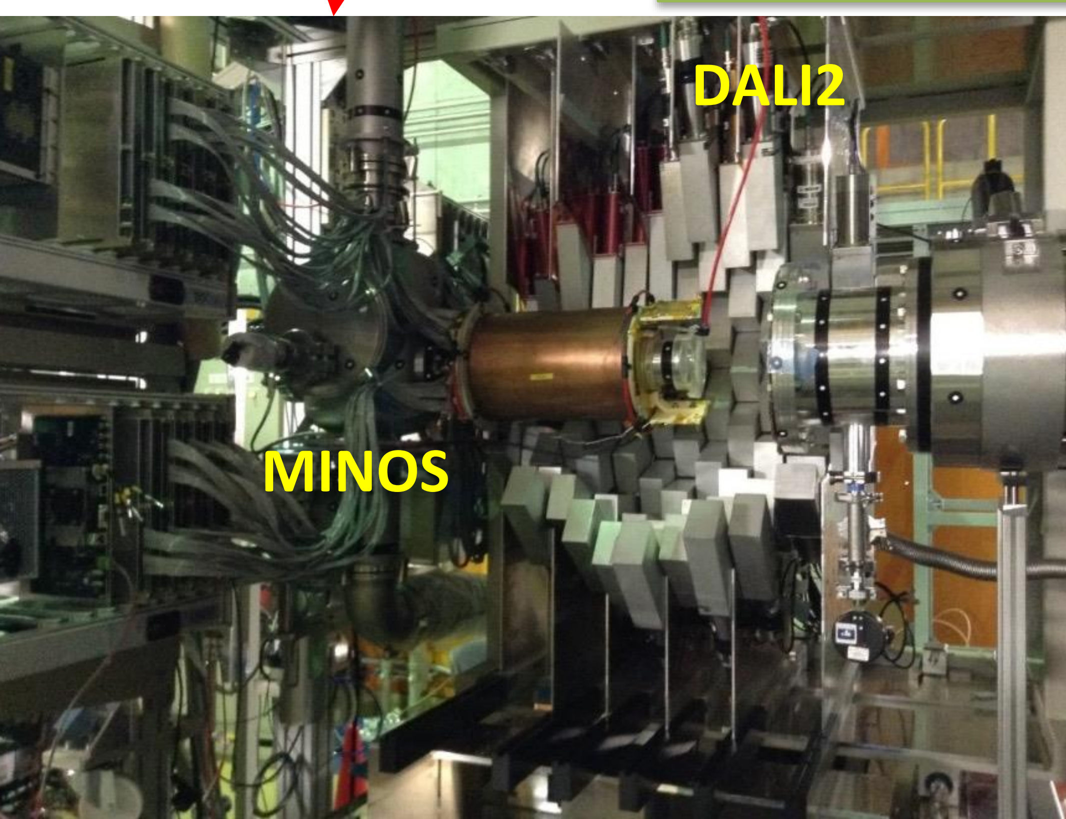
SAMURAI21 : Spectroscopy for $^{27,28}O$
SAMURAI + MINOS + DALI2 + NeuLAND
in Nov-Dev 2015

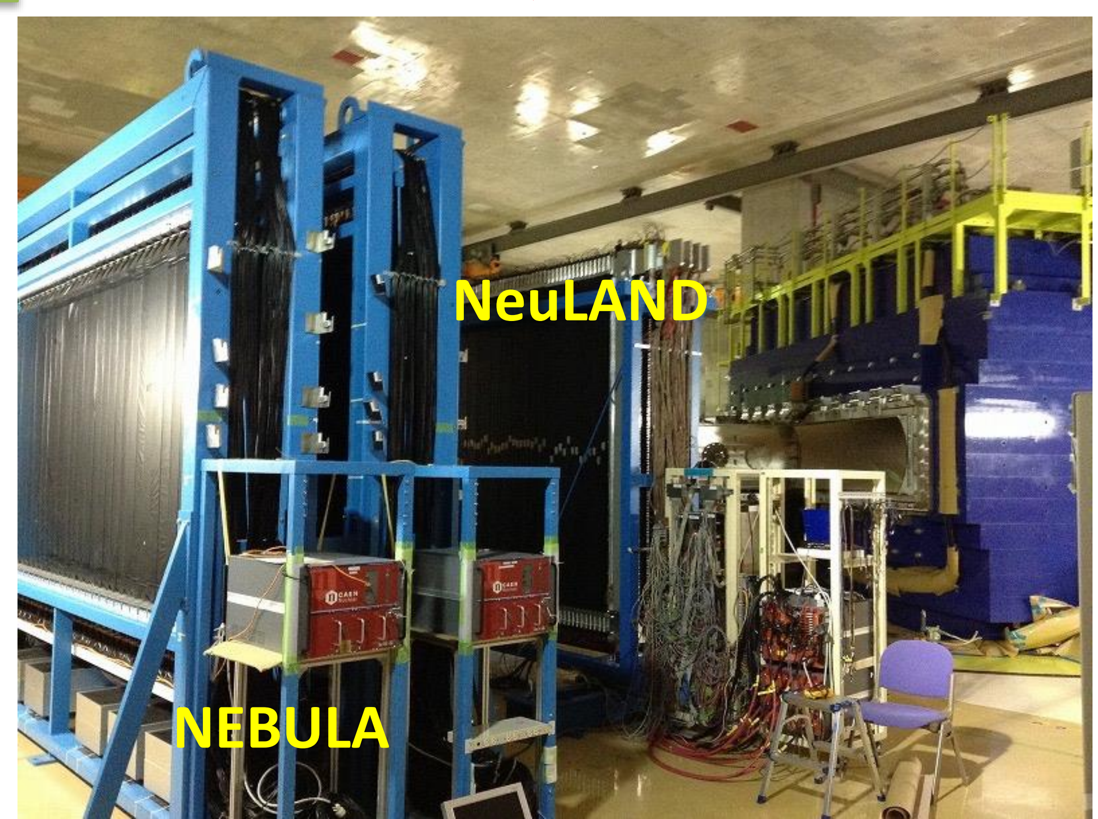
Spokesperson : Y. Kondo



- Successfully done with good collaboration
  - 88 participants from 25 institutes

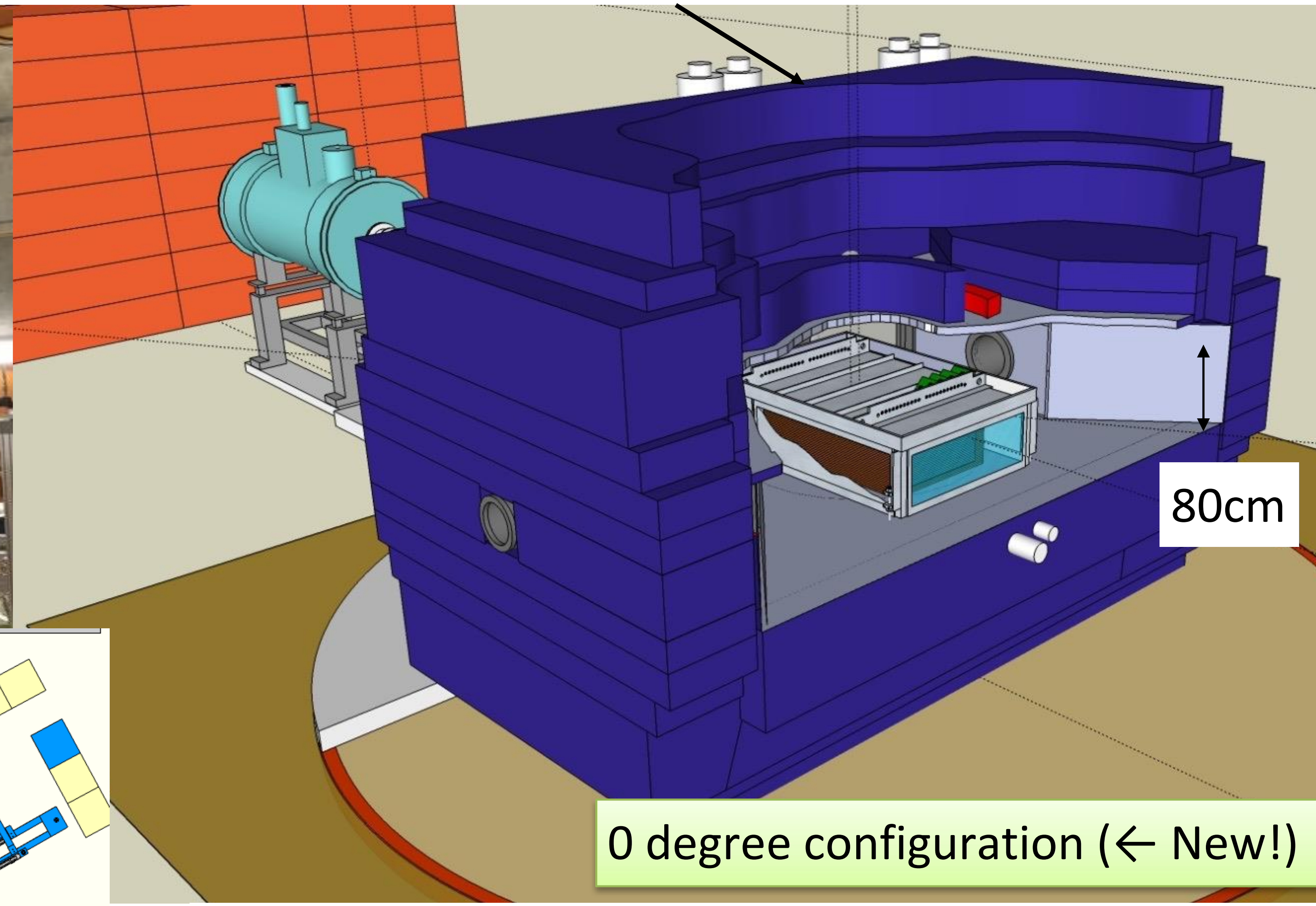
40(NeuLAND)+48(NEBULA) cm thick neutron detector array for 4n detection

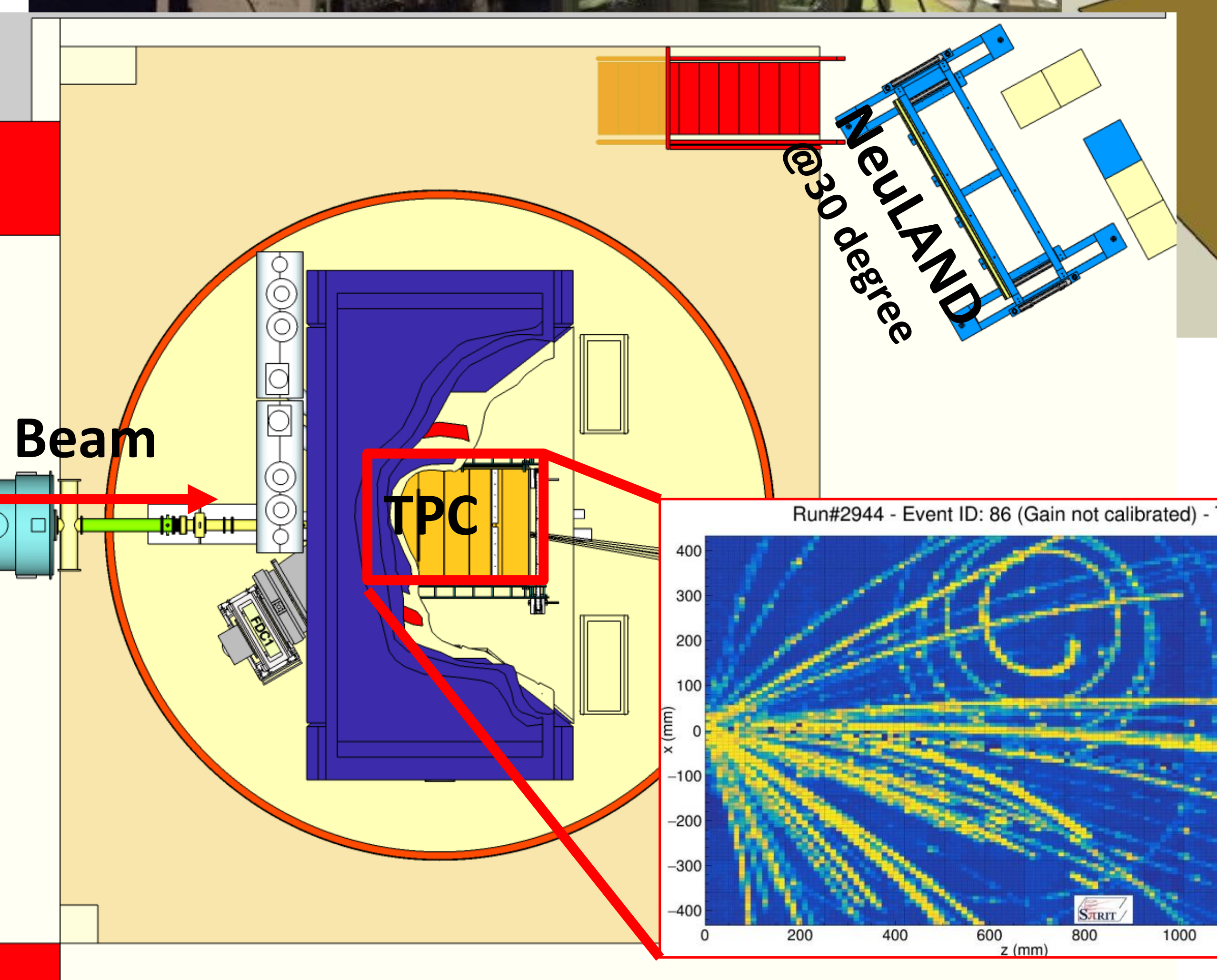




SAMURAI15+21 : SPiRIT: EOS program w/ Time Projection Chamber in SAMURAI in Apr-May 2016

Slide by T. Isobe





Heavy RI collision experiment at SAMURAI with a time projection chamber (TPC) from MSU together with new neutron detector (NeuLAND) from GSI.

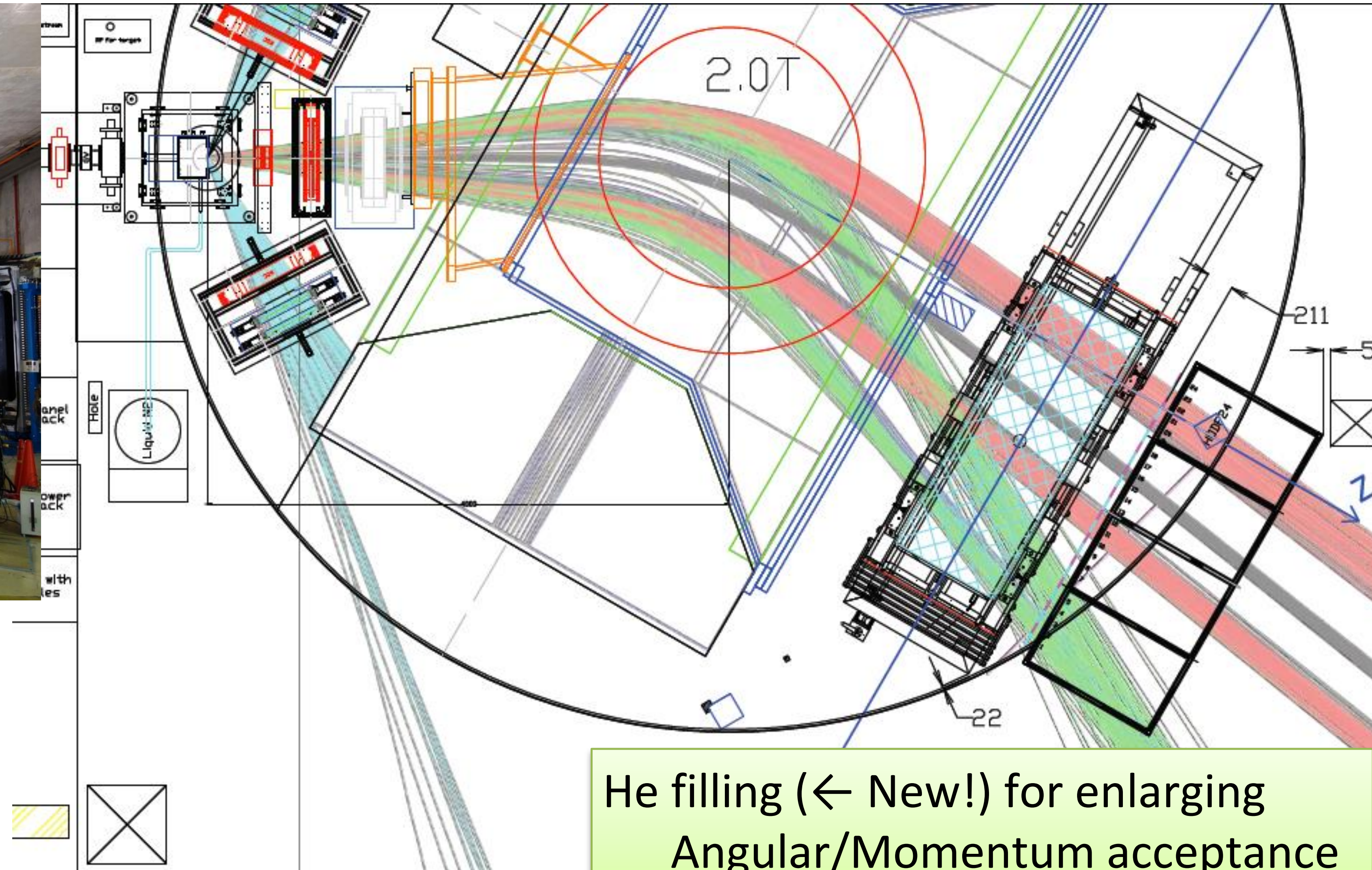
0 degree configuration for the detection of positive/negative pions.

SAMURAI TPC : NIMA 784 (2015) 513

SAMURAI13 : ^{6}He(*p_pol,p*)
Polarization experiment at SAMURAI

Spokesperson : S. Sakaguchi

on June 2016



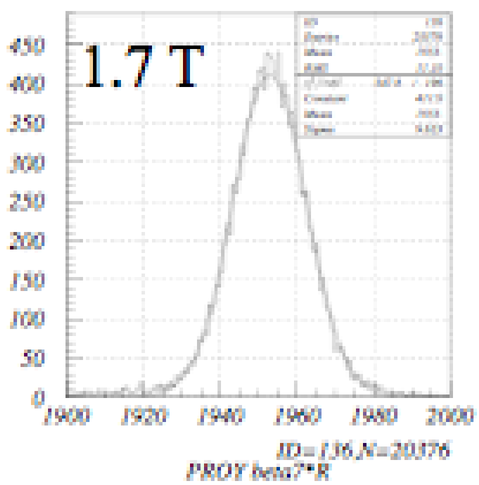
He filling (← New!) for enlarging Angular/Momentum acceptance

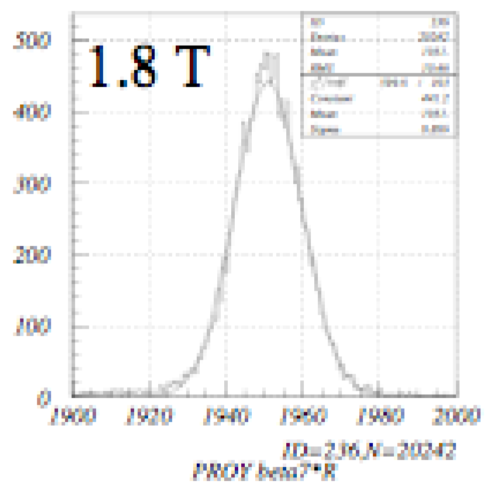
- Measurement:
  - Vector analyzing power for *p*-^{6}He elastic scattering at 200 MeV/A with polarized proton solid target
- He filling in SAMURAI gap chamber
  - FDC2 can cover 6He and 4He (Momentum acceptance)
  - Enlarge angular acceptance : ()
  - Utilized on light ion reaction / HI-p exp.

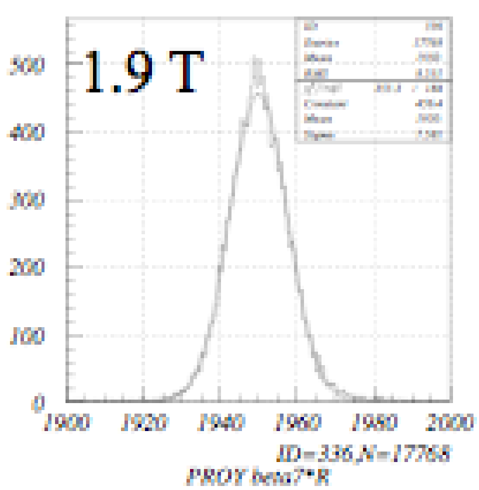
Momentum reconstruction on He filling mode (SAMURAI13)

Analyzed by T. Kobayashi

- Detector position
  - geometry from drawing. PGM is not used yet.
- B= 1.7 T (run113), 1.8 T (run115), 1.9 T (run117)
  - ^{6}He ~200 MeV/u, beam goes through FDC2 & HODF24
  - matching (deviation) @FDC2
    - vertical position : $\langle \Delta Y \rangle \sim$ 0 mm, $\sigma_{\Delta Y} \sim$ 10 mm
    - horizontal angle : $\langle \theta_H \rangle \sim$ -6 mrad (?), $\sigma(\theta_H) \sim$ 2.5 mrad
    - vertical angle : $\langle \theta_V \rangle \sim$ 0 mrad, $\sigma(\theta_V) \sim$ 4 mrad
  - reconstructed rigidity







→ Rigidity [MeV/c]

- beam TOF correction : very small effect
  - mainly depending on the small bending angle(?)
- FDC2 resolution @2.2 kV
  - σ(FDC2-X)~ 390 μm, σ(FDC2-U,V)~ 310 μm
- central value, rms width, & resolution
  - B= 1.7 T :
    - $\langle R \rangle \sim$ 1953, $\sigma_R \sim$ 9.6 MeV/c, $\sigma/R \sim$ 0.49%
  - B= 1.8 T :
    - $\langle R \rangle \sim$ 1951, $\sigma_R \sim$ 8.9 MeV/c, $\sigma/R \sim$ 0.46%
  - B= 1.9 T :
    - $\langle R \rangle \sim$ 1950, $\sigma_R \sim$ 7.6 MeV/c, $\sigma/R \sim$ 0.39%
- resolution becomes better for higher field

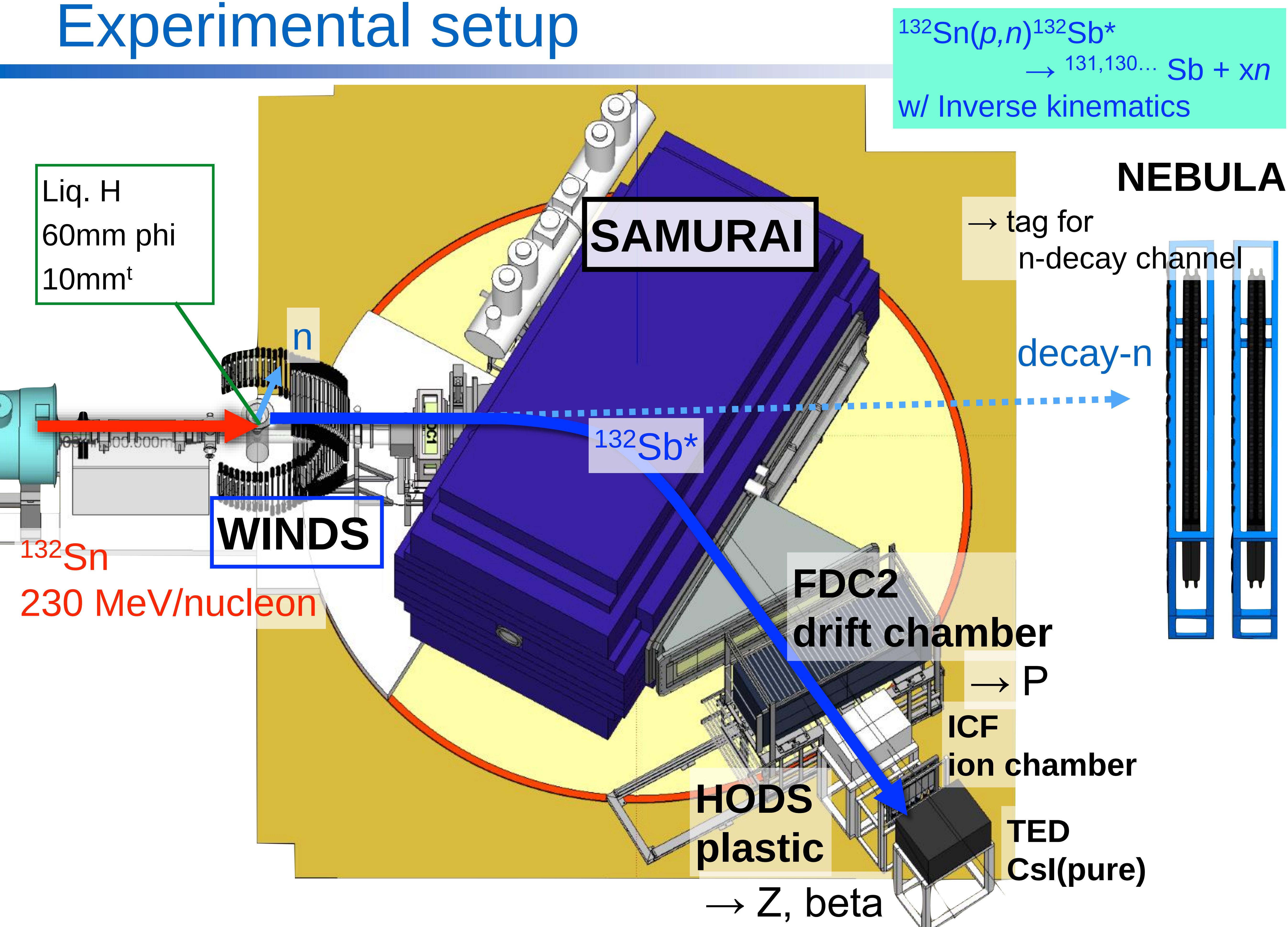
$\sigma_p/p \sim 1/256$ @ 1.9T

2016

Heavy Ion particle identification properties

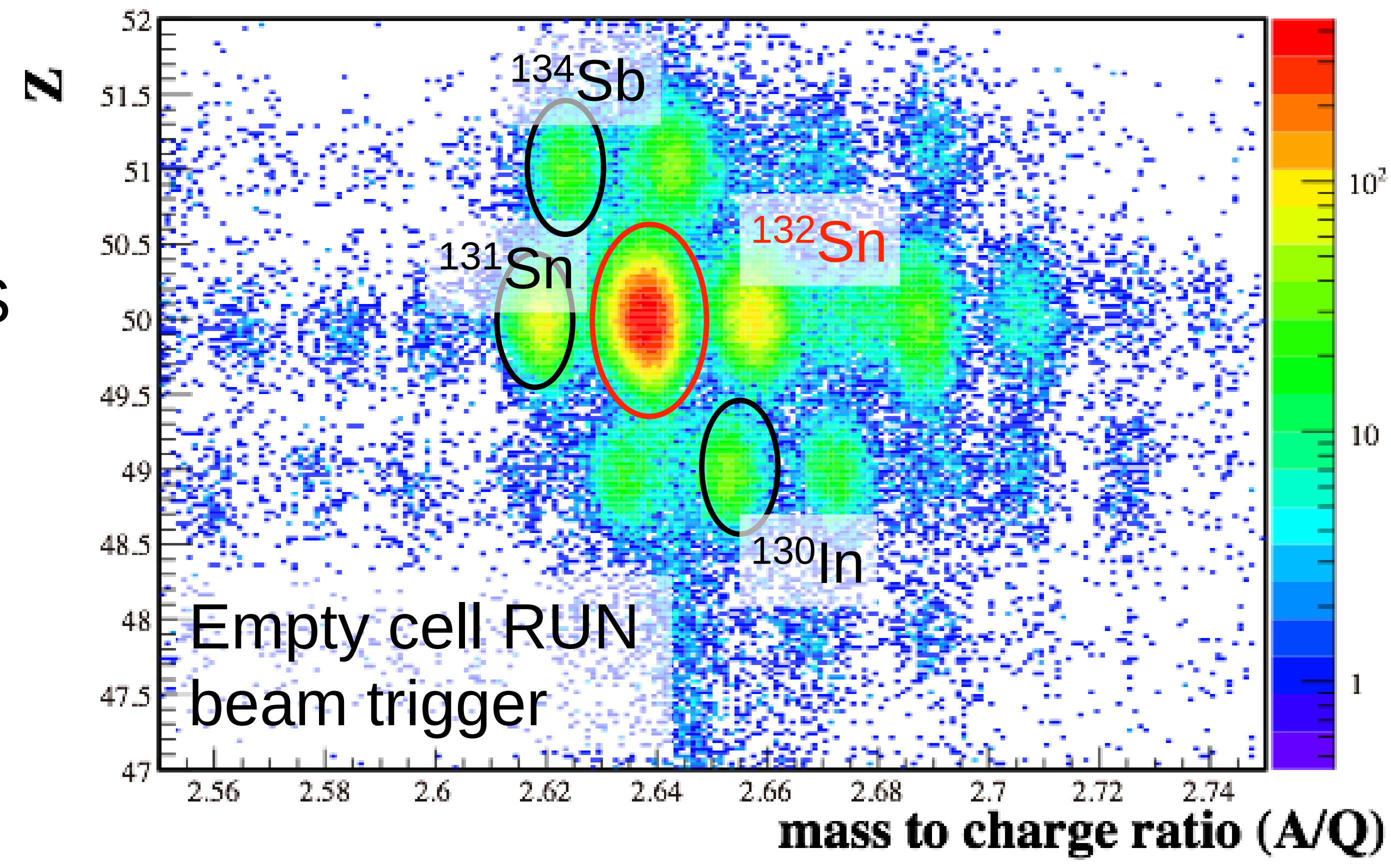
SAMURAI17 : Analysis by J. Yasuda (Kyushu U.)

Experimental setup

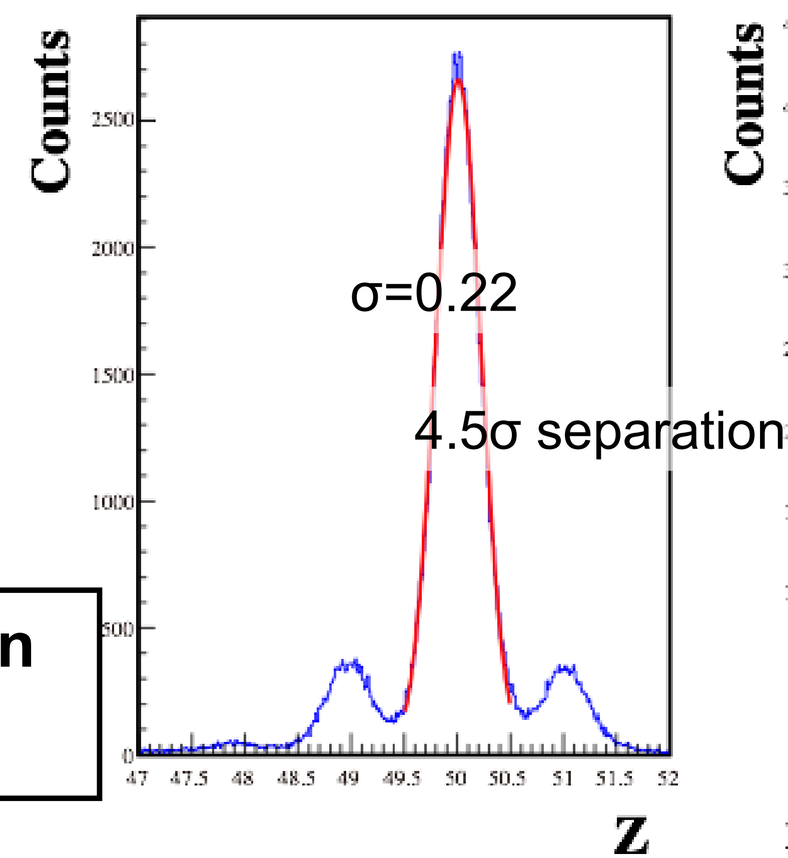


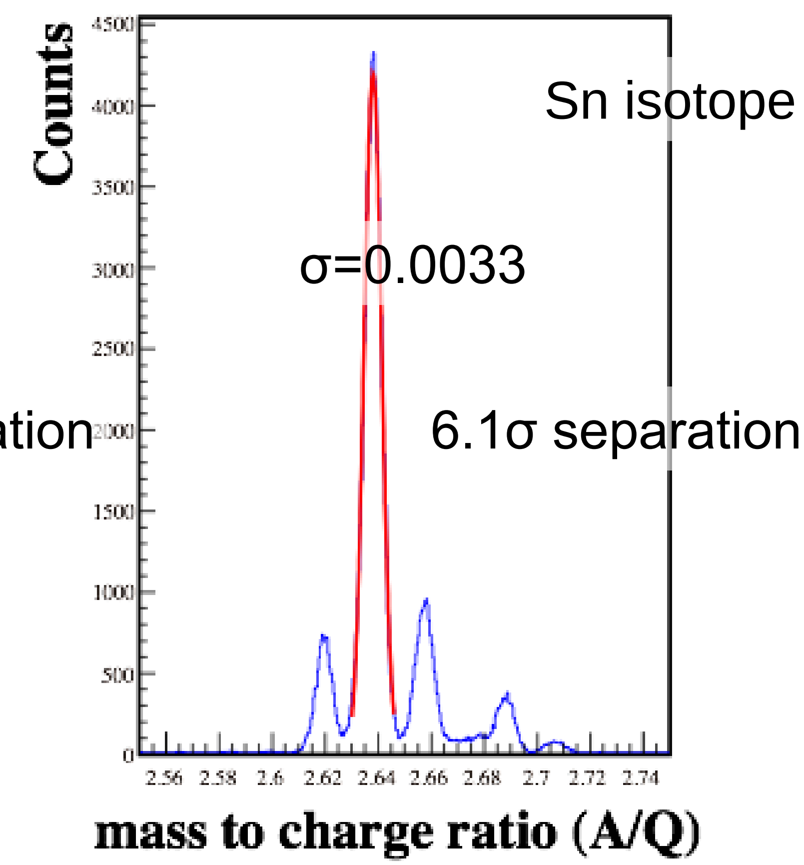
PID for Sn region with SAMURAI

- TOF-Bρ- ΔE method
  - TOF
    - plastic counter SBT1,2 and HODS
    - flight pass length ~ 12.5m
    - resolution : σ_t = 60 ps
  - ΔE
    - plastic counter HODS (5mm)
    - energy loss ~6000MeV
    - resolution : $\sigma_{\Delta E/\Delta E}$ = 0.9 %
  - Bρ
    - drift chamber BDC1,2, FDC1,2
    - SAMURAI magnet : 2.56T
    - resolution : P/σ_P ~ 1300



- **σ_{AOQ} = 0.0033   6.1σ separation**
- **σ_Z = 0.22   4.5σ separation**





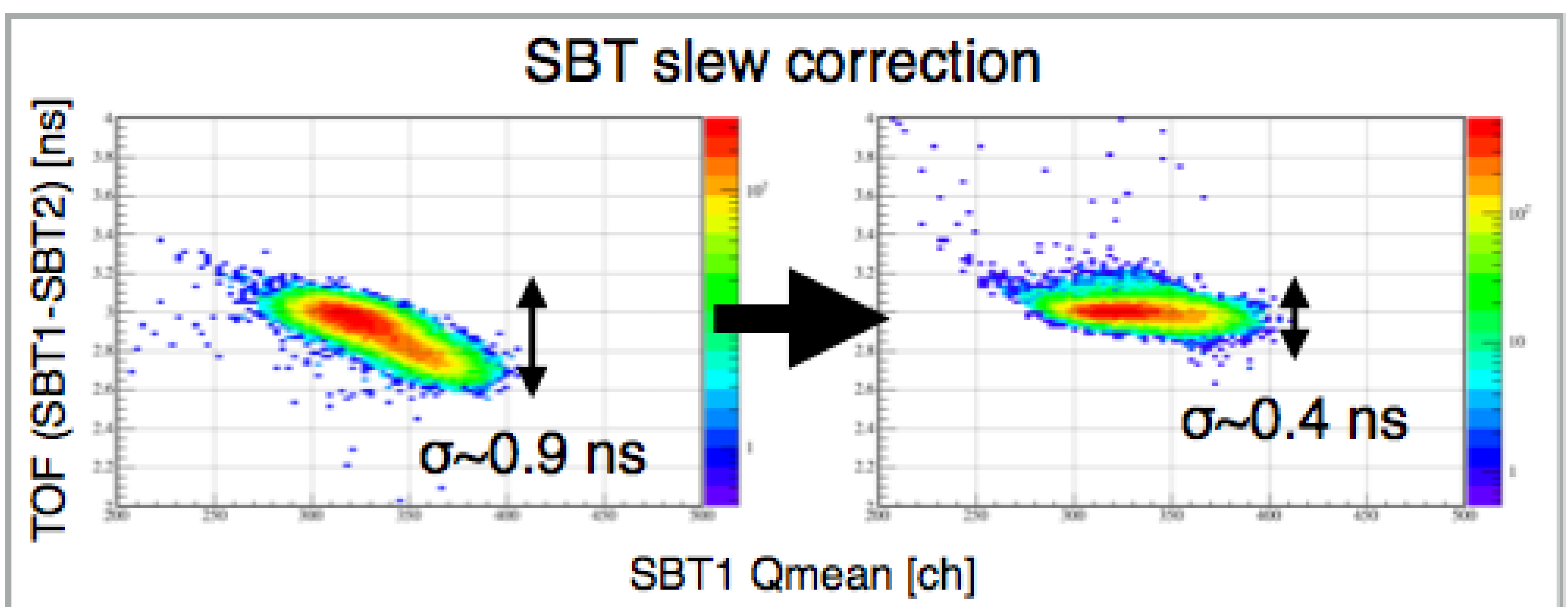
TOF analysis

- **Plastic counter HODS & SBT1,2**
  - HODS : 6 plastic scintillation with size of 450 x 100 x 5 mm
  - SBT1,2 : 130 x 130 x 0.5mm
  - FPL ~12.5 m
  - Resolution estimation
    - Empty cell & beam trigger

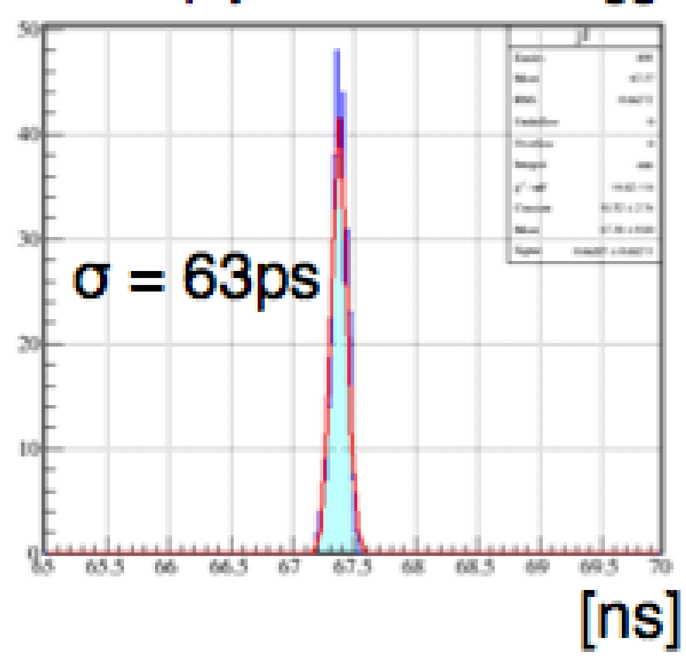
    ➡ SBT1,2 timing resolution (average of SBT1,2) : σ_t = 17ps (w/ slew correction)

    <—> w/o slew correction σ_t = 46 ps

    ➡ **TOF (SBT1,2-HODS) : σ = 63ps**



TOF(SBT1,2—HODS)
@ Empty cel & Beam trigger



Momentum analysis

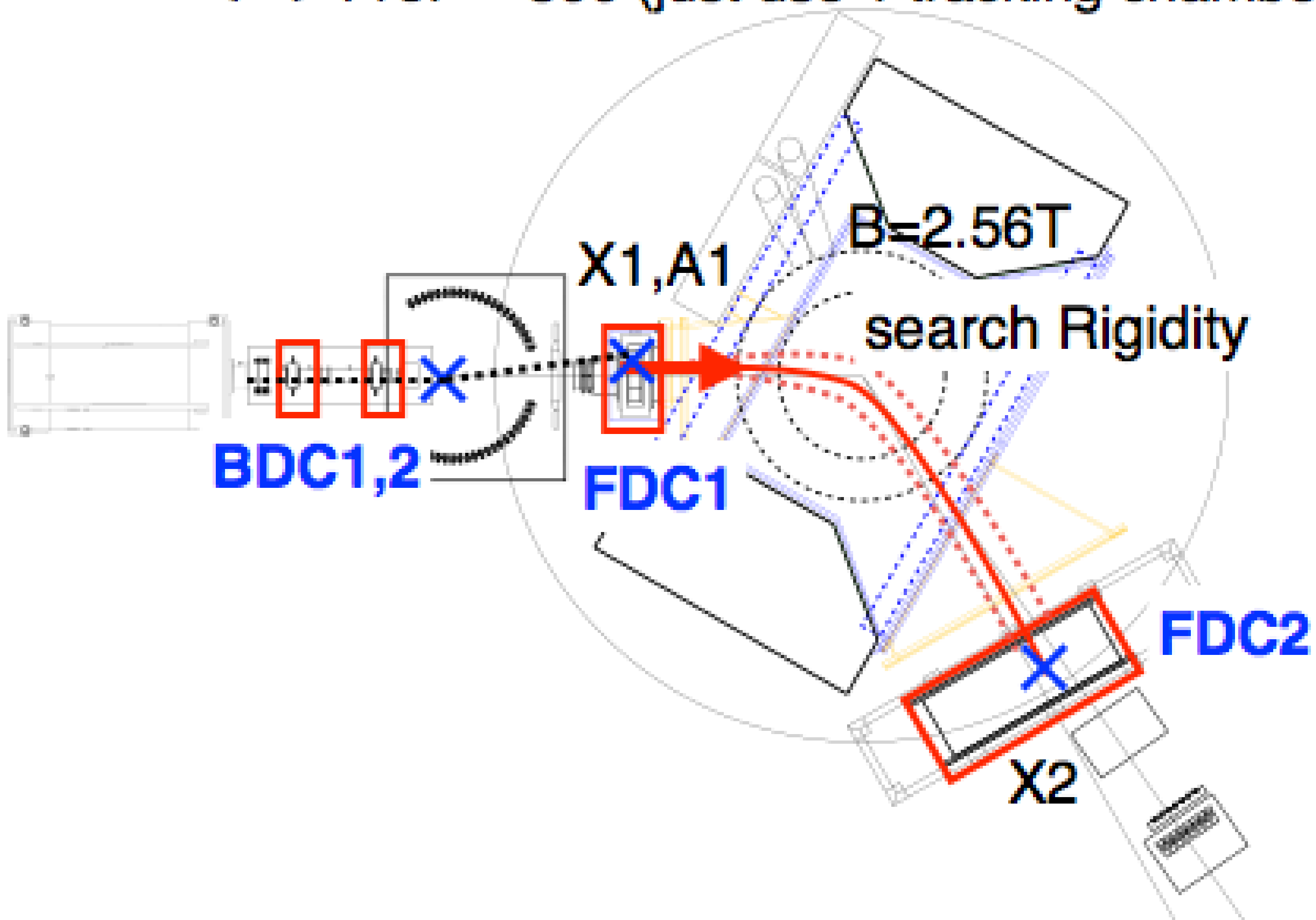
- **Input parameter**
  - Upstream vector (X1, A1), Magnetic Field, Downstream position (X2)
  - **A1 was derived by using 3 tracking detectors**

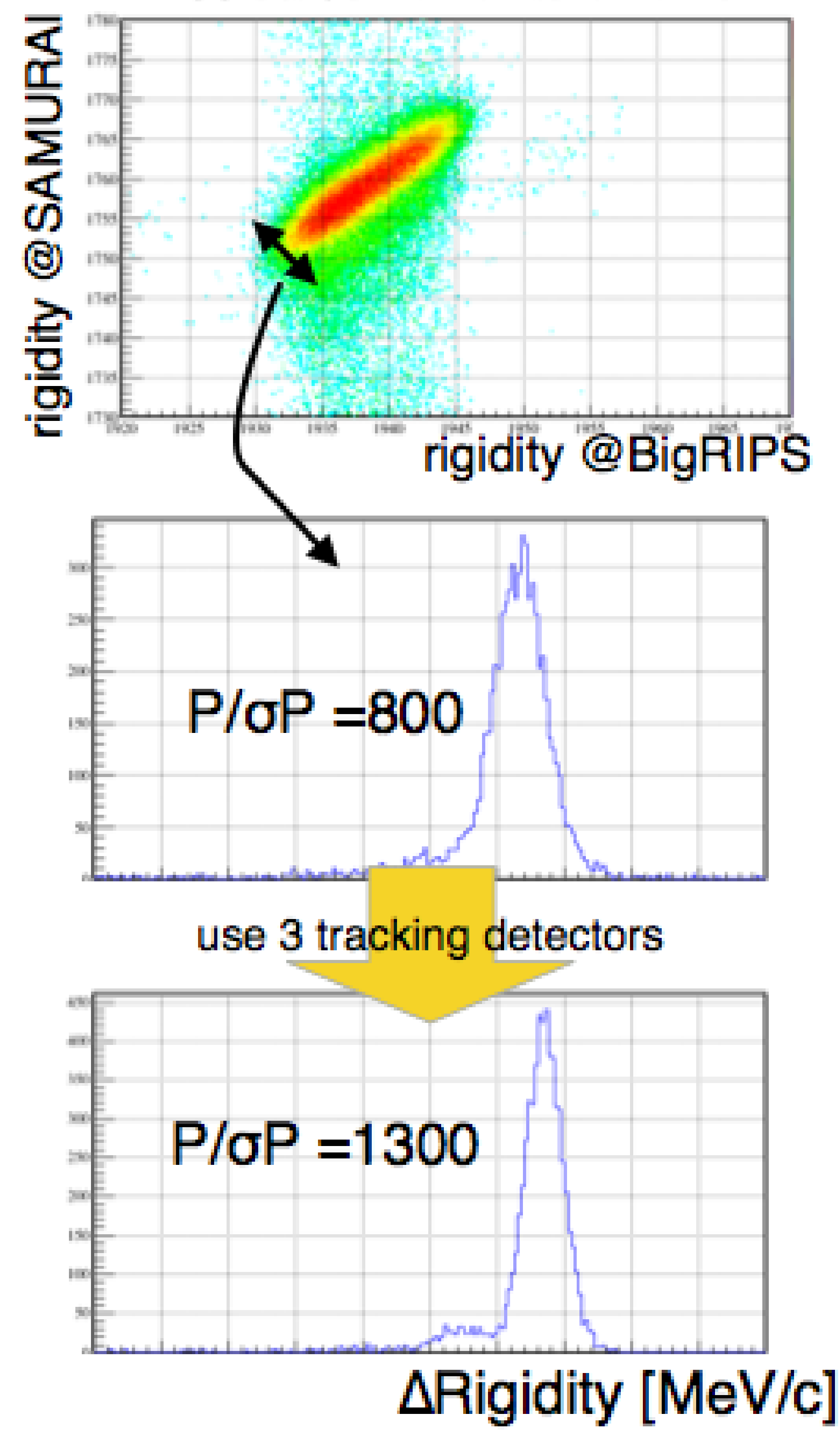
➡ High angular resolution σA ~0.3 mrad

<—> σA~0.8 mrad (just use 1 tracking chamber)

➡ **Resolution : P/σP = 1300**

<—> P/σP = 800 (just use 1 tracking chamber for ini. p)





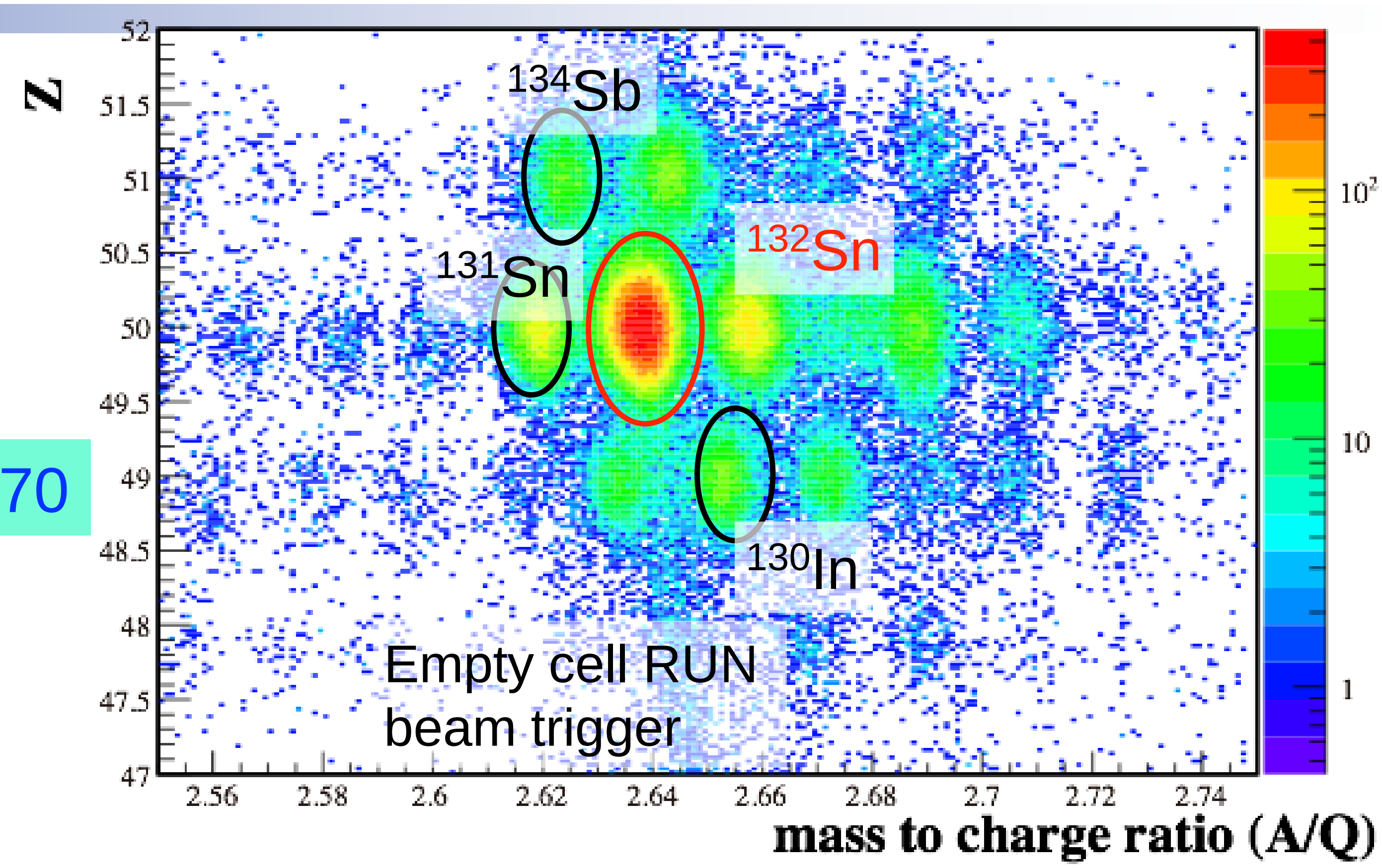
PID Achievement

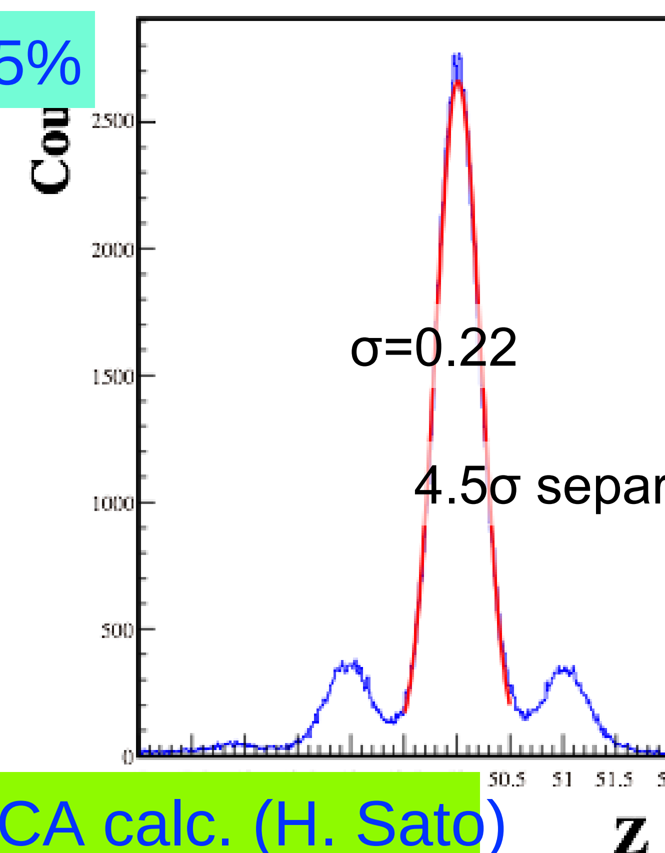
- TOF-Bρ- ΔE method
  - TOF
    - plastic counter SBT1,2 and HODS
    - flight pass length ~ 12.5m : ~70ns
    - resolution : σ_t = 60 ps

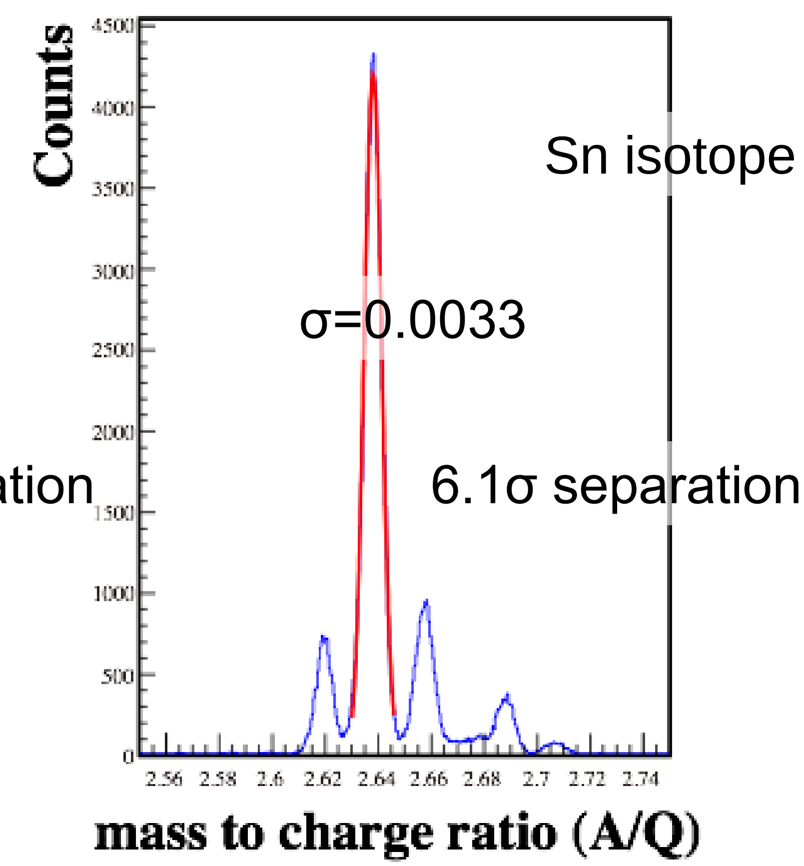
σ_t/t ~ 1/1170

  - ΔE
    - plastic counter HODS (5mm)
    - energy loss ~6000MeV
    - resolution : $\sigma_{\Delta E}/\Delta E$ = 0.9 %
  - Bρ
    - drift chamber BDC1,2, FDC1,2
    - SAMURAI magnet : 2.56T
    - resolution : σ_P/P ~ 1/1300

σ_Z/Z~ 0.45%







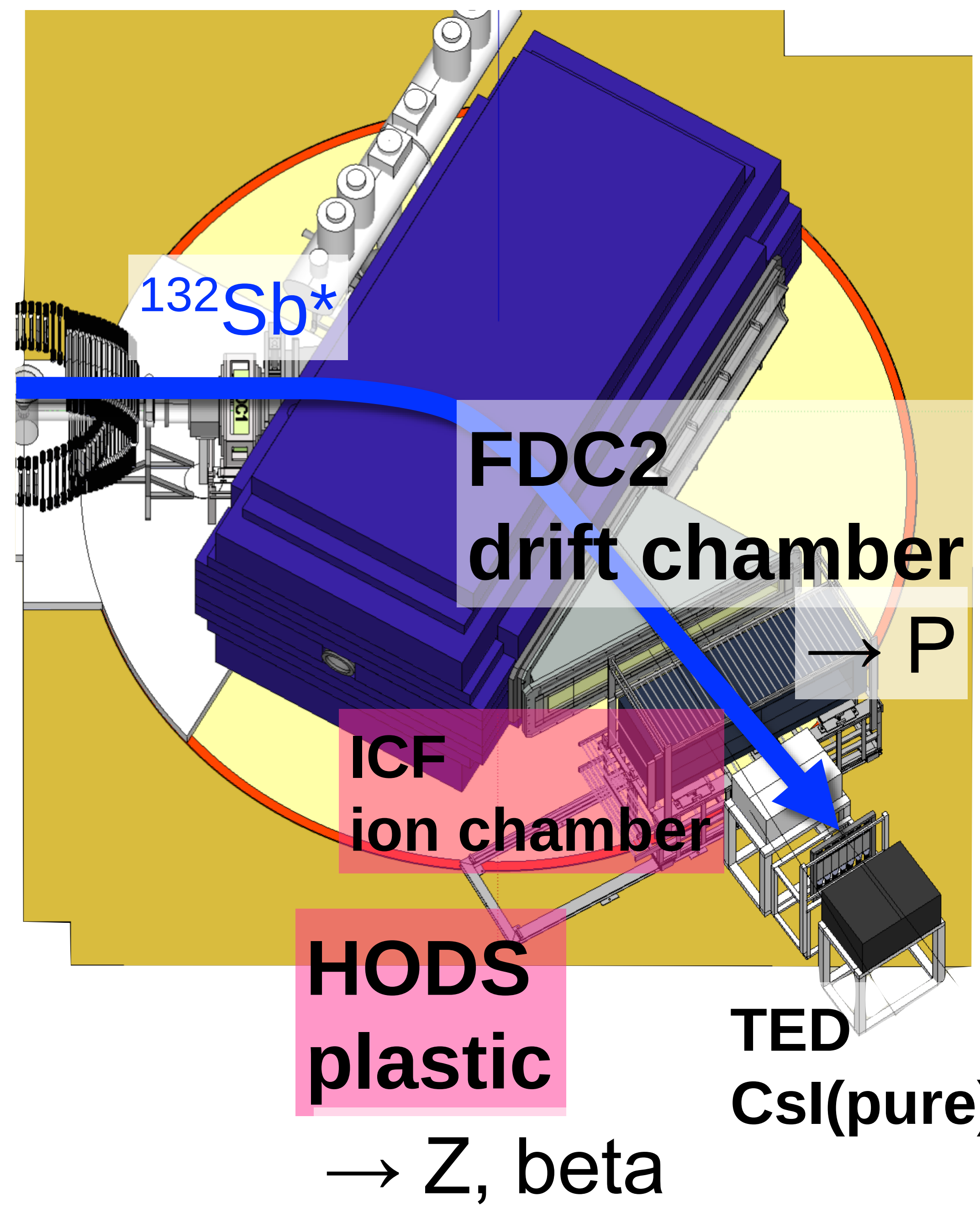
PID (AOQ, Z) resolution

σ_{AOQ} = 0.0033   6.1σ separation
← σ_{AOQ}/AOQ ~ 1/800
σ_Z = 0.22   4.5σ separation

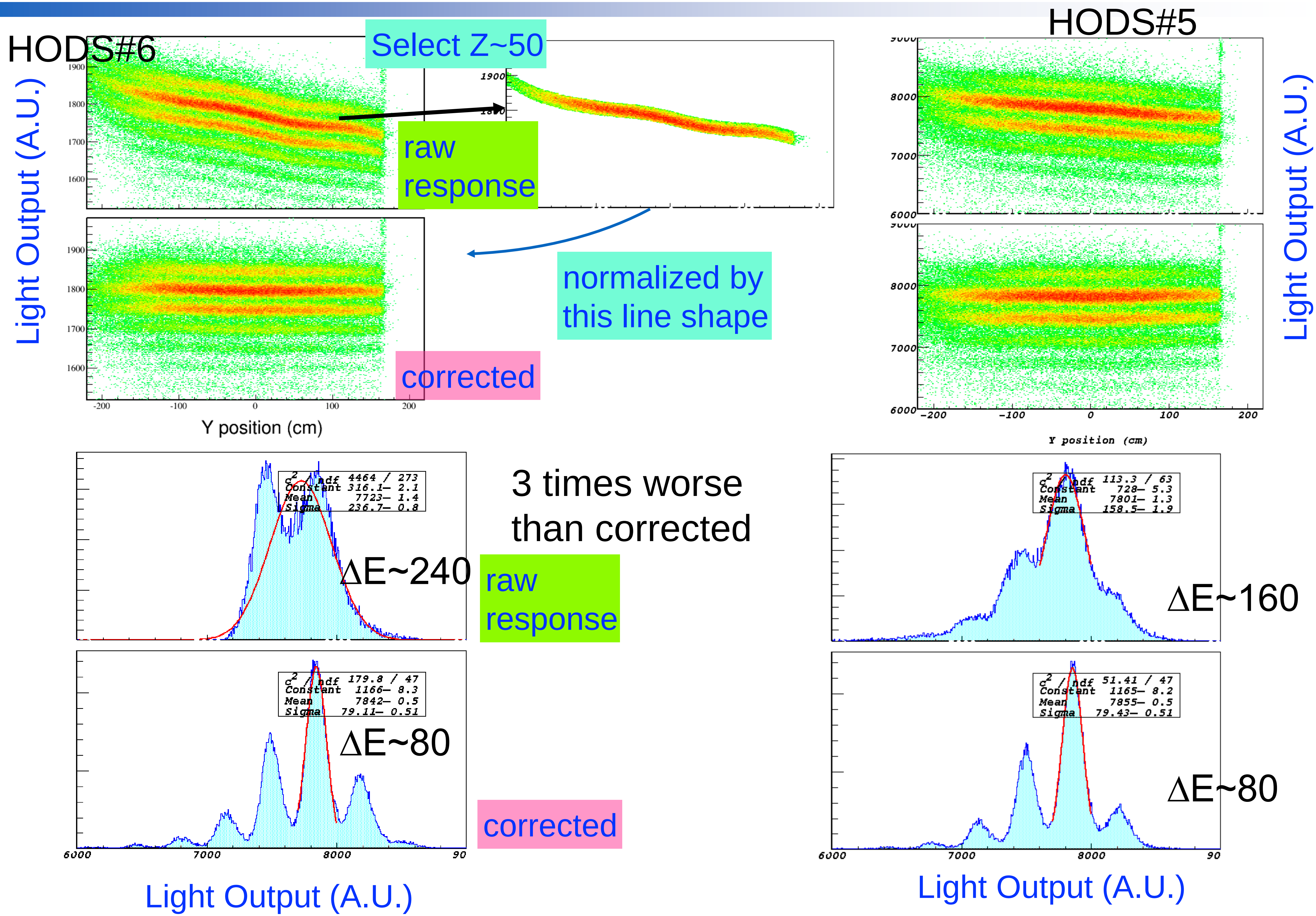
Reproductivity of magnetic field by TOSCA calc. (H. Sato)
Position determination of devices by PGS

PID Problems

- ICF (standard detector) problem
  - ICF did not work well on 2x10^4 secondary beam circumstances
  - 10^3 test circumstances : well operated sufficient resolution of Z obtained
    - c.f. σ_z =0.24 @ BigRIPS IC@F7 / SAMURAI ICB
  - ? Rate
  - → ΔE by HODS (for emergency)
- HODS problem
  - Finally sufficient resolution was obtained
    - $\sigma_{\Delta E}/\Delta E$ = 0.9 % → σ_Z/Z~ 0.45% ≡ σ_Z=0.22
  - but…
  - position dependence of light output response



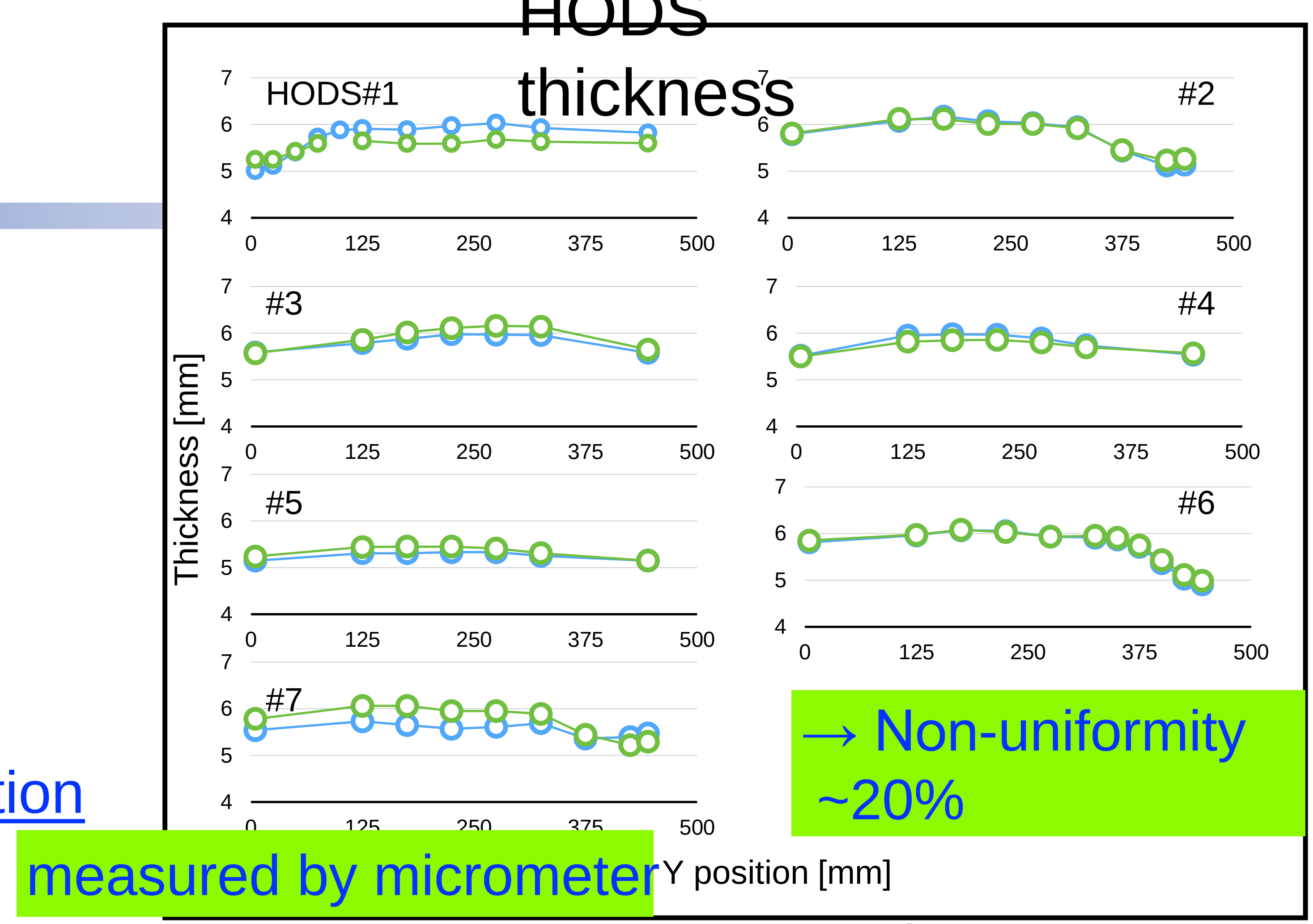
Problem for ΔE analysis

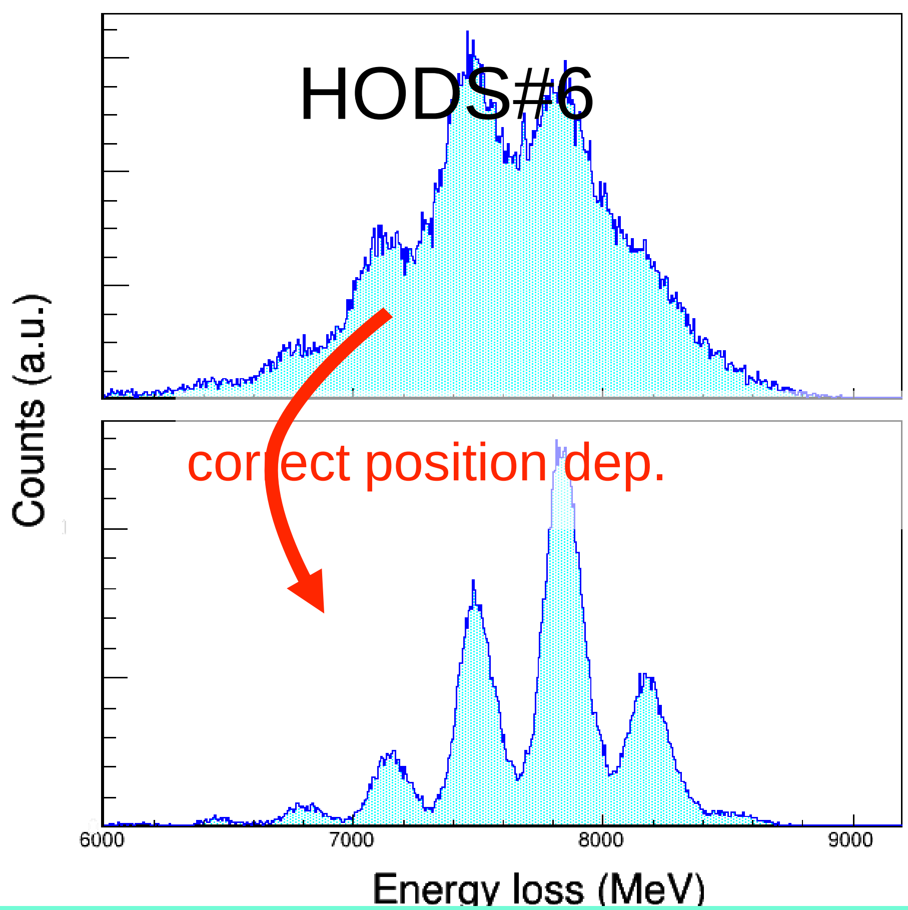


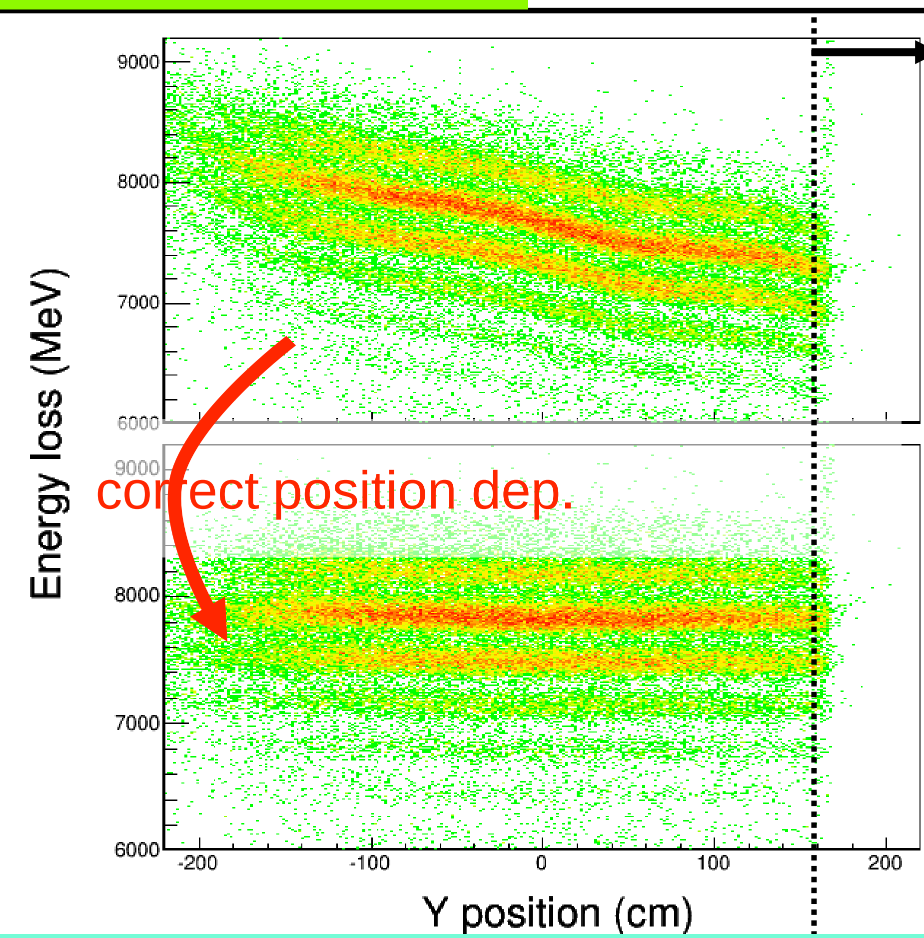
ΔE analysis

- Energy loss at plastic scintillator HODS
  - HODS thickness : ~ 6 mm
    - Non-uniformity ~ 20%
    - Energy loss ~ 6000 MeV
  - Correct position dependence by using FDC2 tracking information

→ Resolution : $\sigma_{\Delta E}/\Delta E$ = 1%







out of acc.
due to ICF

→ Measured thickness trends are not always identical with light output position dependence

Problem for ΔE analysis

- Gain attenuation
  - especially for beam hit bar
  - parameter for ΔE should be changed for each RUN

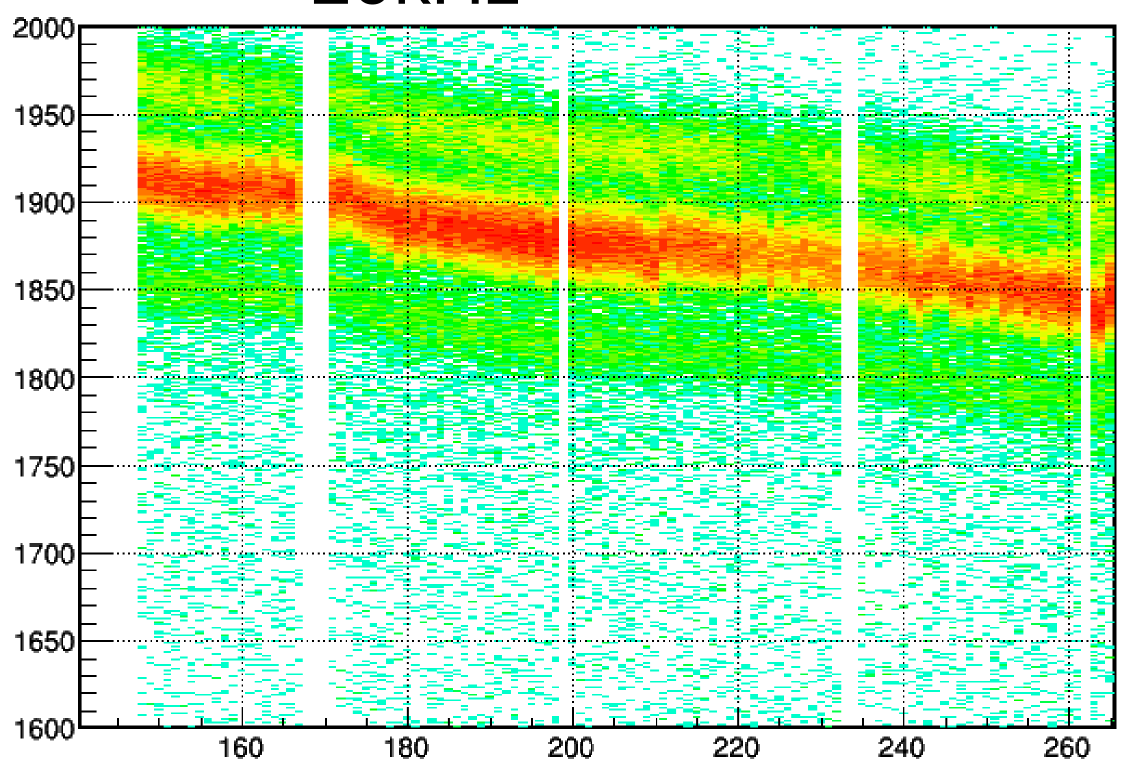
➞ PMT w/ booster might help to solve this problem (?)

➞ or Plastic would be damaged by heavy particles

Beam hit bar

~20kHz HODS#4

Light output (ch)

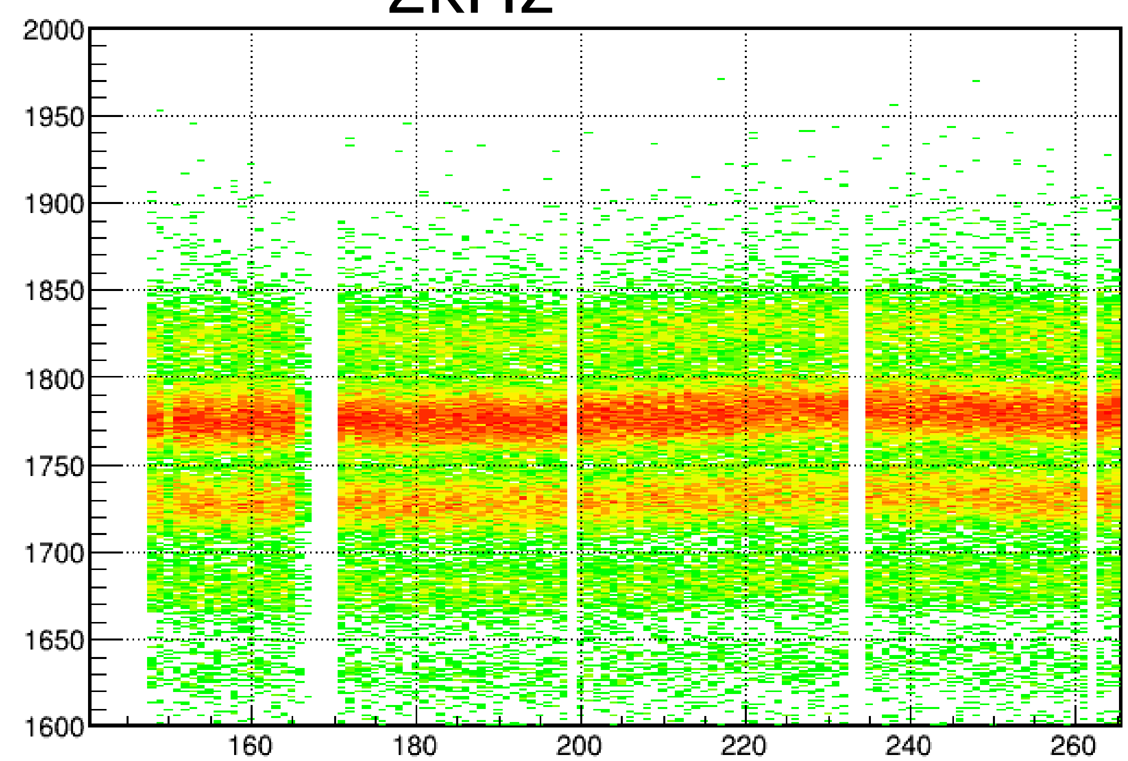


RUN NUMBER

~40h

Fragment hit bar

~2kHz HODS#5



RUN NUMBER

~40h

Short Summary

- SAMURAI17 : $^{132}Sn(p,n)$: heaviest region ever with SAMURAI

→ Benchmark for SAMURAI spectrometer properties

- TOF- Bρ- ΔE method works well on A~132 region
  - AOQ resolution : 1/800 : 6.1σ separation achieved
    - TOF : 1/1170 Flight Length : 12.5 m ~ 70ns, σt ~ 60 ps
    - Bρ : 1/1300 @ 2.56T, Tracking with BDC1+2 - FDC1 for incident angle
  - Z resolution : σz ~ 0.22 : 4.5 σ separation achieved
    - by 5mm t plastic HODoscope "S"

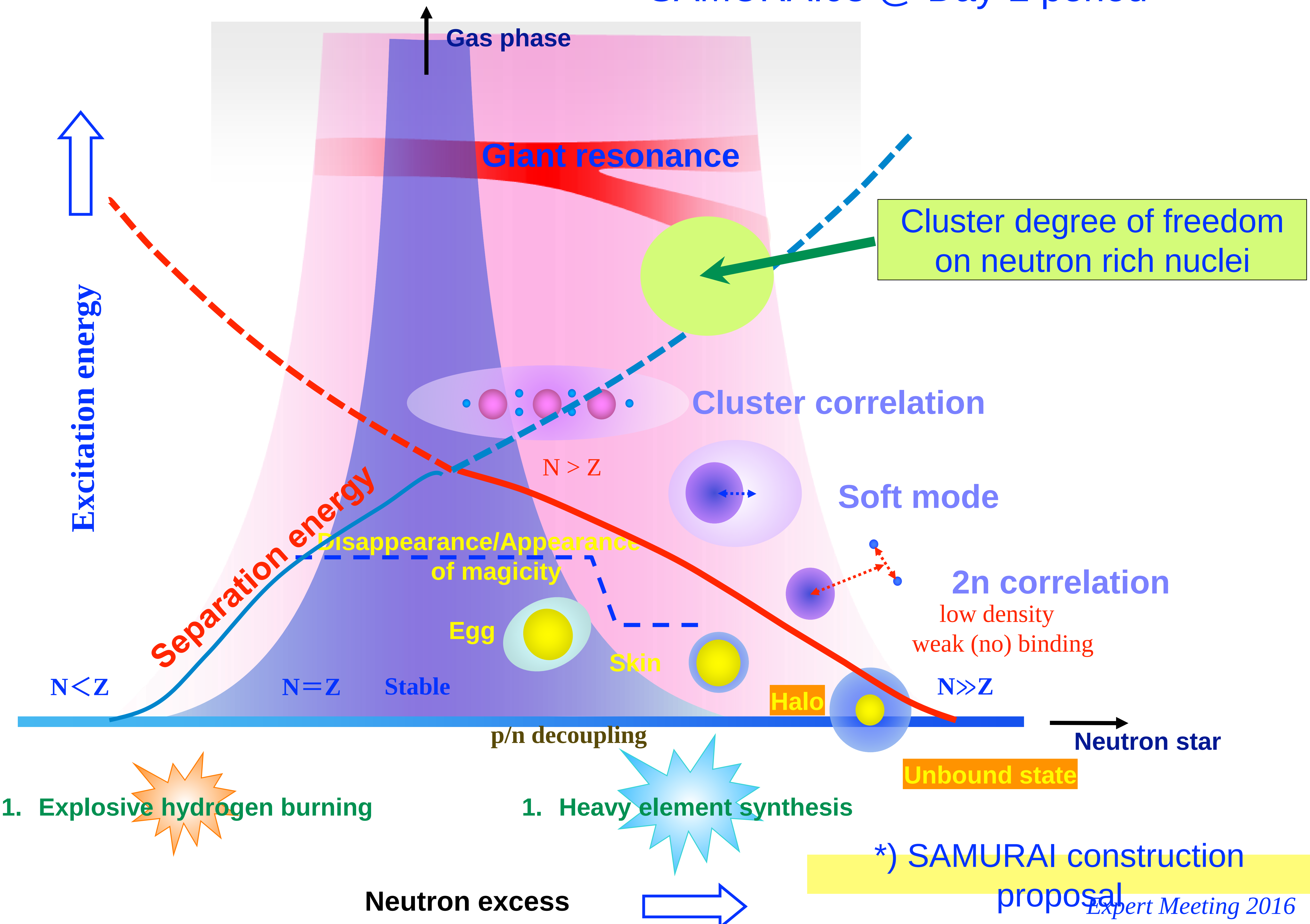
- Device problems remain
  - ICF : Ion Chamber for Fragments did not work well on over $2x10^4$ circumstances
    - Not well understood well. To be solved
  - HODS : light output response : position dependence,
    rate damage on beam slat

Two charged particle tracking properties

SAMURAI08 by S. Koyama (U. Tokyo)

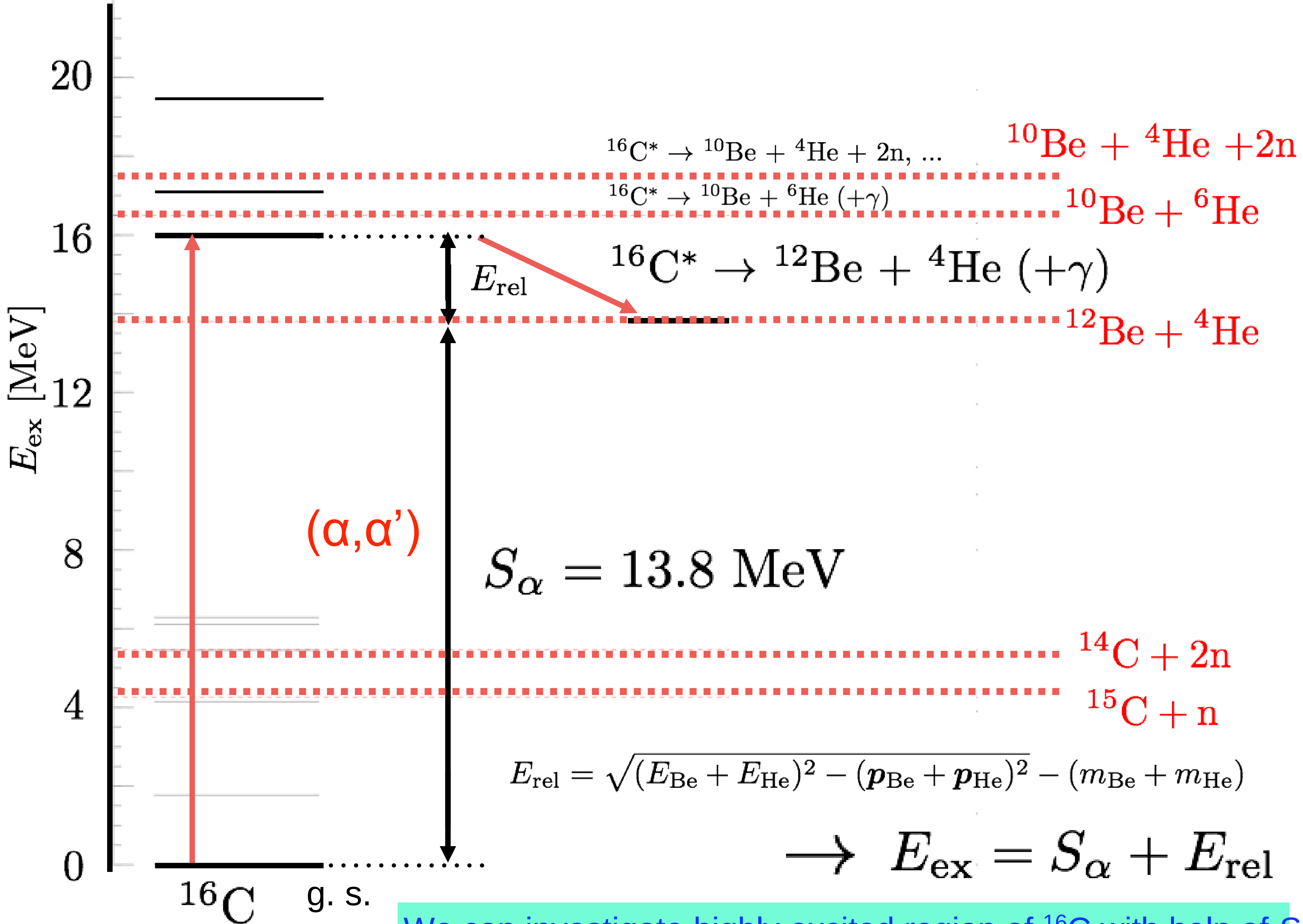
Cluster studies with SAMURAI

SAMURAI08 @ Day-2 period



*) SAMURAI construction proposal

Invariant-mass + (α,α')



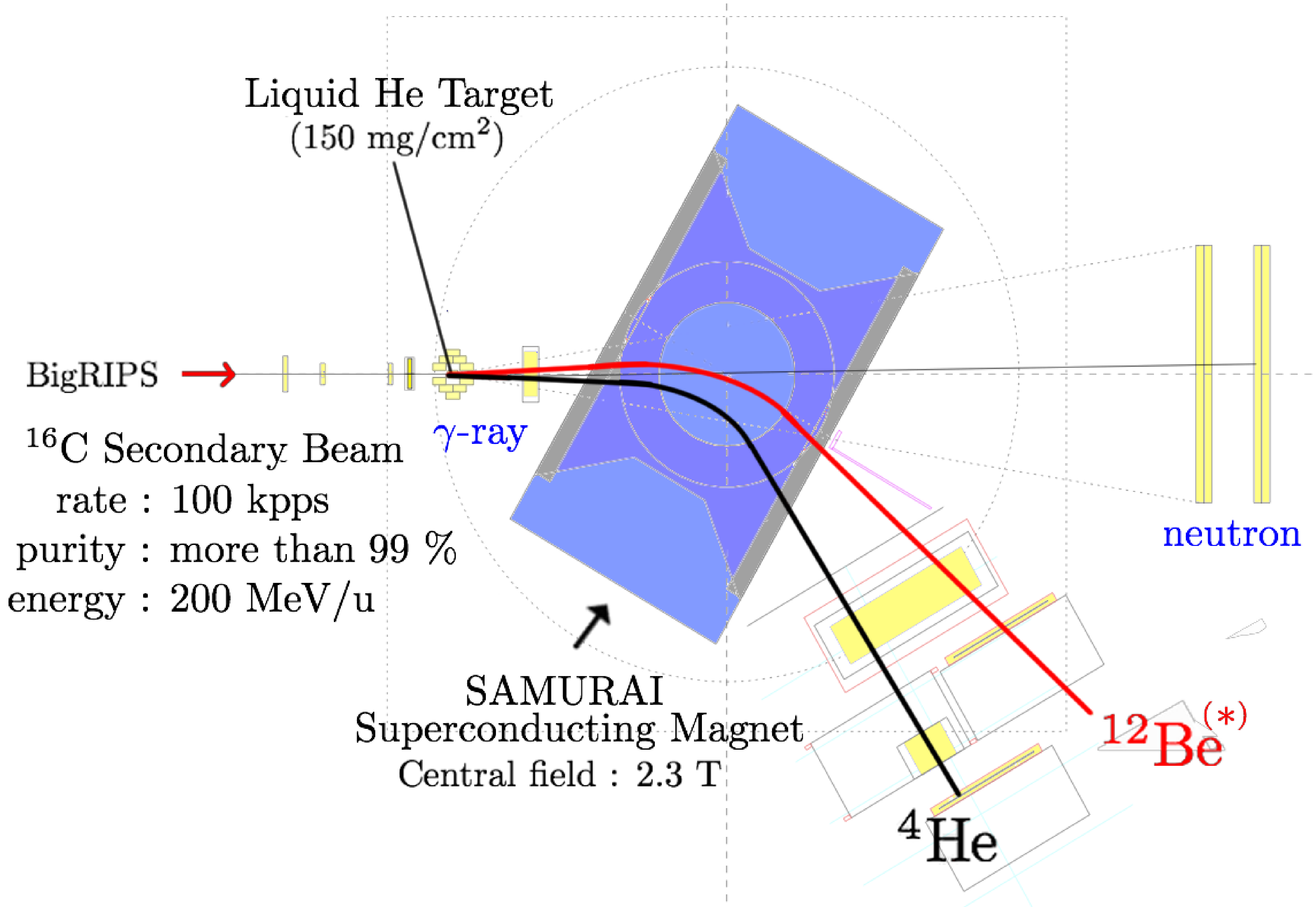
$$E_{rel} = \sqrt{(E_{Be} + E_{He})^2 - (\boldsymbol{p}_{Be} + \boldsymbol{p}_{He})^2} - (m_{Be} + m_{He})$$

$$\to \quad E_{ex} = S_\alpha + E_{rel}$$

We can investigate highly excited region of ^{16}C with help of S

Experimental Setup

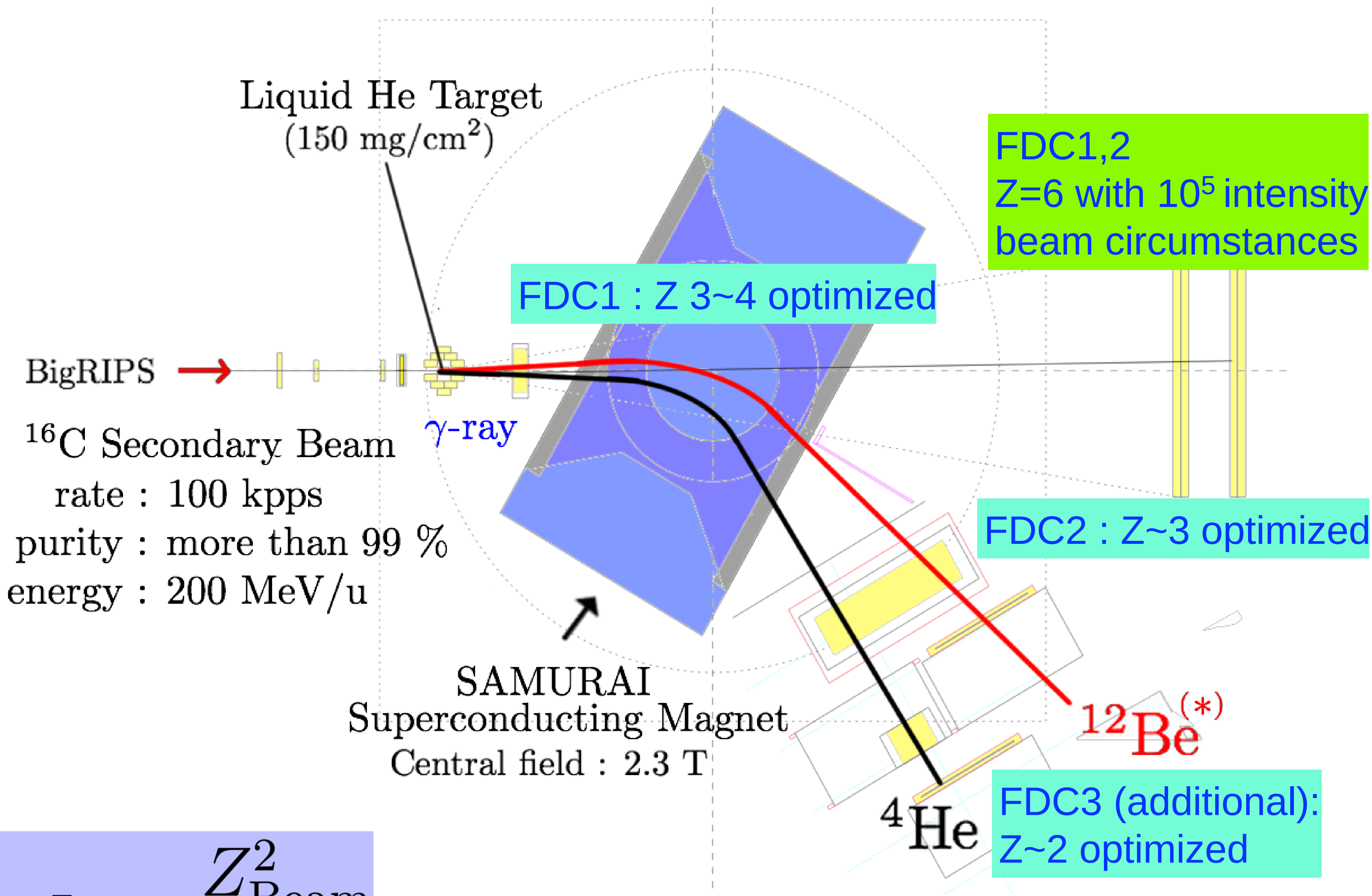
Multi-particle Spectrometer SAMURAI



Experimental Setup

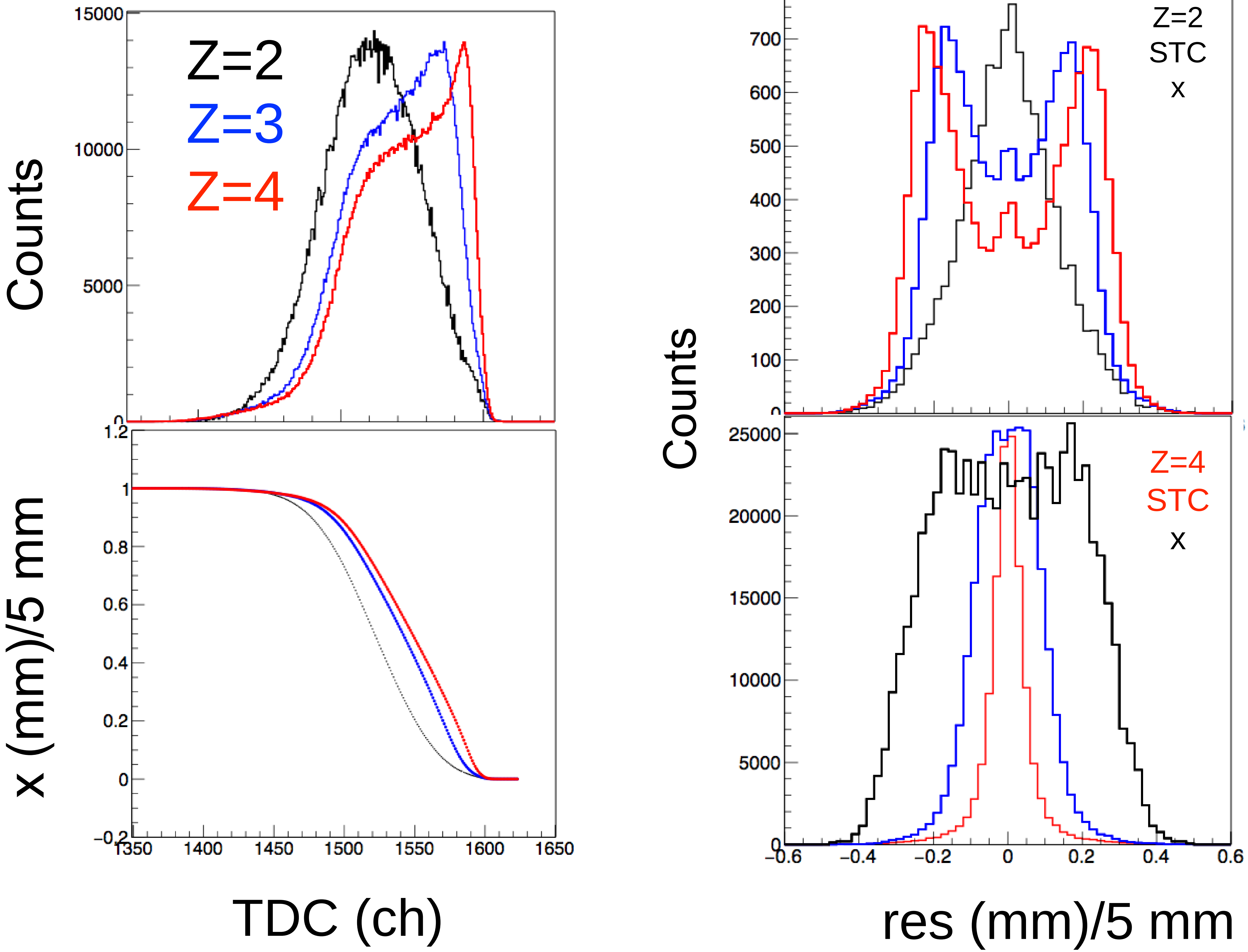
Drift Chamber operation concept

Multi-particle Spectrometer SAMURAI

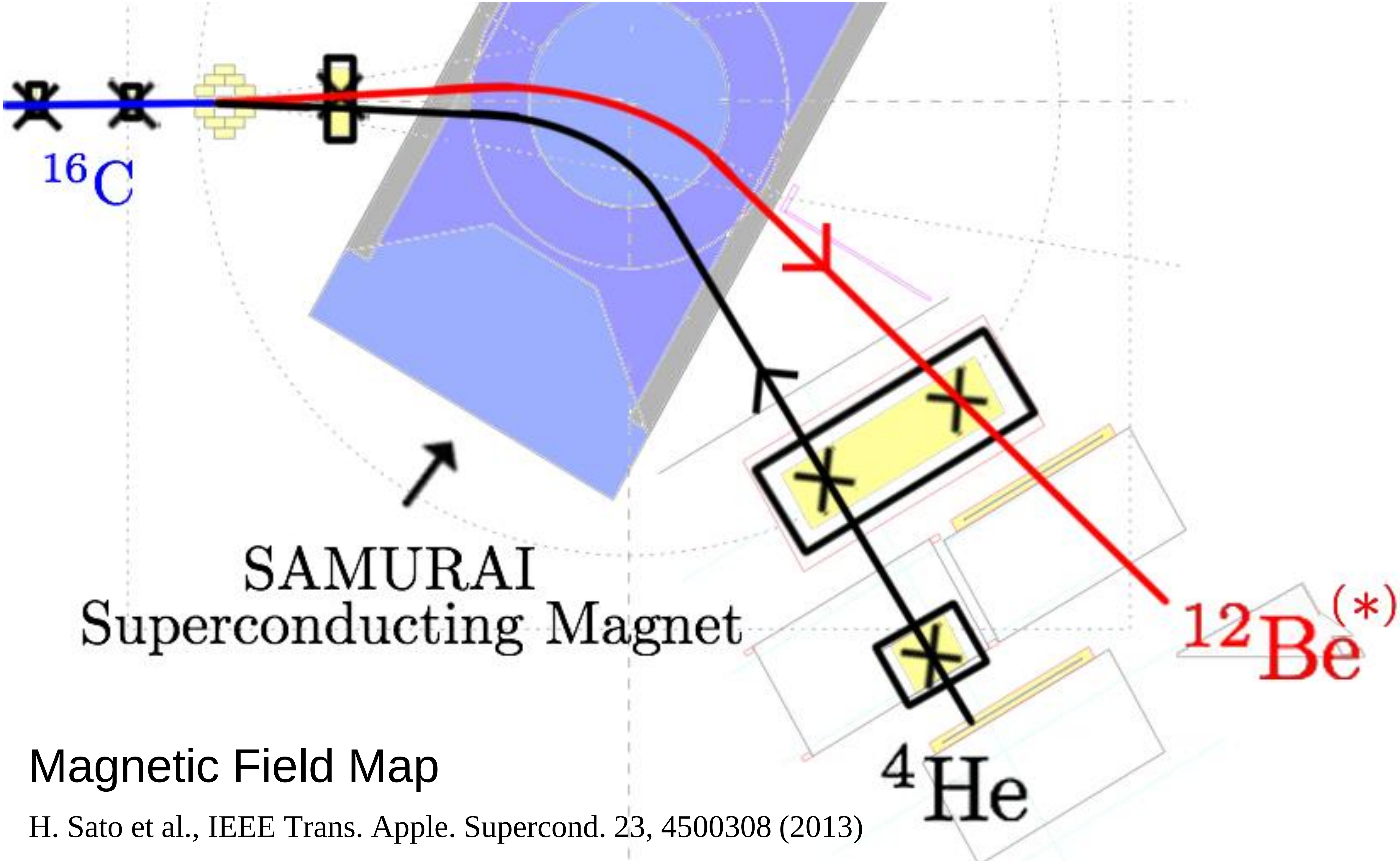


$$I_{\rm eff} = I_{\rm Beam}\frac{Z^2_{\rm Beam}}{Z^2_{\rm Opt}}$$

FDC1



Momentum Analysis

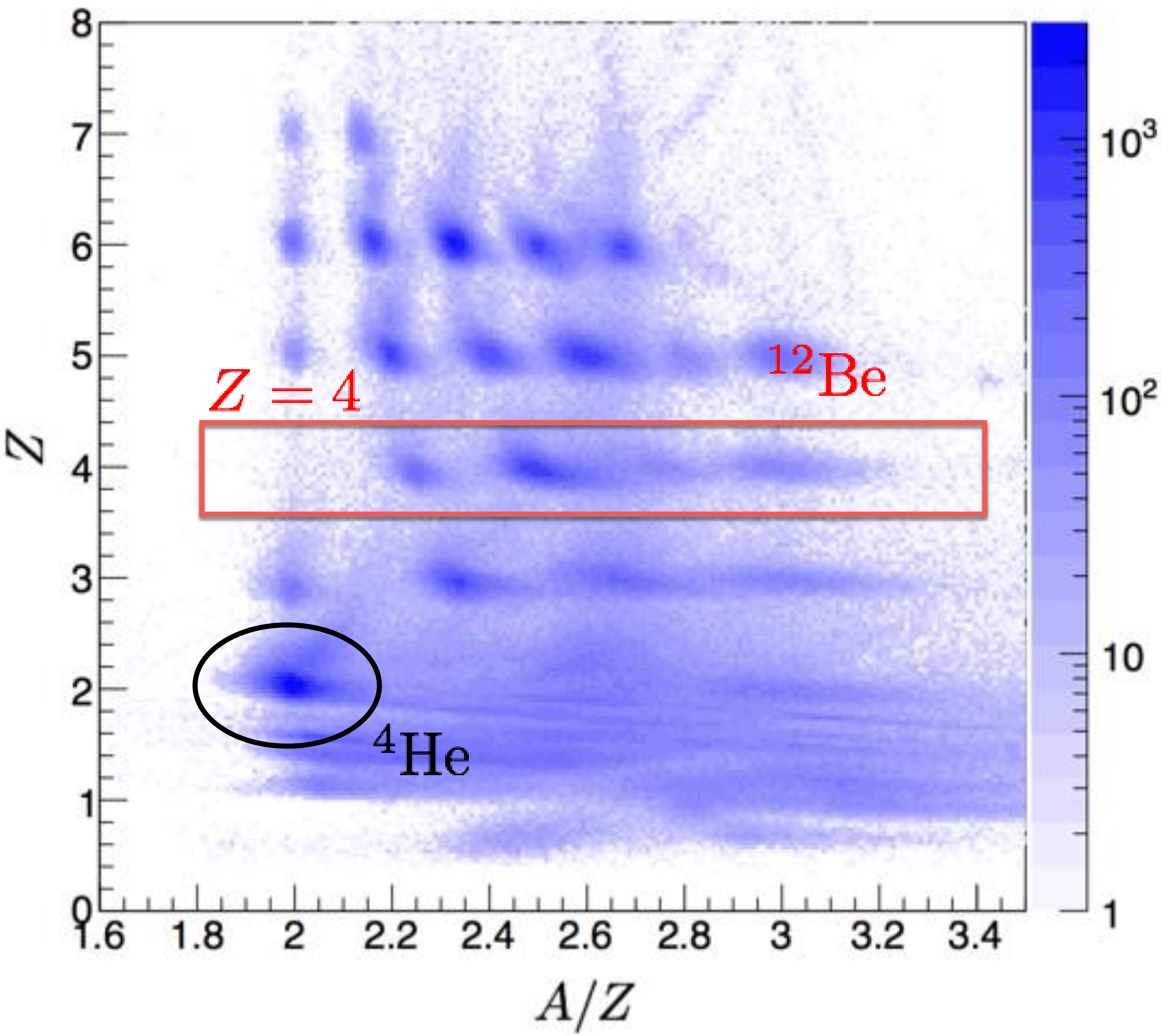


Magnetic Field Map

H. Sato et al., IEEE Trans. Apple. Supercond. 23, 4500308 (2013)

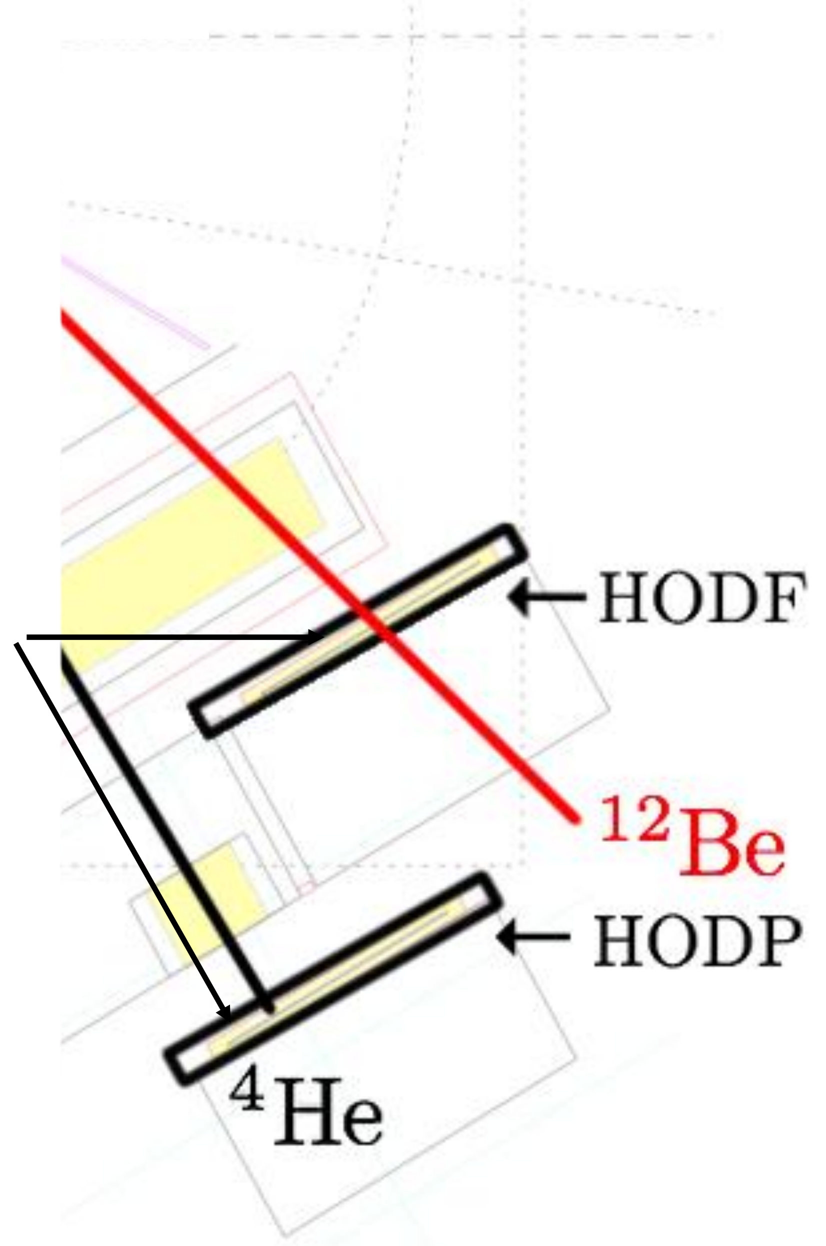
PID

TOF-- Hodoscope Position



$Z \propto \sqrt{\Delta E}/TOF$

$A/Z \propto TOF \times B\rho$

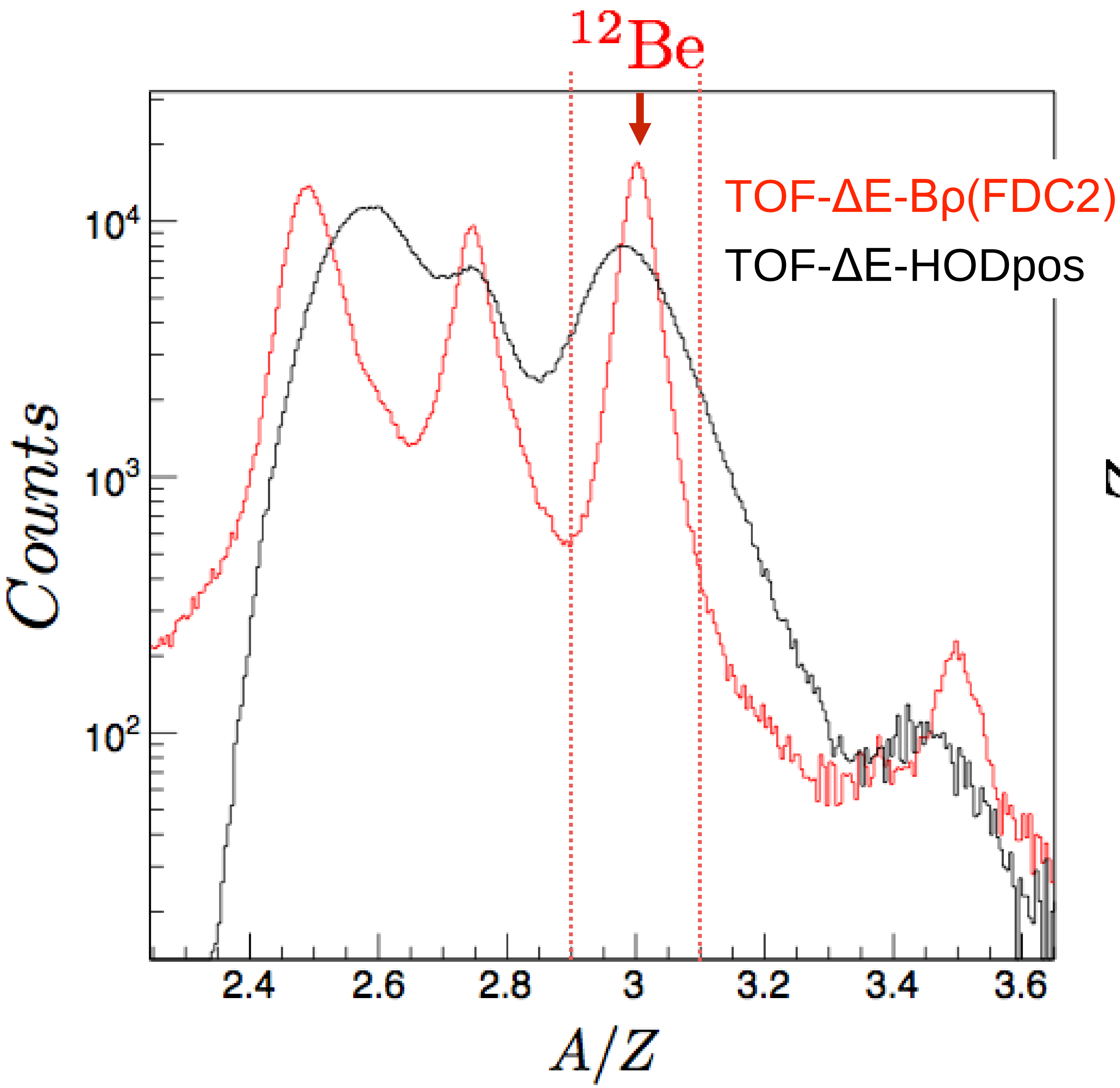


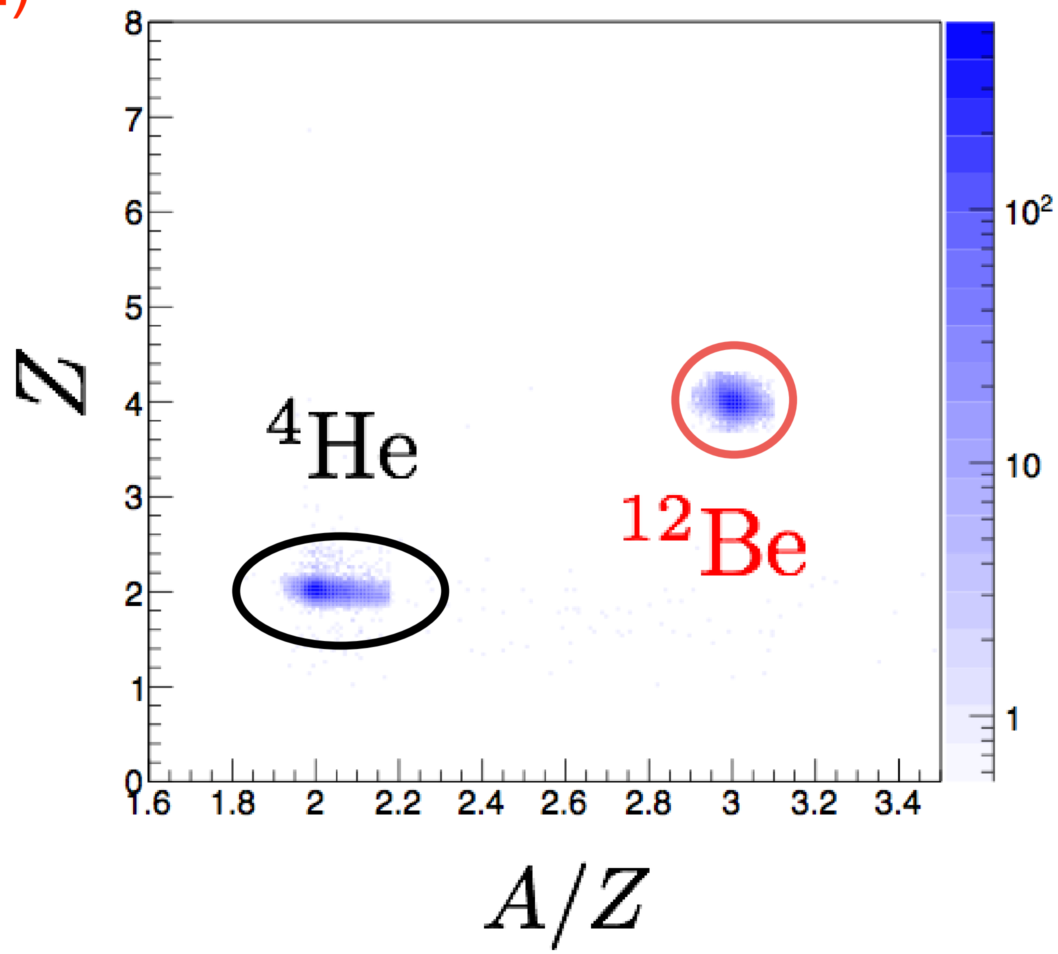
A/Z , Coincidence

$$Z \propto \sqrt{\Delta E}/TOF$$

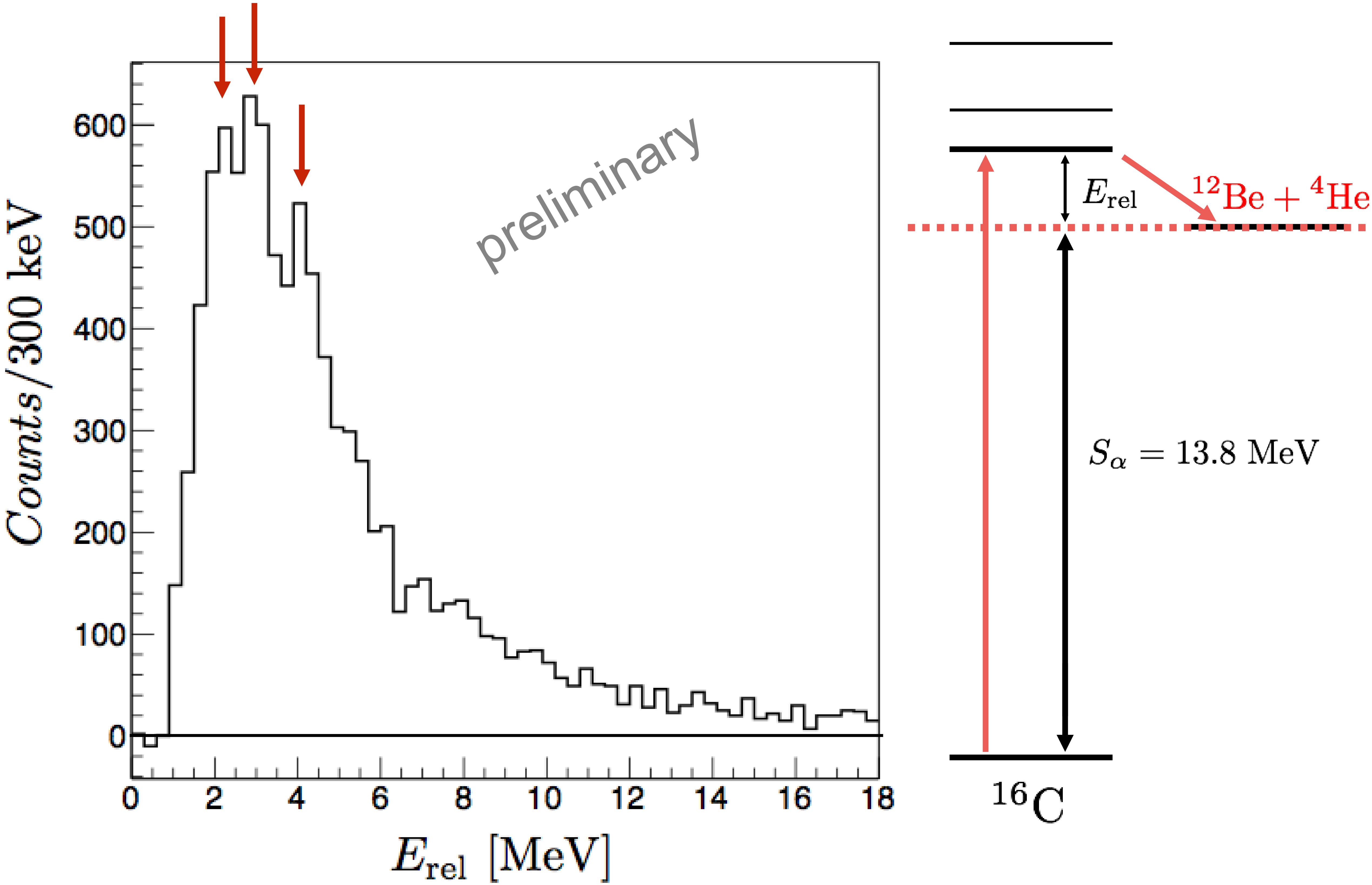
$$A/Z \propto TOF \times B\rho$$

TOF-ΔE -Bρ (for Z=4)



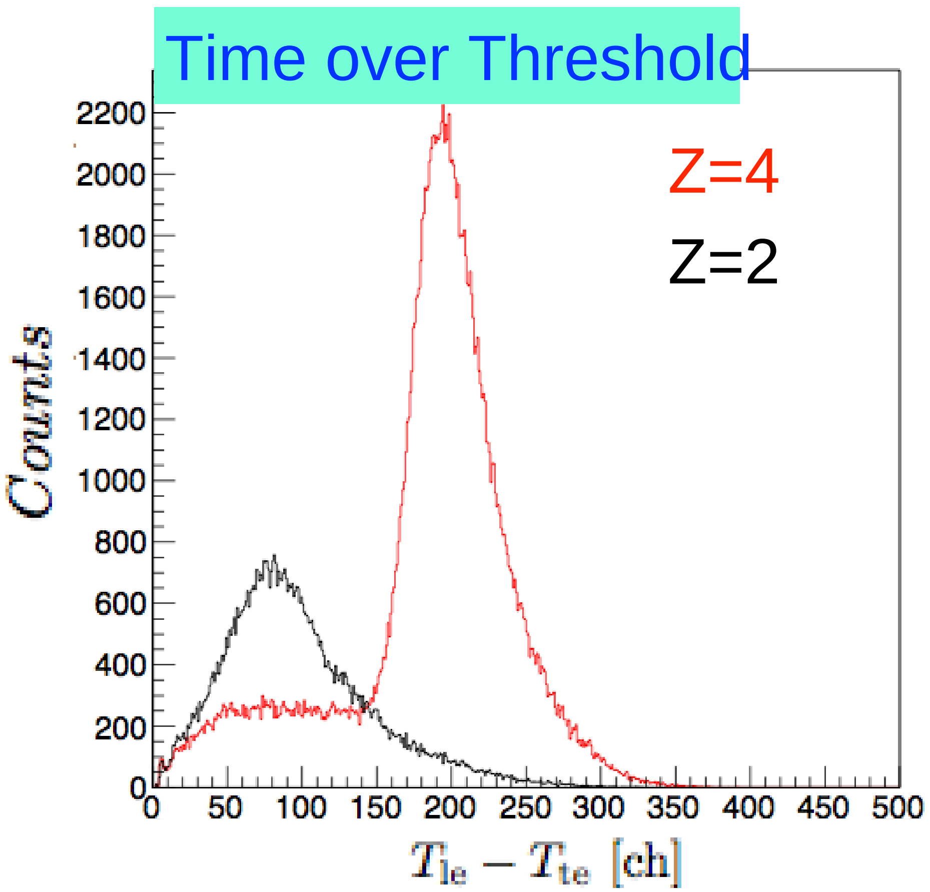


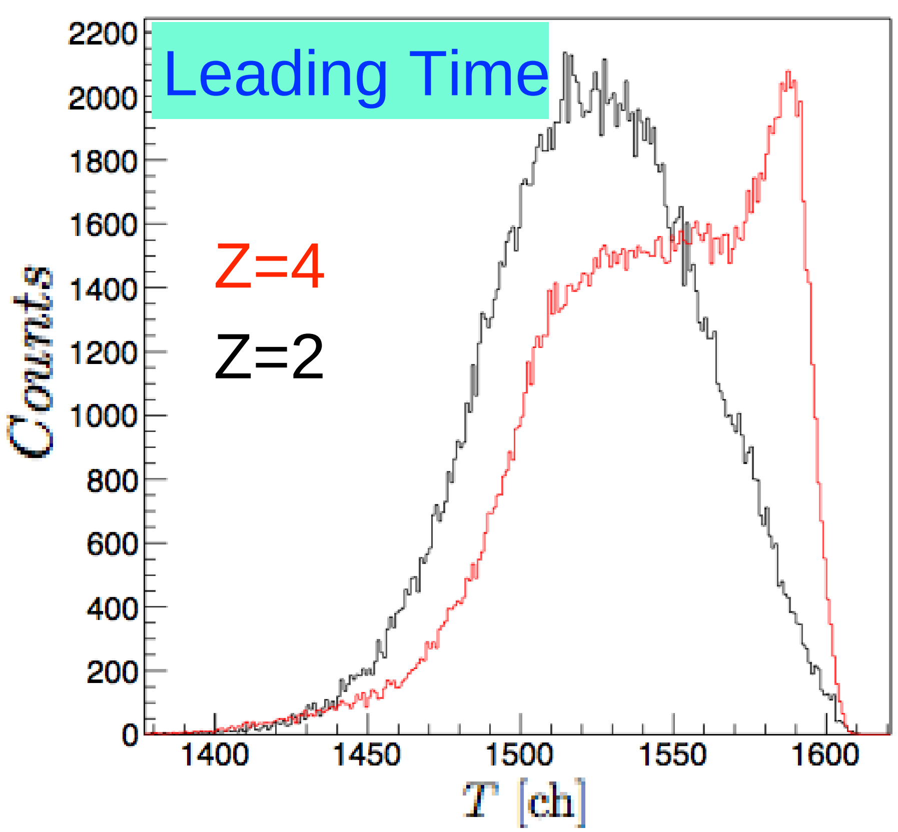
Relative Energy Spectrum

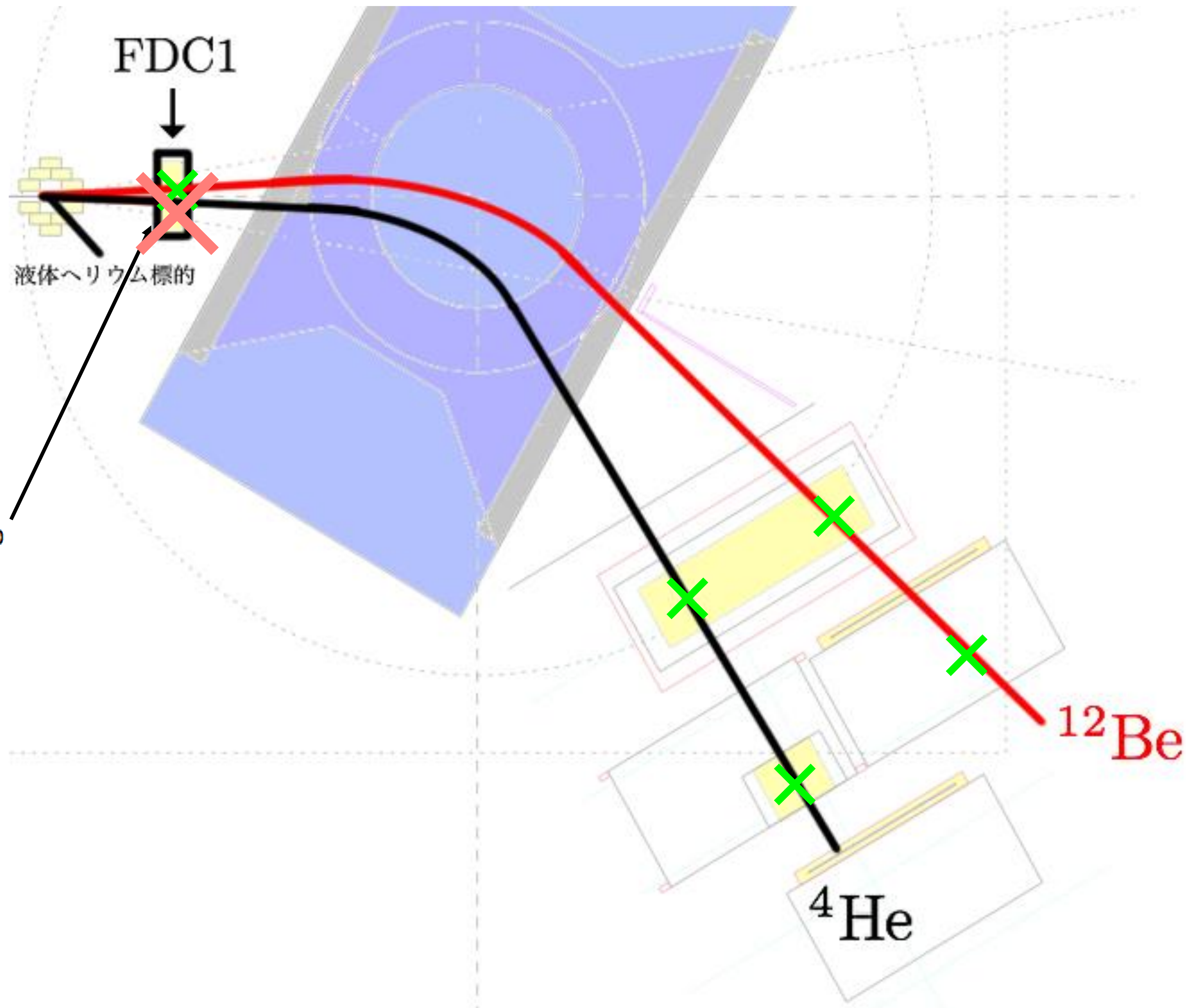


Z=2 track added on FDC1 by using ToT separation

FDC1 response diff. between Z=4 and Z=2



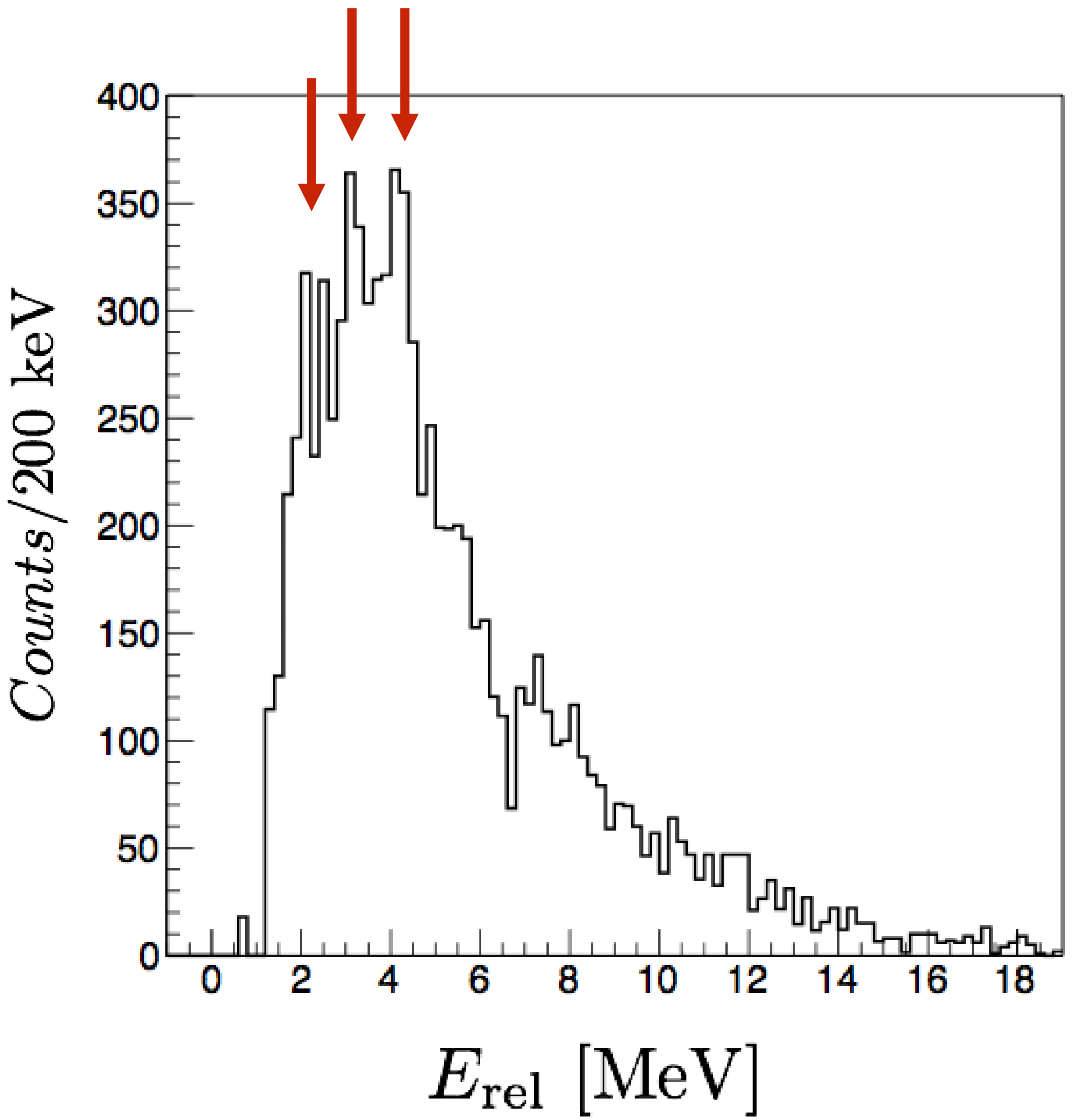




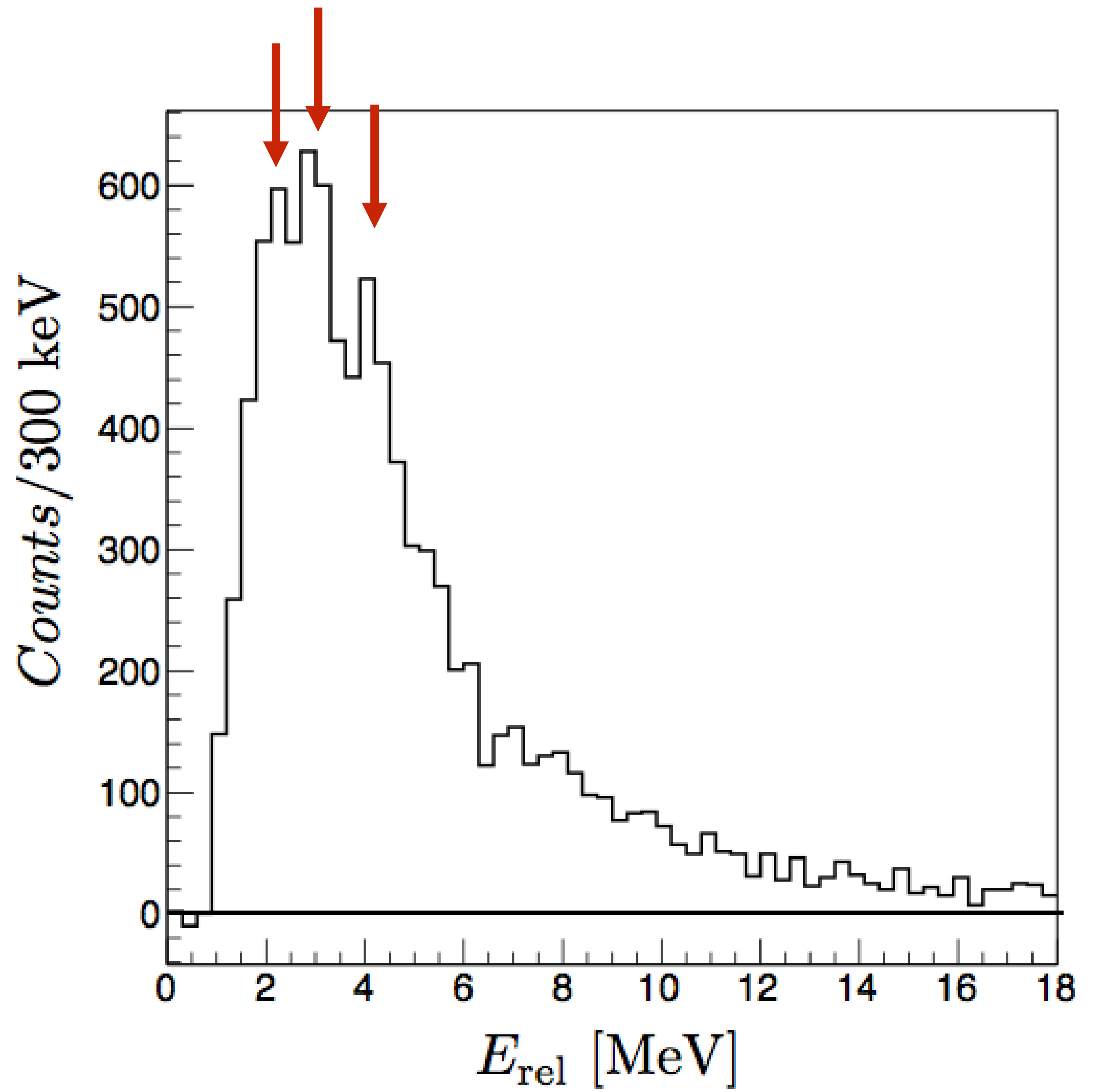
Demerit : Z=2 detection efficiency : low
Inefficiency at θ_{open} ~ 0

Relative Energy Spectrum

w/ ^{4}He Track on FDC1



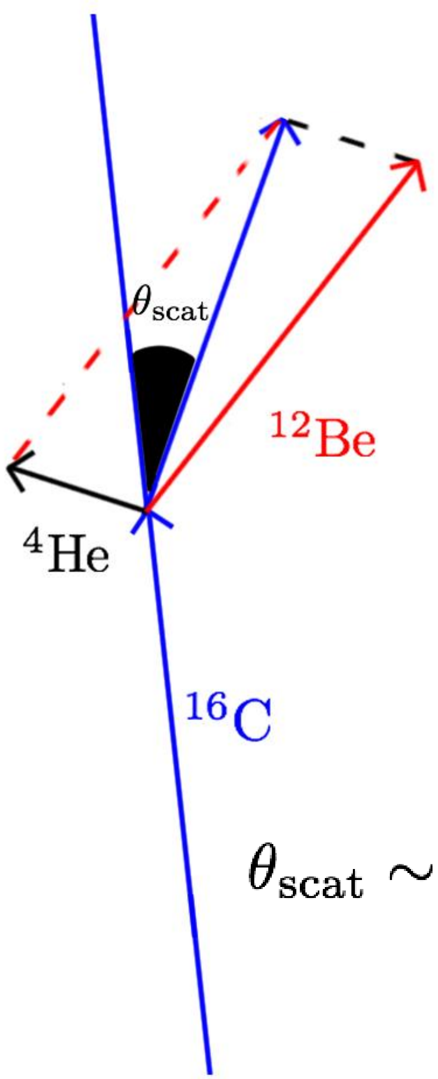
Original Method



θ_{Open} improved → better E_{rel} resolution

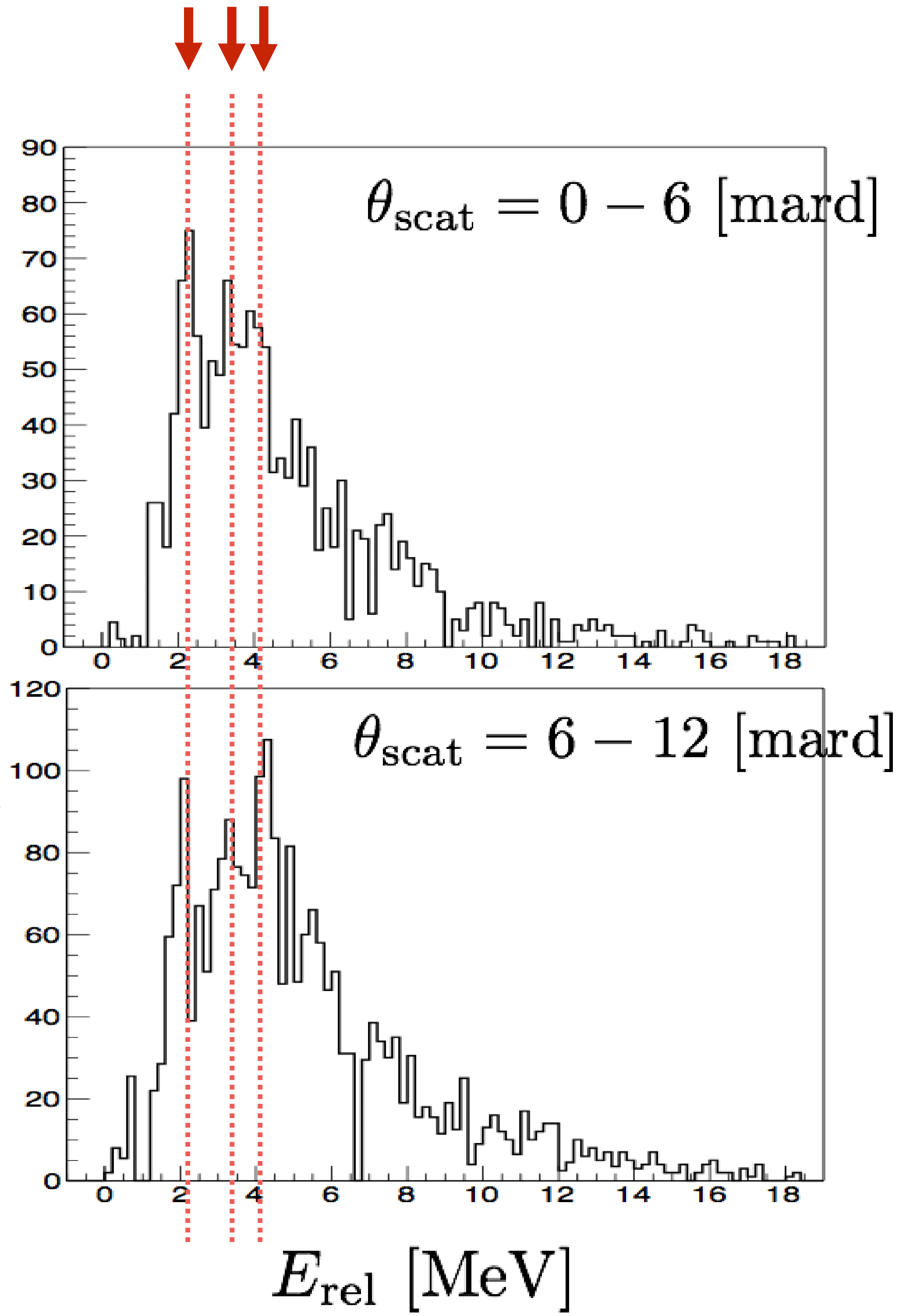
Lose statistics by requiring Z=2 on FDC1

Angular distribution

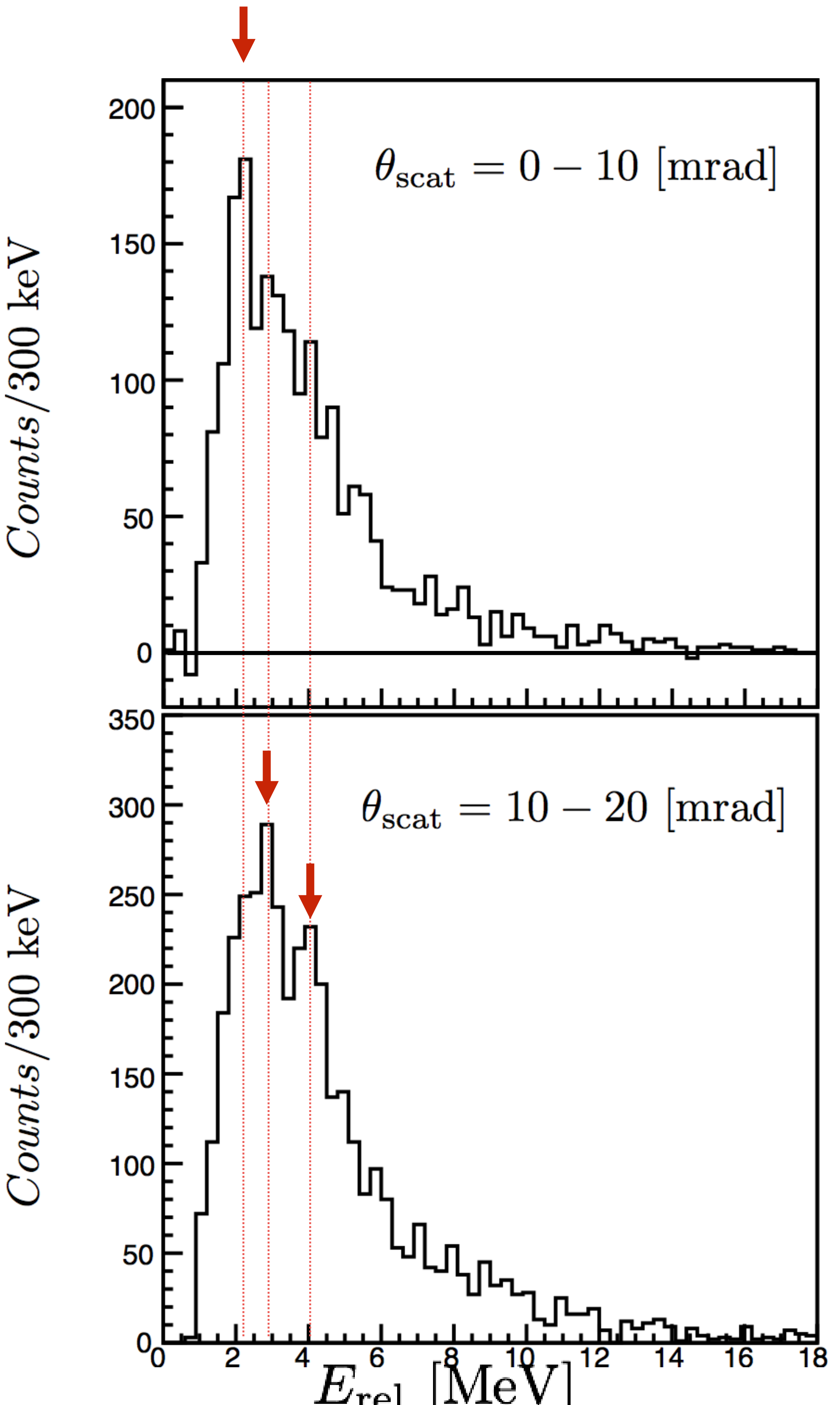


$\theta_{scat} \sim \Delta L$

w/ ^{4}He Track on FDC1



Original Method



Fitting

$S_\alpha = 13.8$ MeV

Lorentzian
(resonance state)

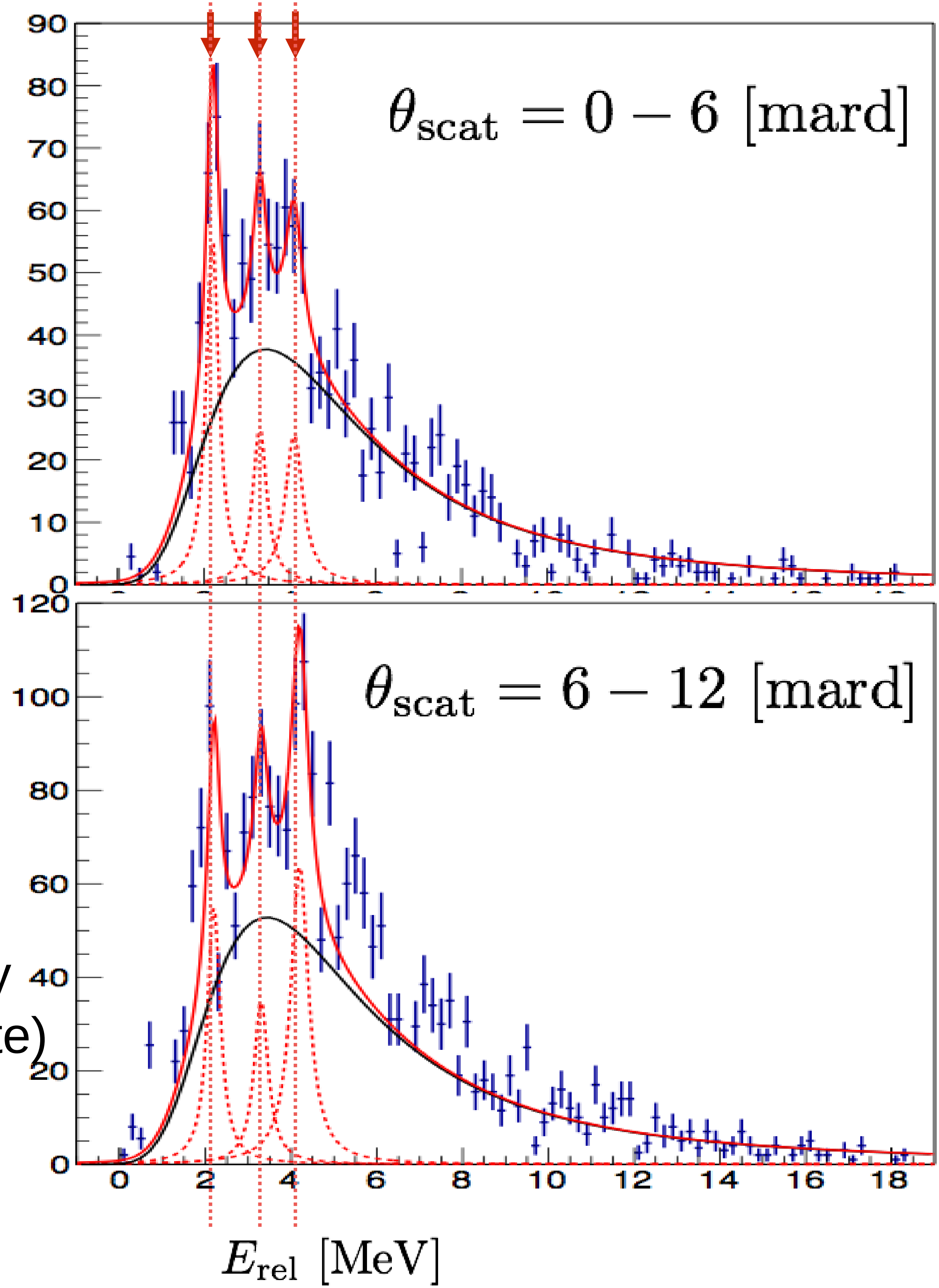
2.2 (1)MeV
3.3 (1)MeV
4.2 (1)MeV

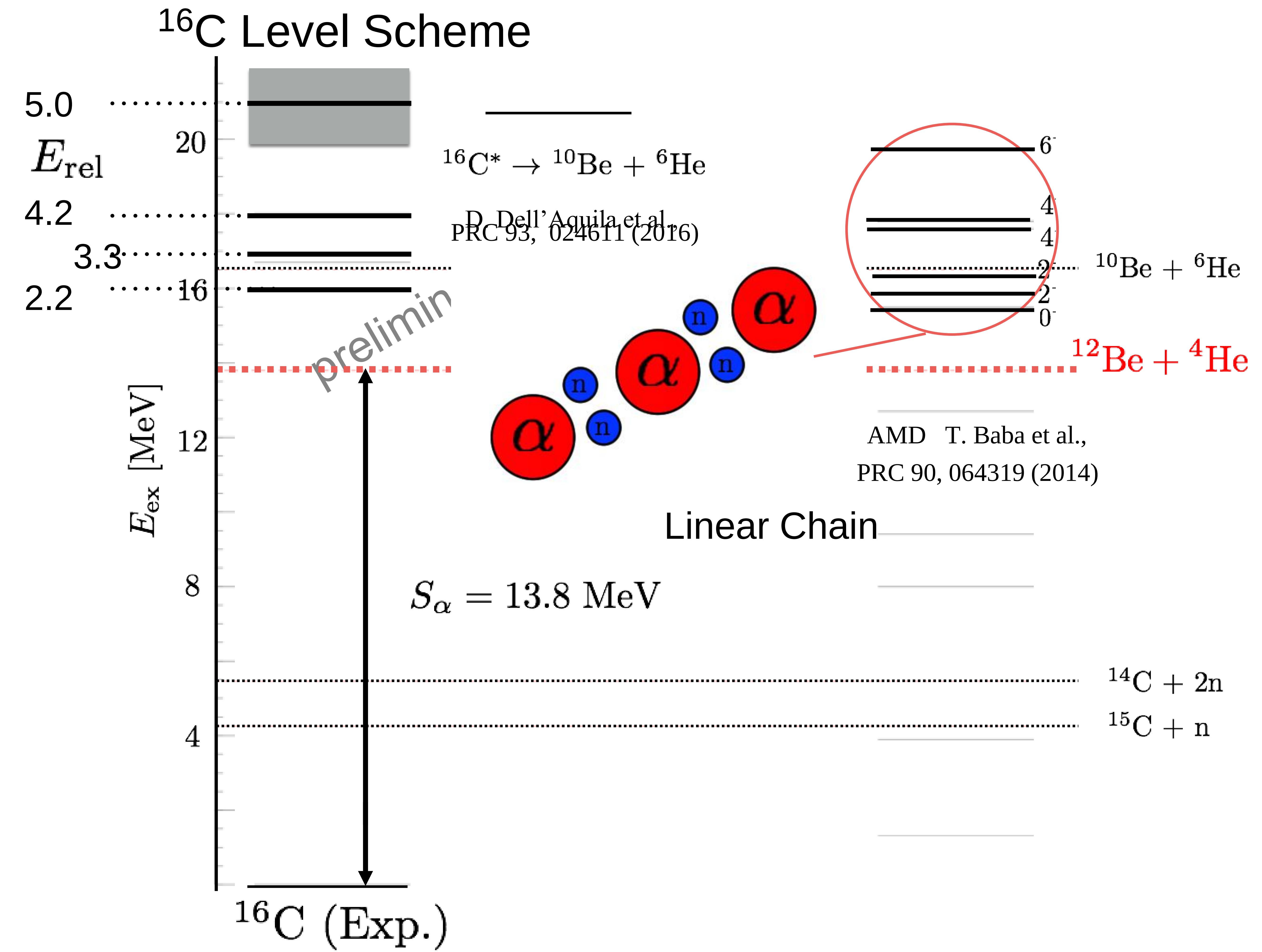
preliminary

+

Phase Space Decay
(non-resonance state)

w/ ^{4}He Track on FDC1



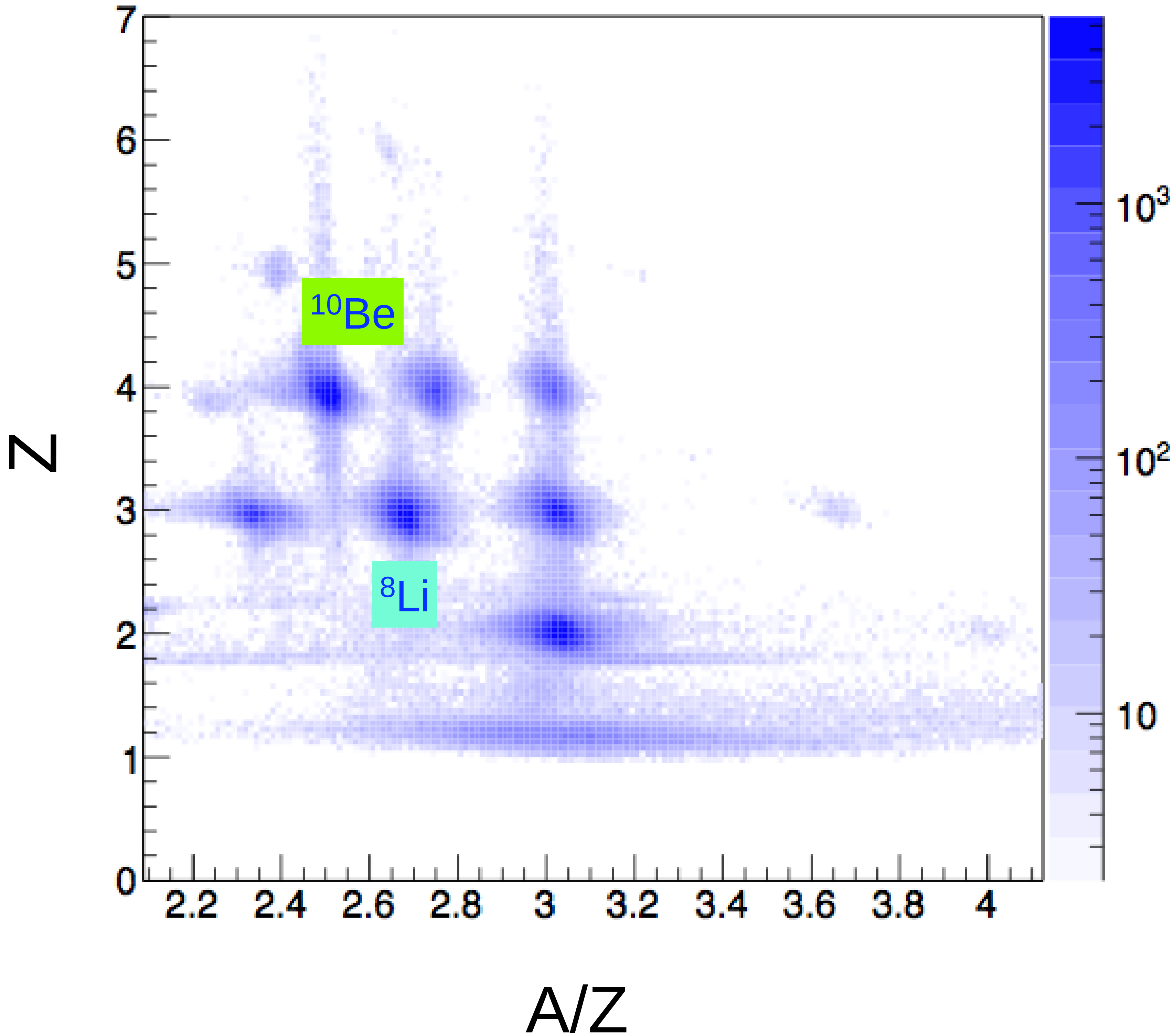


^{16}C Level Scheme
5.0
E_{rel}
4.2
3.3
2.2
20
16
12
8
4
E_{ex} [MeV]
^{16}C (Exp.)
prelimin
$^{16}C^* \rightarrow {}^{10}Be + {}^{6}He$
D. Dell'Aquila et al.,
PRC 93, 024611 (2016)
$S_\alpha = 13.8$ MeV
Linear Chain
n
α
6
4
4
2
2
0
$^{10}Be + {}^{6}He$
$^{12}Be + {}^{4}He$
AMD T. Baba et al.,
PRC 90, 064319 (2014)
$^{14}C + 2n$
$^{15}C + n$

Benchmarks by other coincidence combinations with α

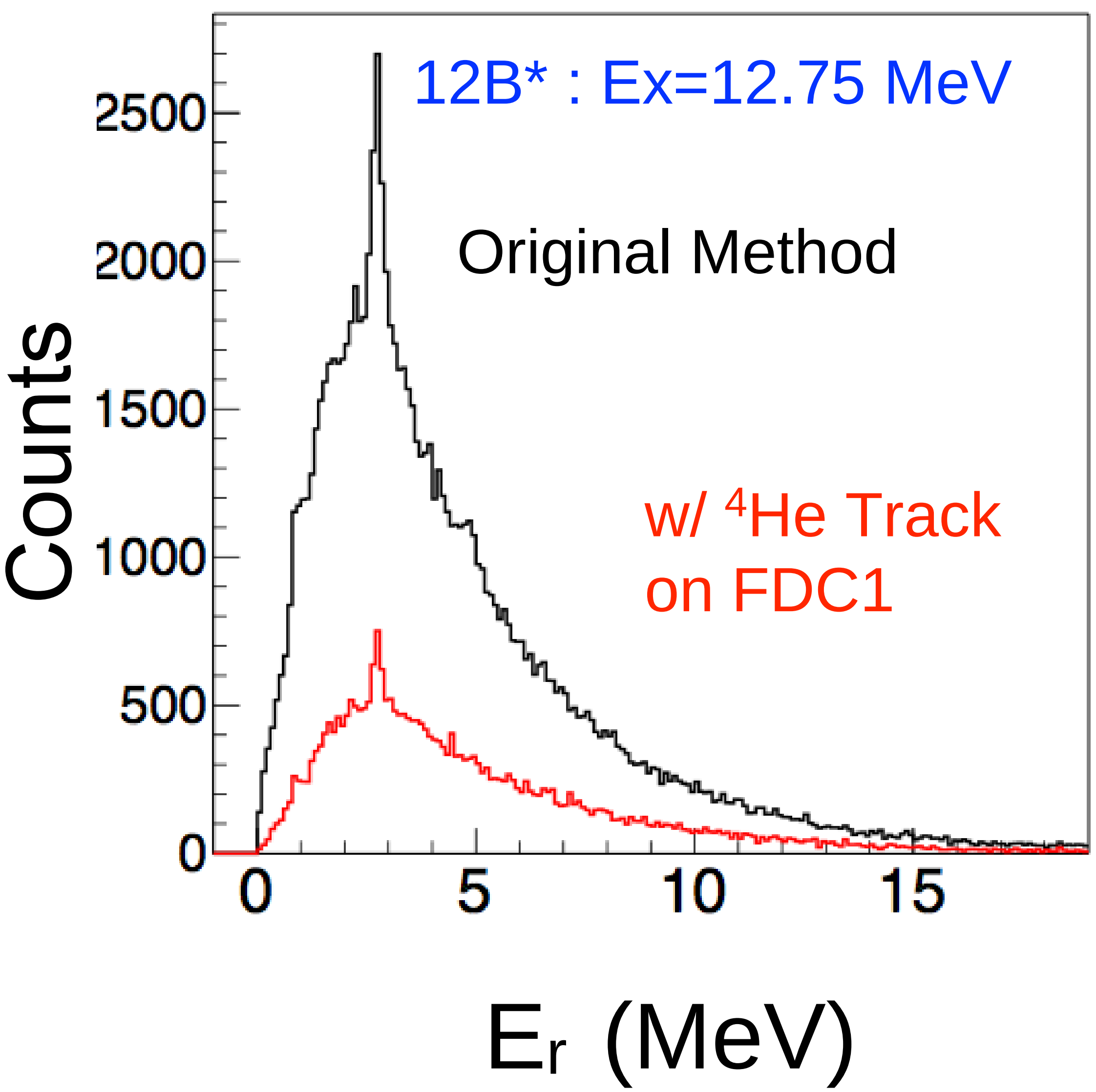
HOD : ΔE, TOF

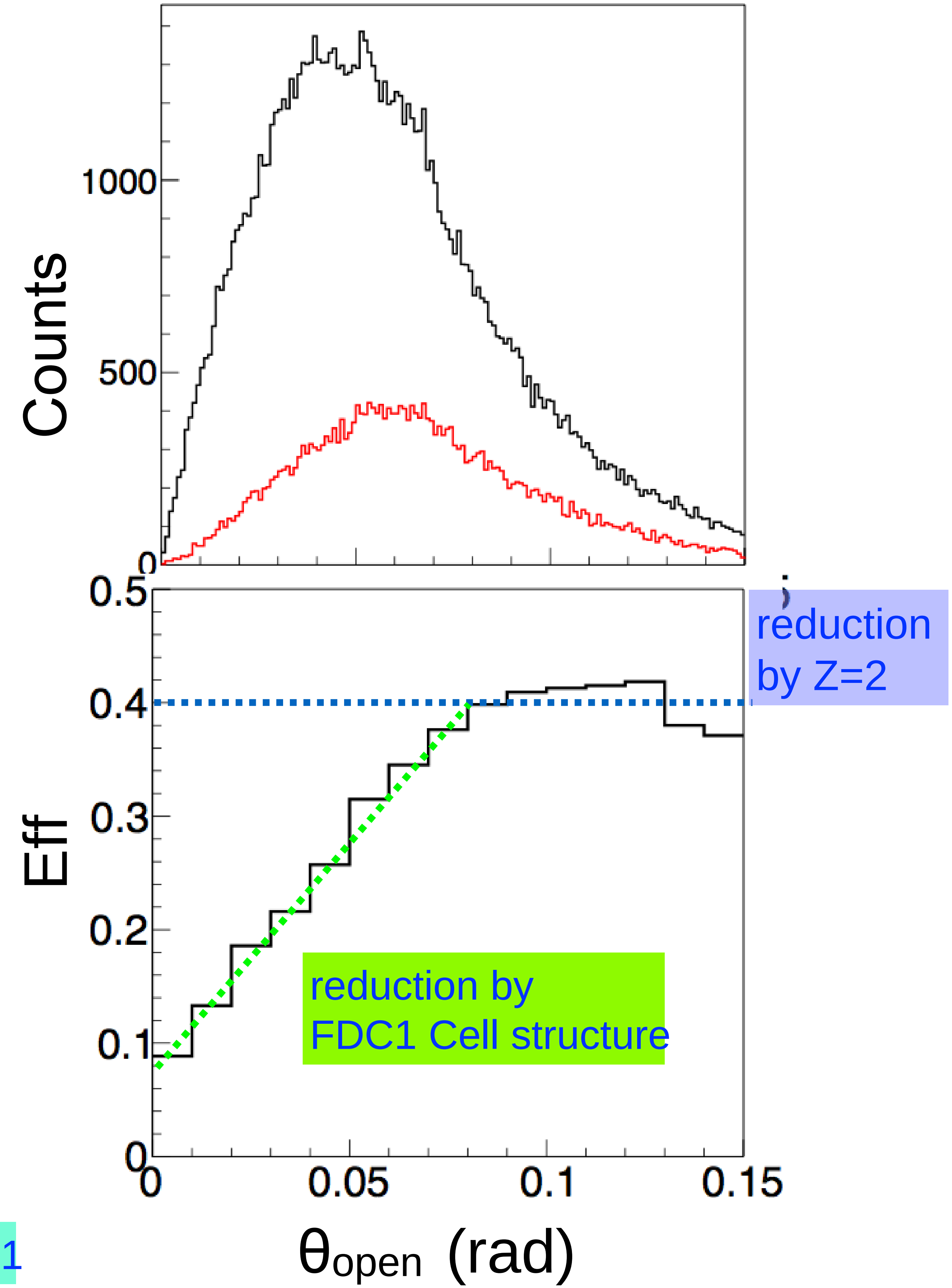
FDC2 : angle (X)



$^{12}B^* \rightarrow {}^{8}Li + {}^{4}He$

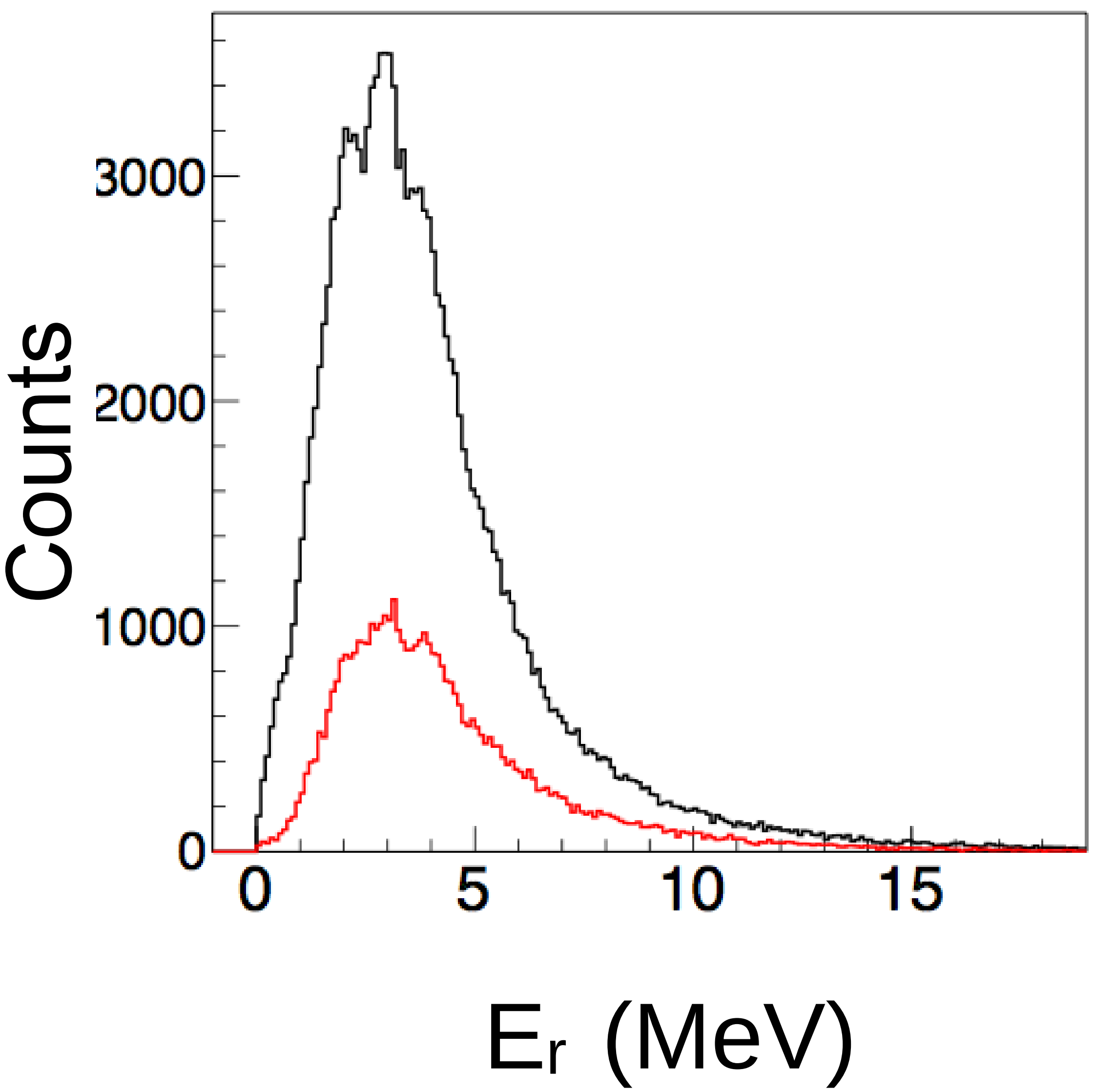
R.J. Charity et.al., PRC78 05407(2008)

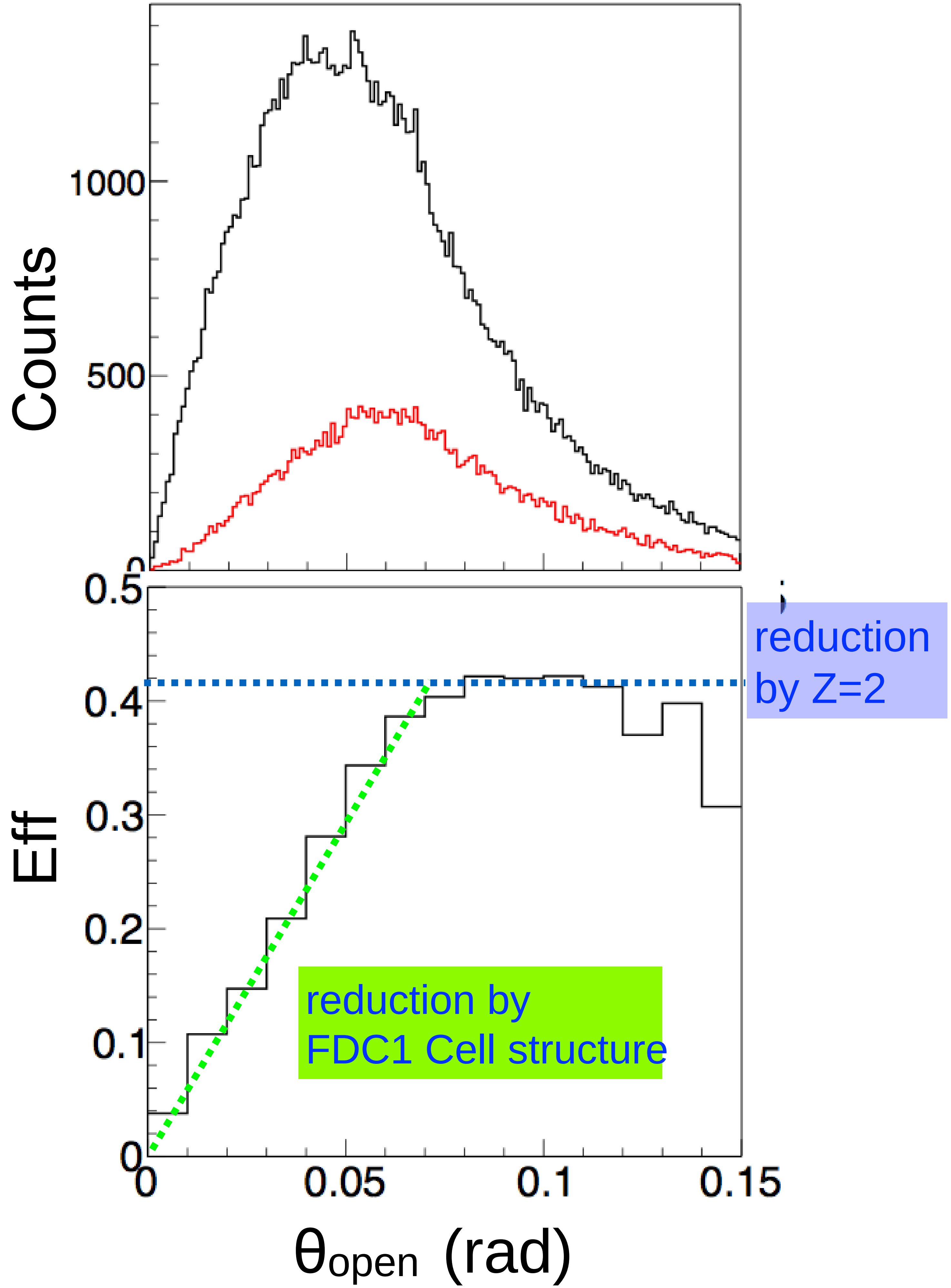




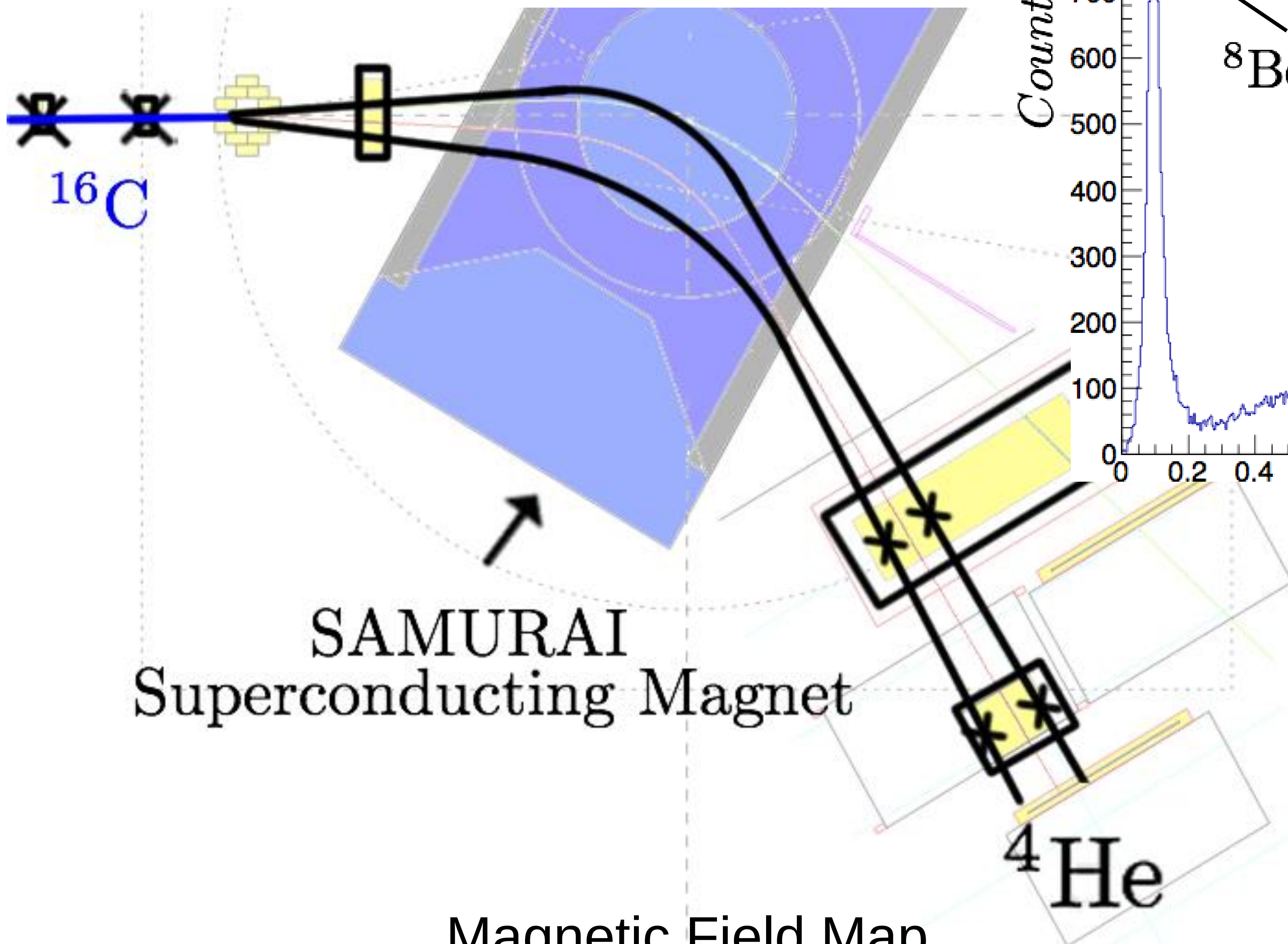
c.f. Anode wire spacing : 10mm on FDC1

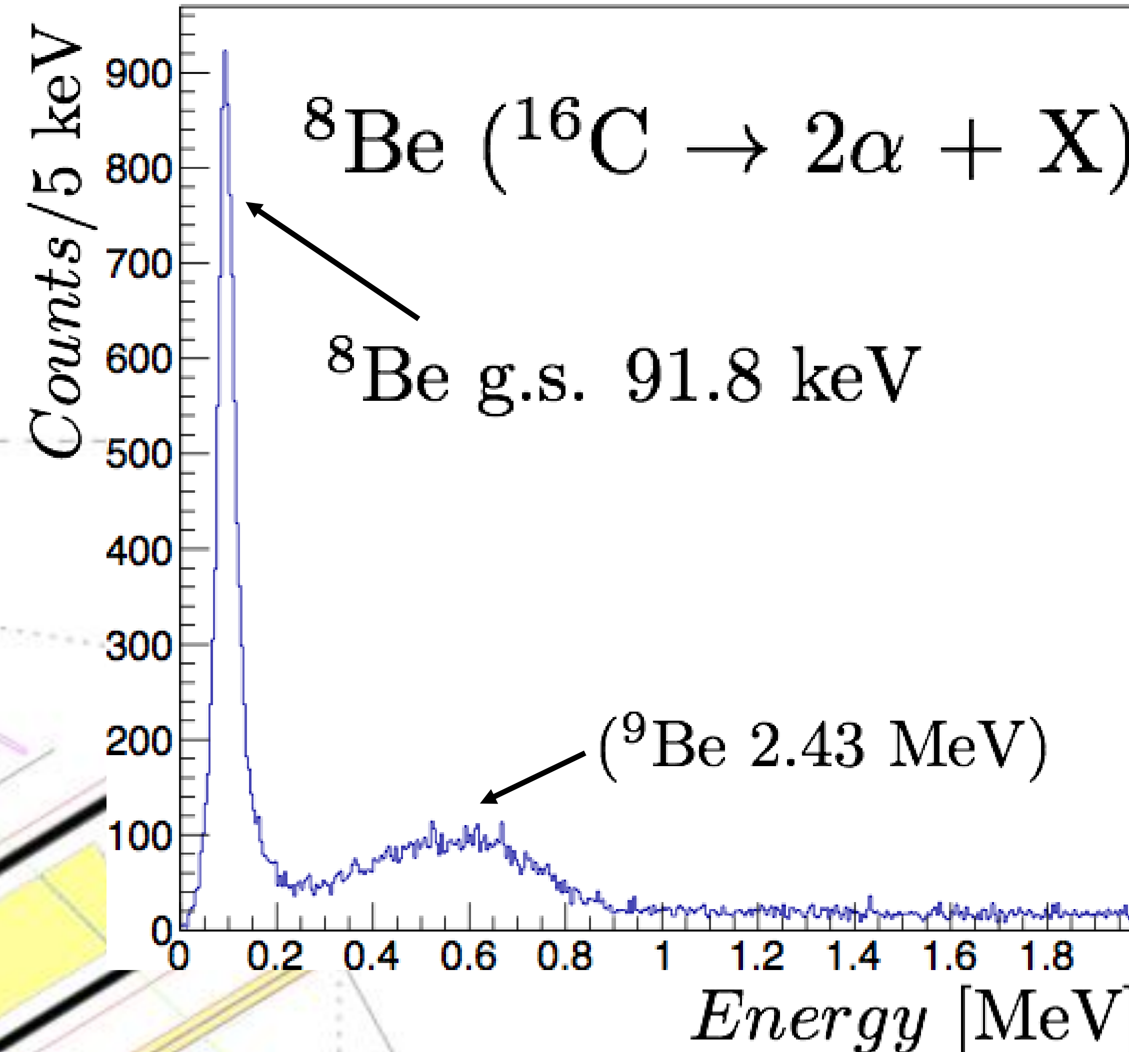
$^{14}C^{*} \rightarrow {}^{10}Be + {}^{4}He$





Momentum Analysis





Magnetic Field Map

H. Sato et al., IEEE Trans. Apple. Supercond. 23, 4500308 (2013)

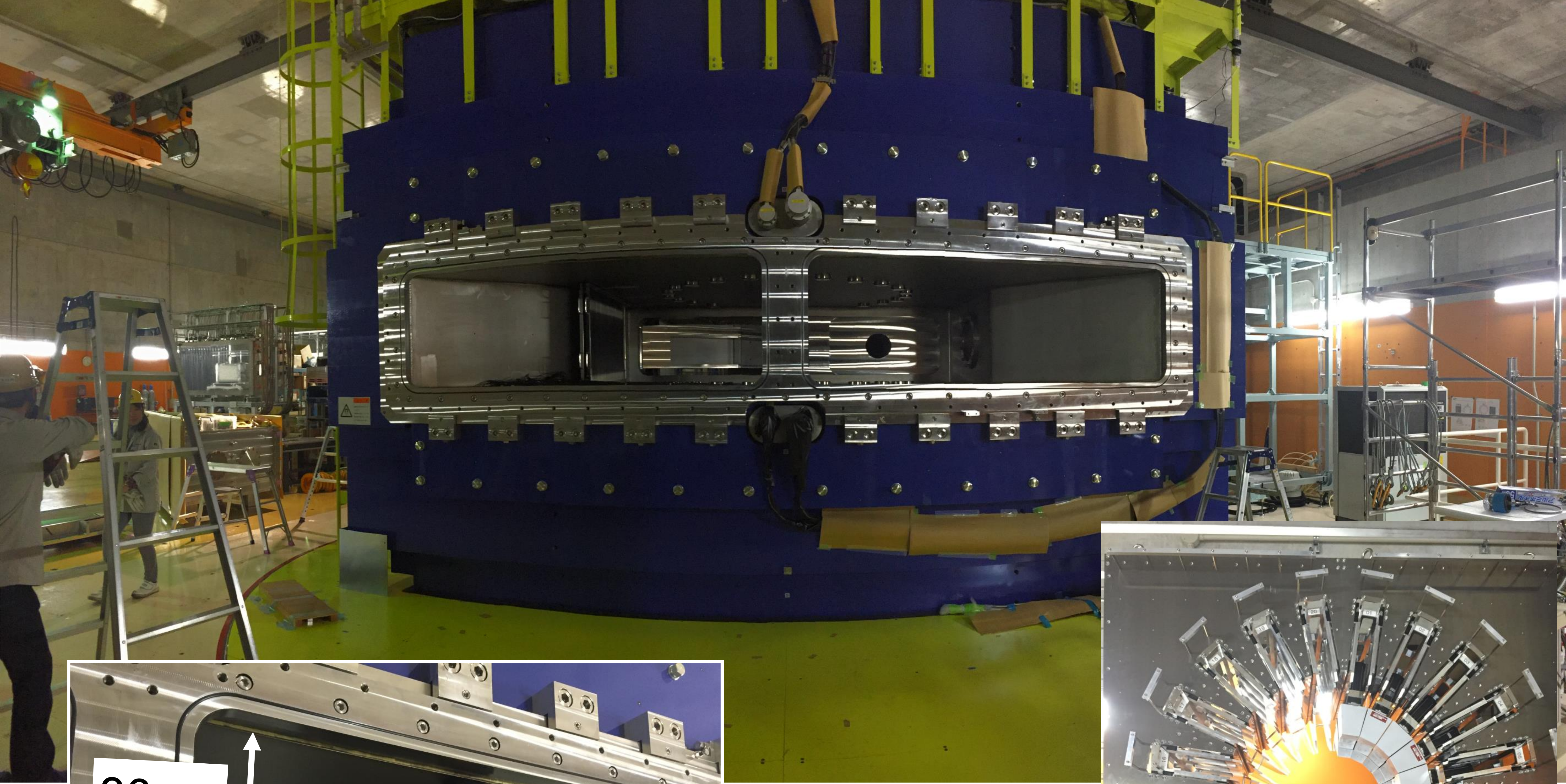
Short Summary on Two charged particle tracking properties

- SAMURAI08 exp.
  - $^{16}C(\alpha,\alpha')^{16}C^*$ -> ^{12}Be + ^{4}He
  - Z=2 + Z=4 tracking analysis @ SAMURAI is performed
  - Spectroscopy above α threshold becomes possible to study the degree of freedom of cluster structure
- Drift Chamber optimization
  - higher operation voltage :
    - high eff. and high multiplicity on 1 track
    - limitation of 2nd beam intensity
  - Space Time conversion should be optimized by each Z
- Z=2 analysis on FDC1 (upstream of magnet)
  - Improve E_{rel} resolution
    - (Opening) Angle resolution improved
    - Lose statistics by 2 reasons : (low eff. on Z=2, θ_{open} ~0)

Summary

- SAMURAI 2015-2016
  - ^{28}O (SAMURAI21), SAMURAI-TPC, pol. exp(SAMURAI13)
  - Configuration varieties : 0 deg. , He filling mode

- Details for Particle Identification property
  - PID at A~132
    - 6σ separation on A/Q achieved (as designed)
    - 4.5σ separation on Z but several (severe) problems remain
      to be solved
- Details for multi-track property
  - 2 charged particle detection at Focal plane (← New)
    - Importance of DC optimization
    - FDC1 for Z=2 improve angular resolution
  - Spectroscopy above α threshold become possible



Thank you
for your attention

Backup Slides

Collaboration

Shunpei Koyama

RIKEN Nishina Center
- Hideaki Otsu
- Y. Shimizu
- K. Yoneda
- H. Sato
- T. Motobayashi
- K. Kusaka
- J. Ohnishi
- T. Isobe
- S. Takeuchi
- P. Doornenbal
- M. Nishimura
- M. Sasano
- J. Zenihiro
- N. Fukuda
- J. Lee
- H. Baba
- H. Liu
- H. Sakurai

Soeul U.
- Y. Satou
- J. Hwang

Tohoku U.
- T. Kobayashi
- K. Sekiguchi
- N. Chiga
- T. Shumikama
- K. Muto
- Y. Wada

Kyoto U.
- T. Kawabata
- Y. Matsuda
- N. Nakatsuka
- T. Murakami

Tokyo Tech.
- Y. Kondo
- Y. Togano
- R. Minakata
- S. Ogoshi
- T. Nakamura

U. of Tokyo
- N. Kobayashi
- M. Niikura

Peking U. - RNC
- R. J. Chen
- Z. Li

CNS, U-Tokyo
- M. Matsushita

LPC Caen
- J. Gibelin
- S. Leblond

CEA Saclay
- V. Lapoux

Kyusyu U.
- S. Sakaguchi

Kurchatov Inst. - RNC
- E. Nikolskii

Orsay - RNC
- D. Beaumel

GANIL
- A. Navin

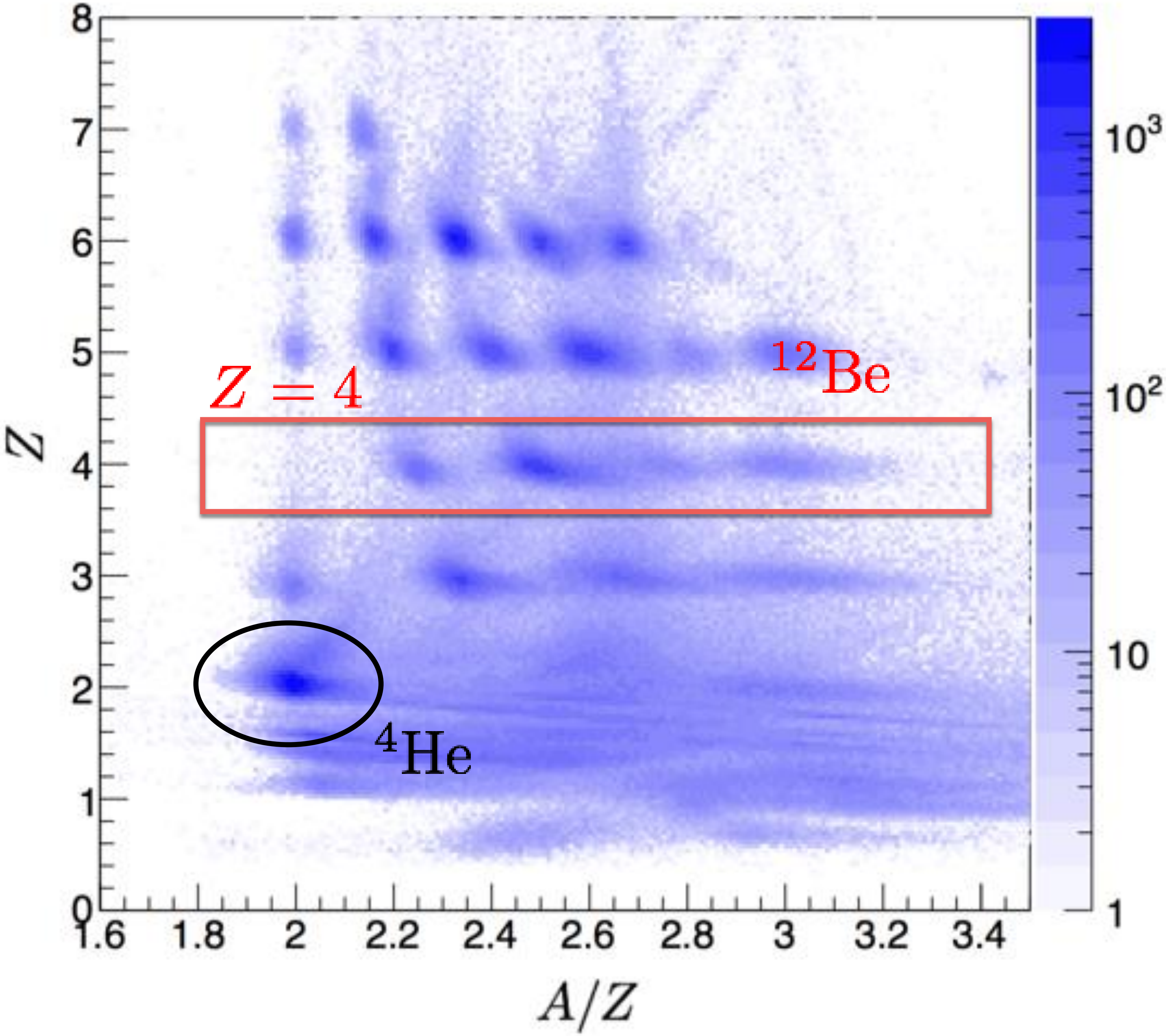
Kansai U.
- M. Ito

Hokkaido U.
- M. Kimura

Tsukuba U.
- Y. Taniguchi

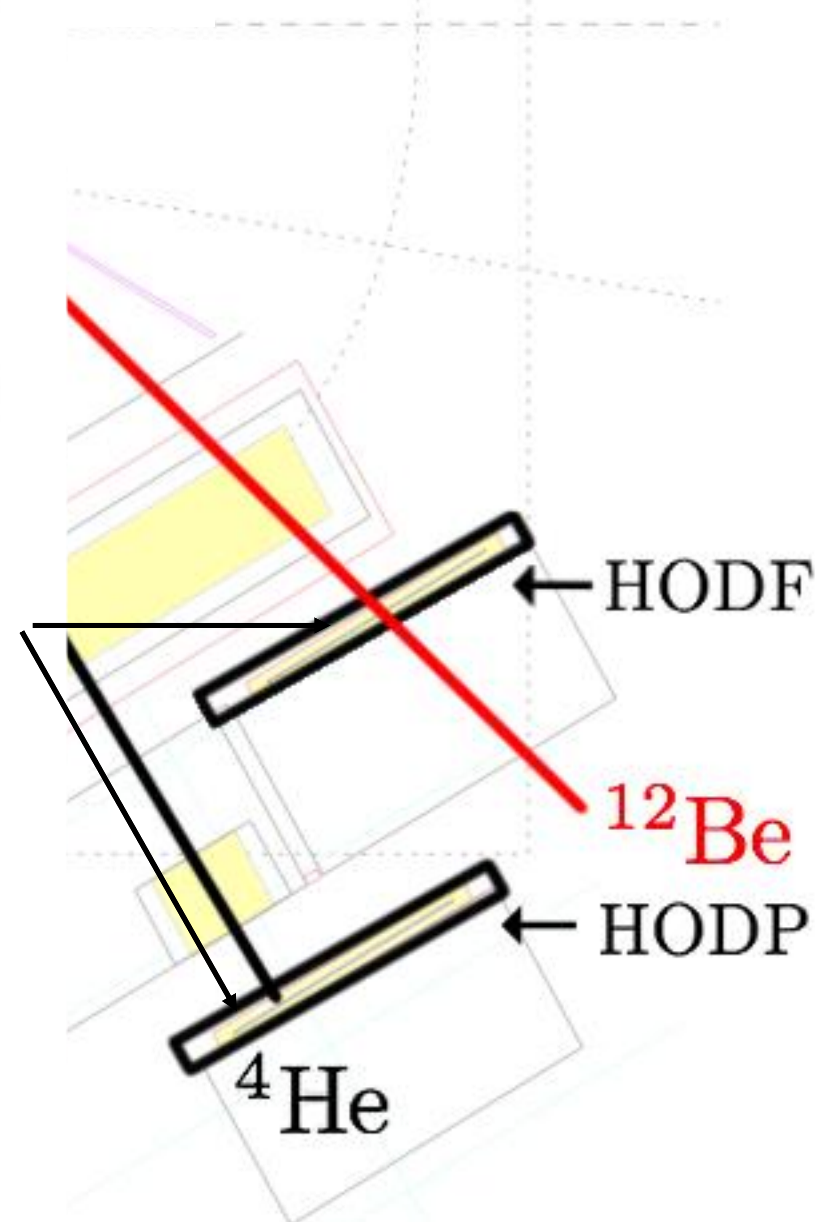
PID

TOF-ΔE



$$Z \propto \sqrt{\Delta E}/TOF$$

$$A/Z \propto TOF \times B\rho$$

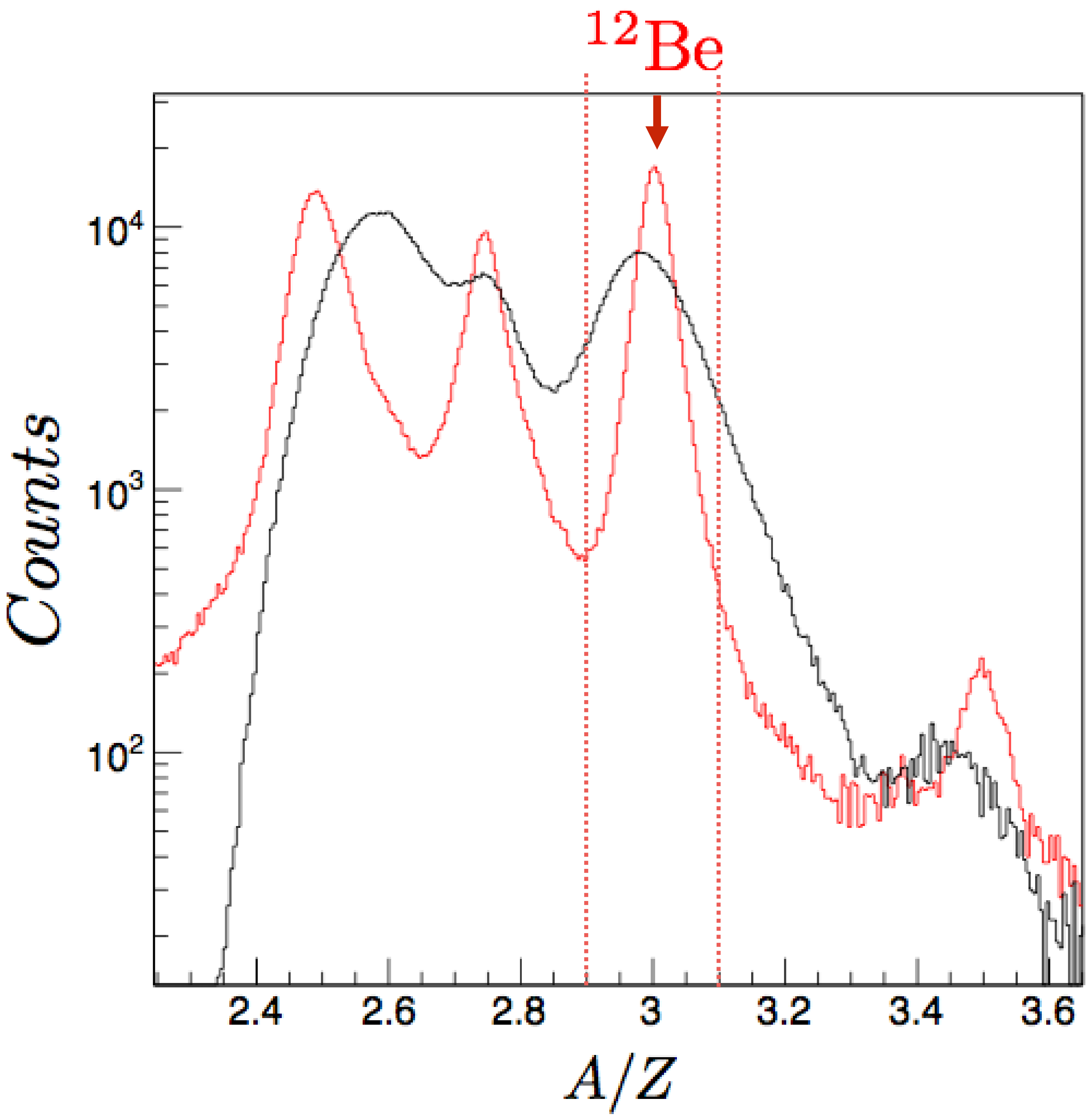


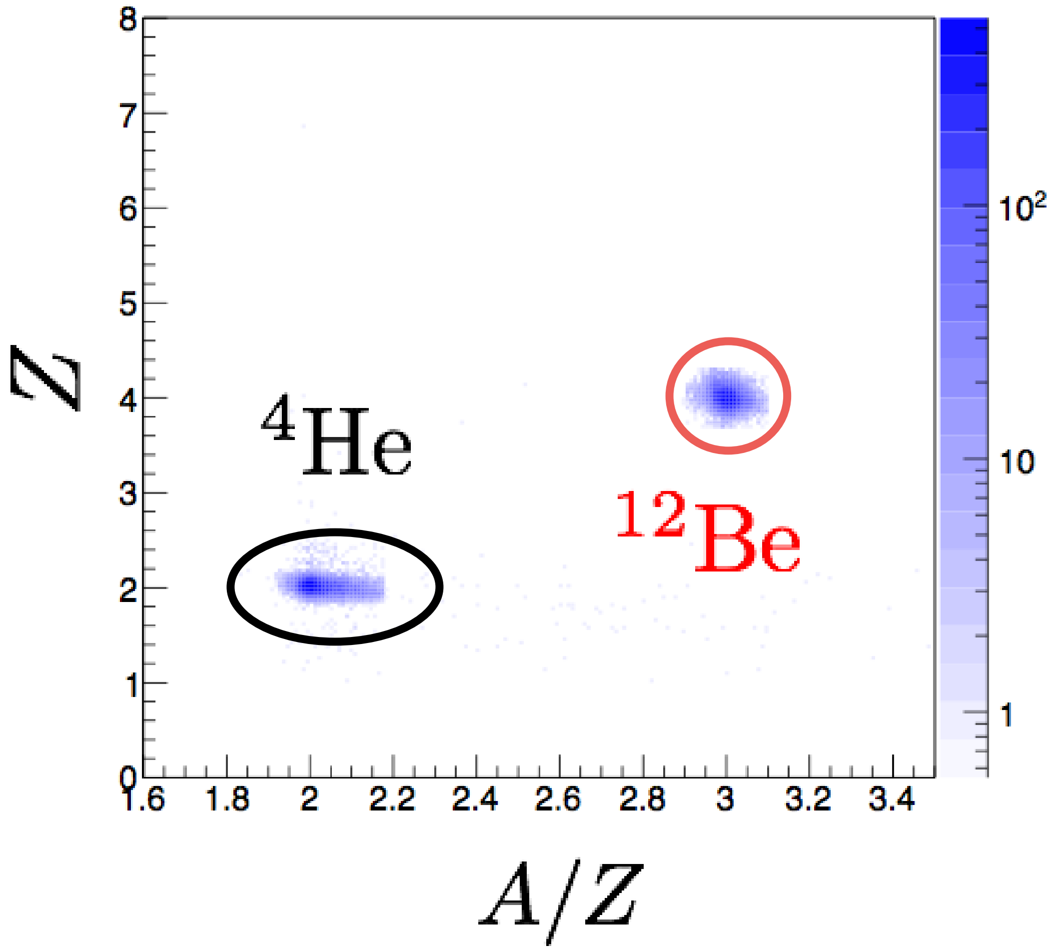
AoZ , Coincidence

$$Z \propto \sqrt{\Delta E}/TOF$$

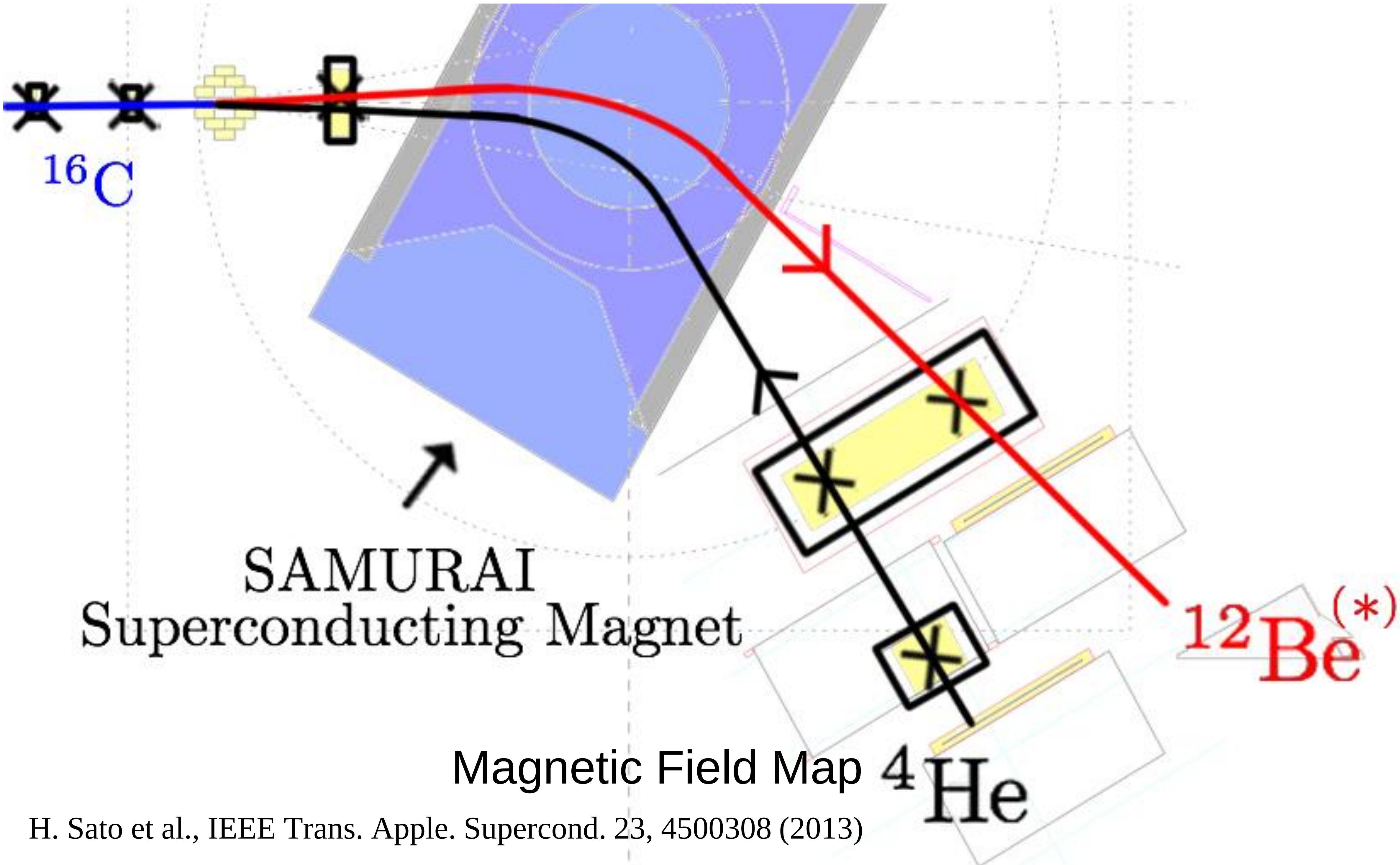
$$A/Z \propto TOF \times B\rho$$

TOF-ΔE -Bρ (for Z=4)





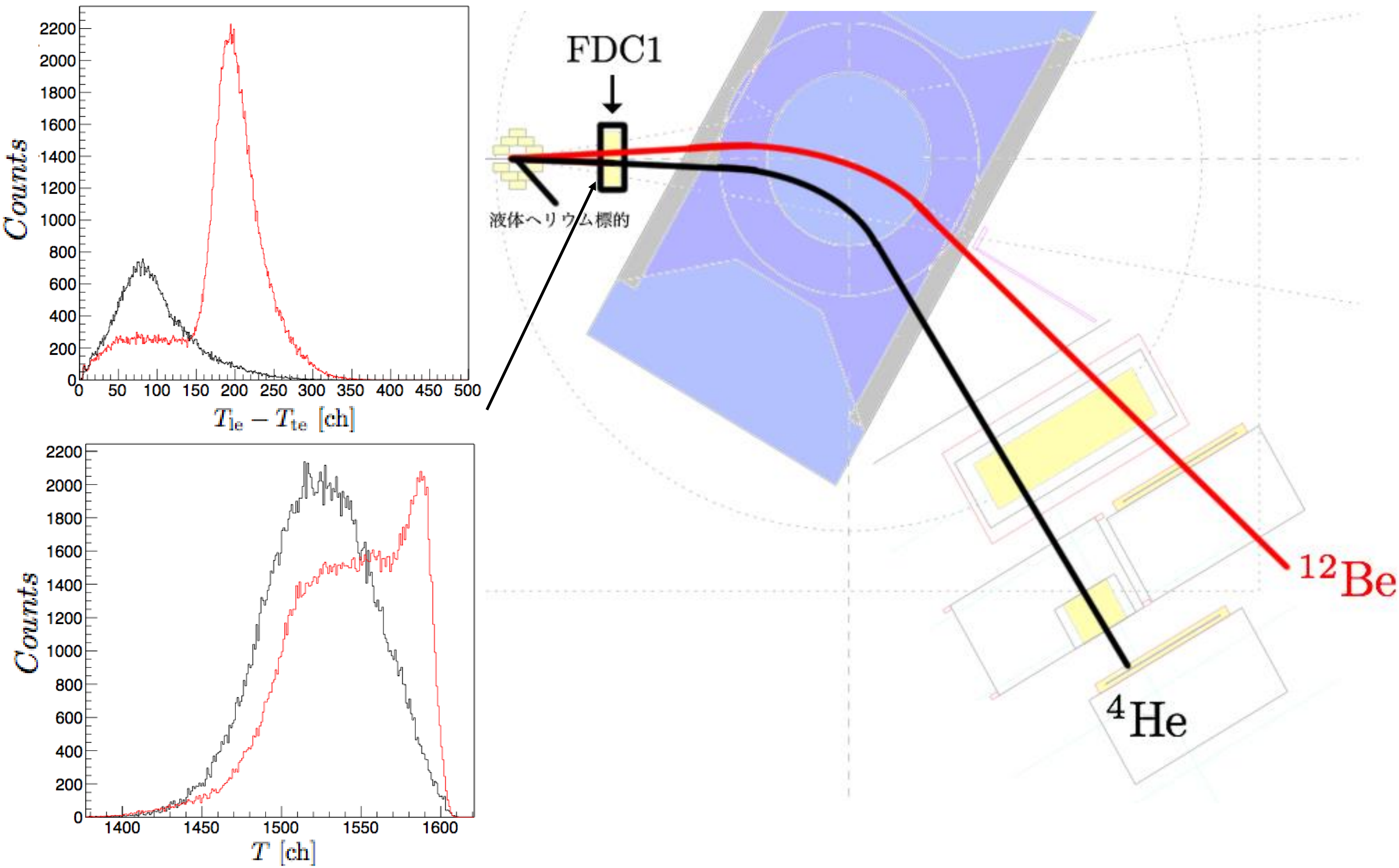
Momentum Analysis



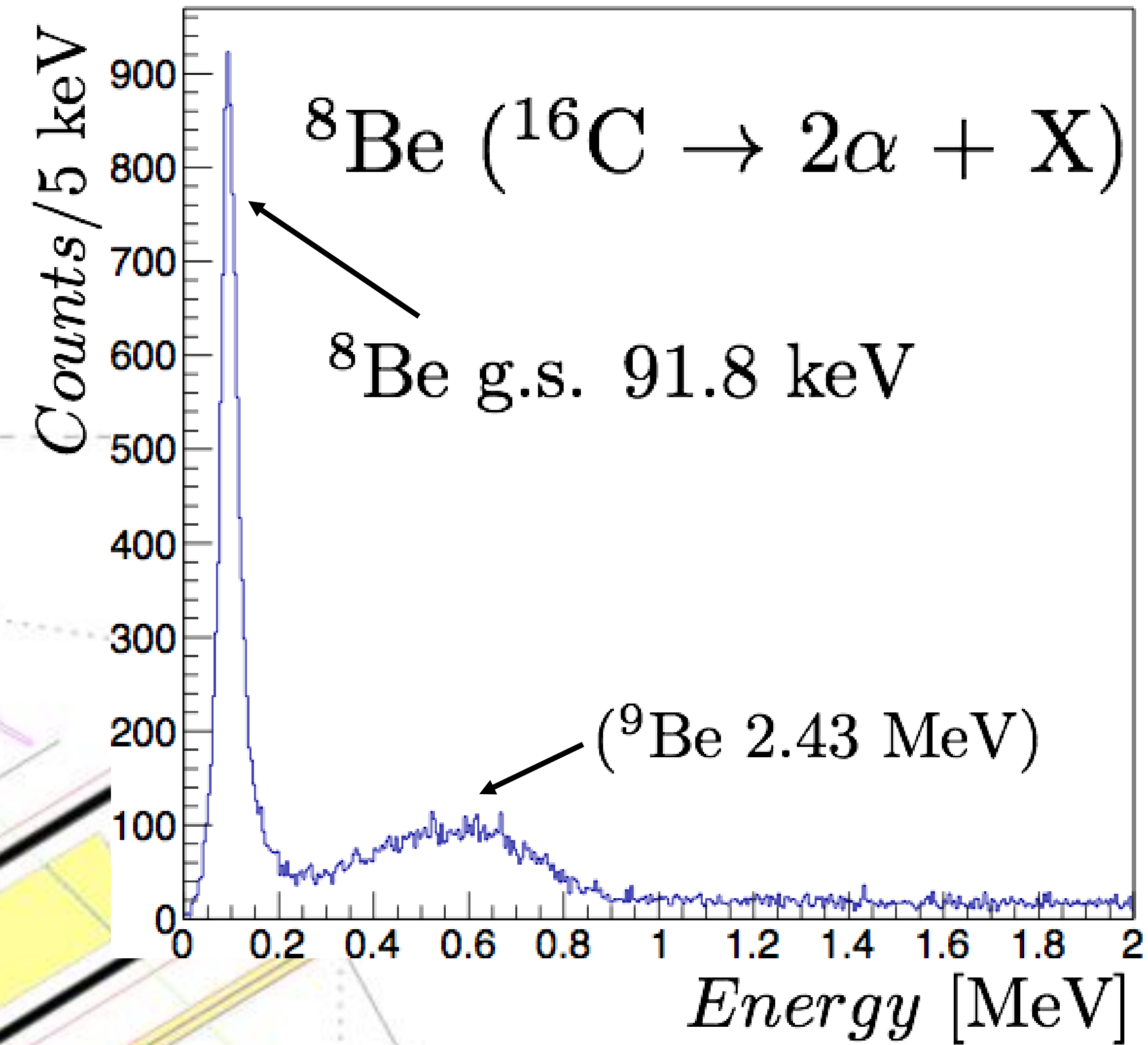
Magnetic Field Map

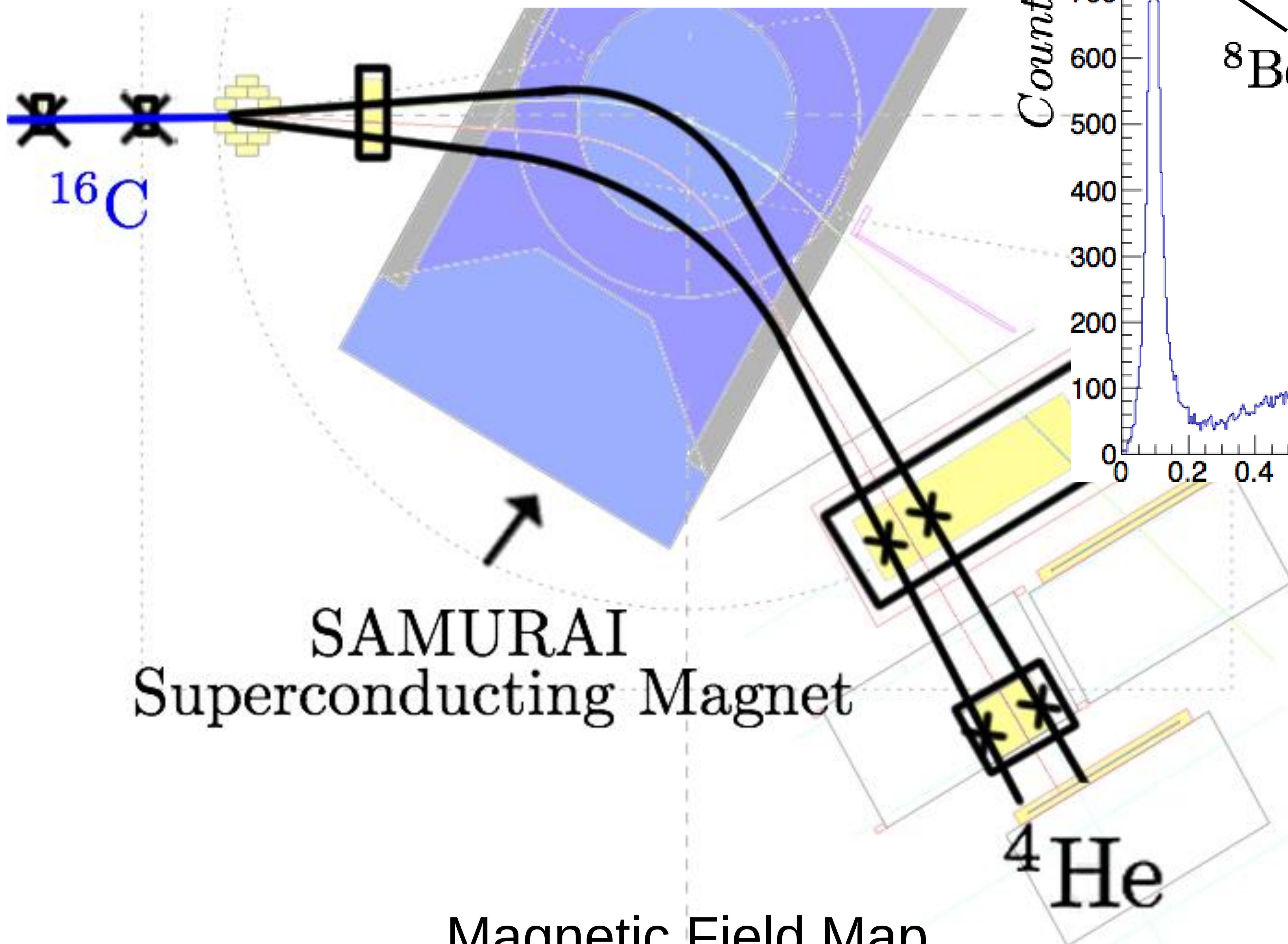
H. Sato et al., IEEE Trans. Apple. Supercond. 23, 4500308 (2013)

ToT separation at FDC1



Momentum Analysis

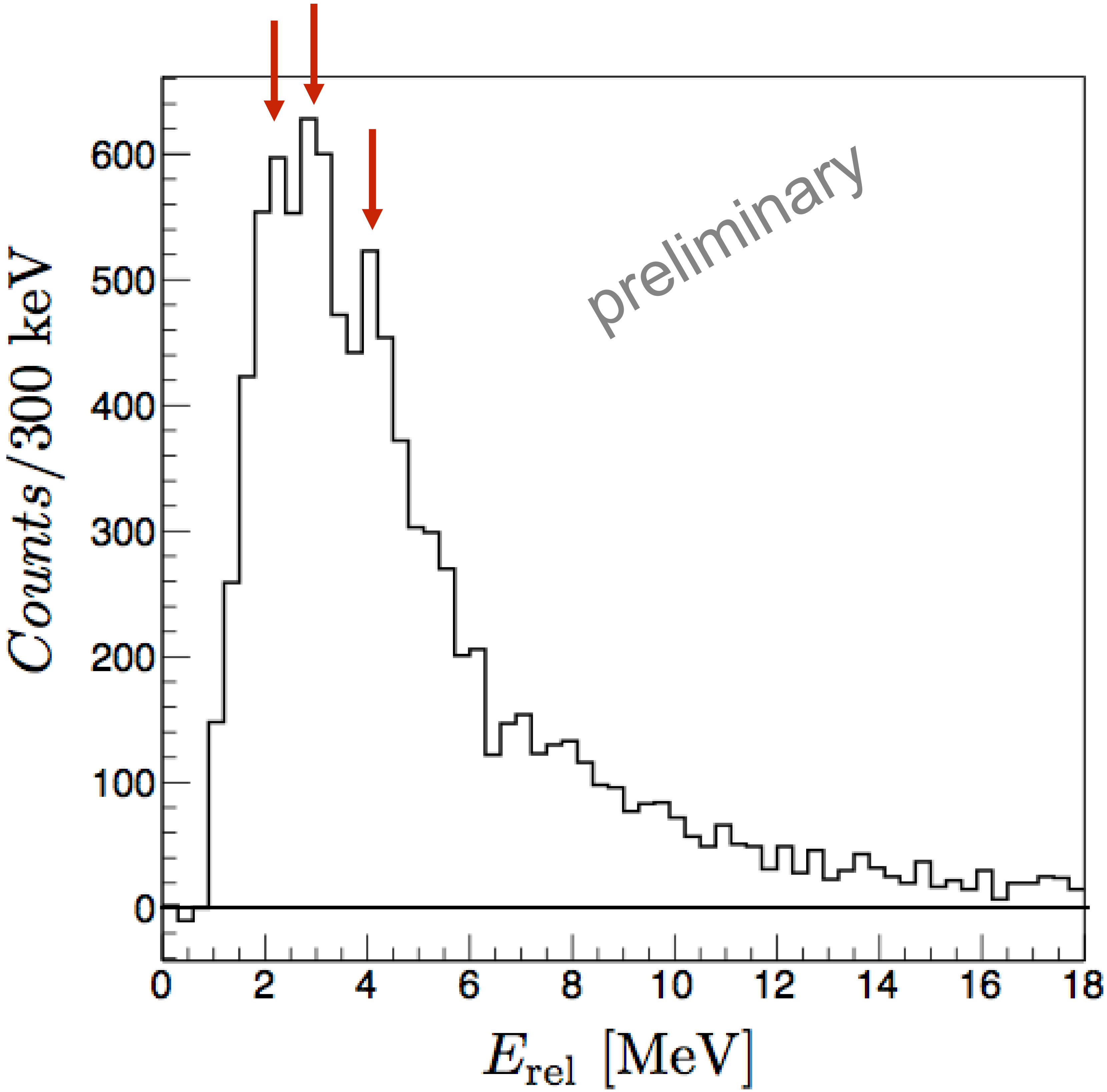


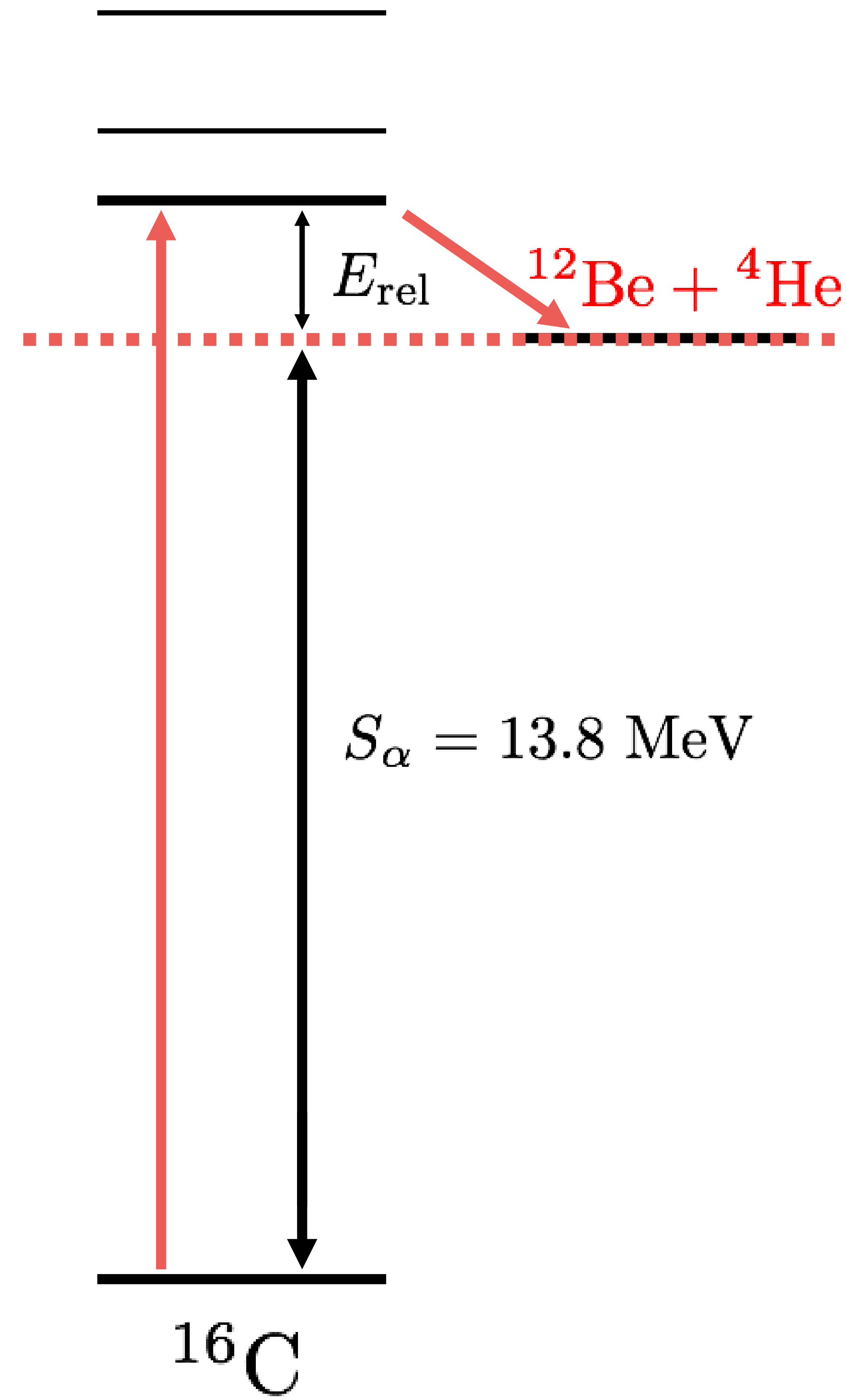


Magnetic Field Map

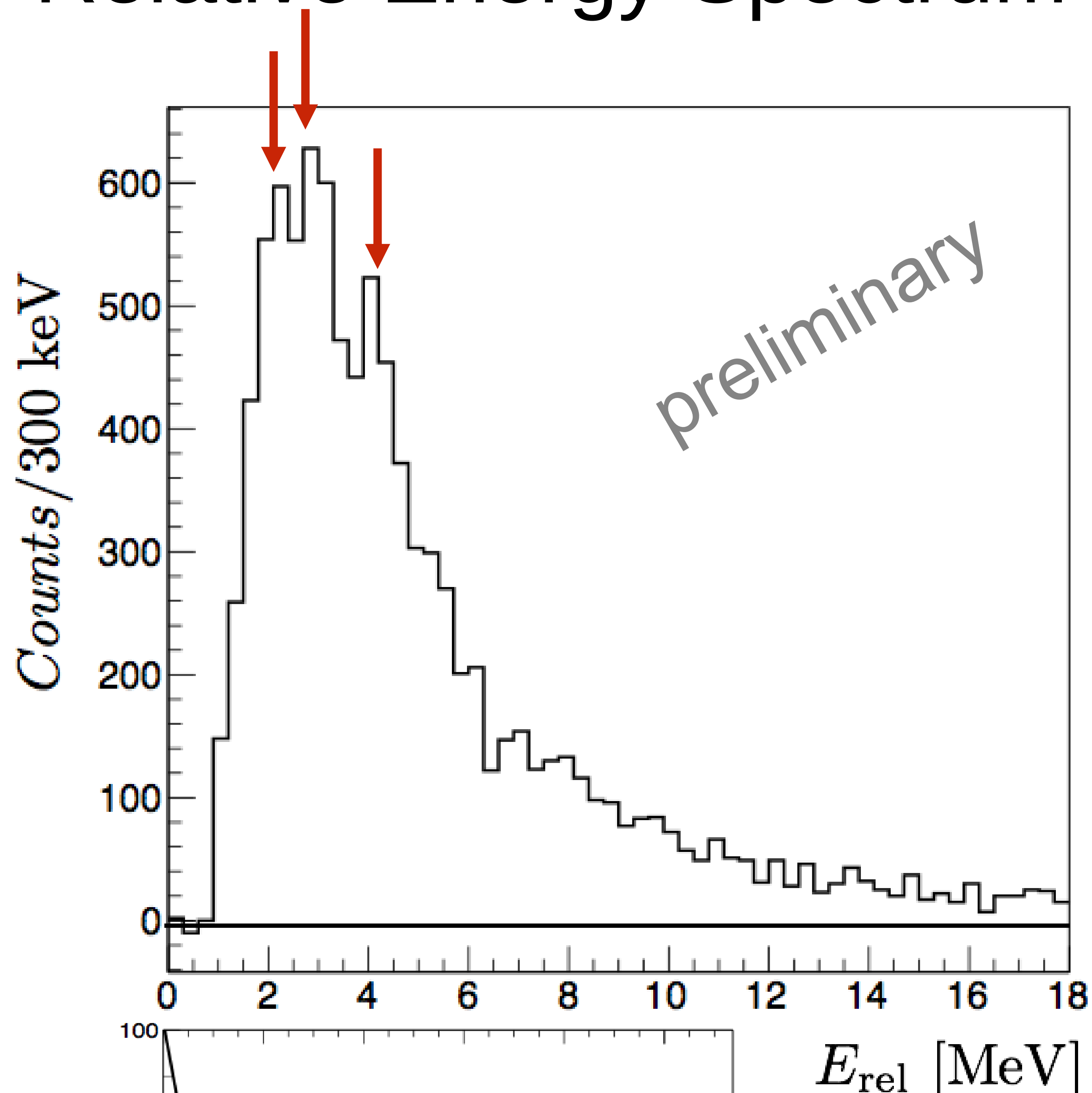
H. Sato et al., IEEE Trans. Apple. Supercond. 23, 4500308 (2013)

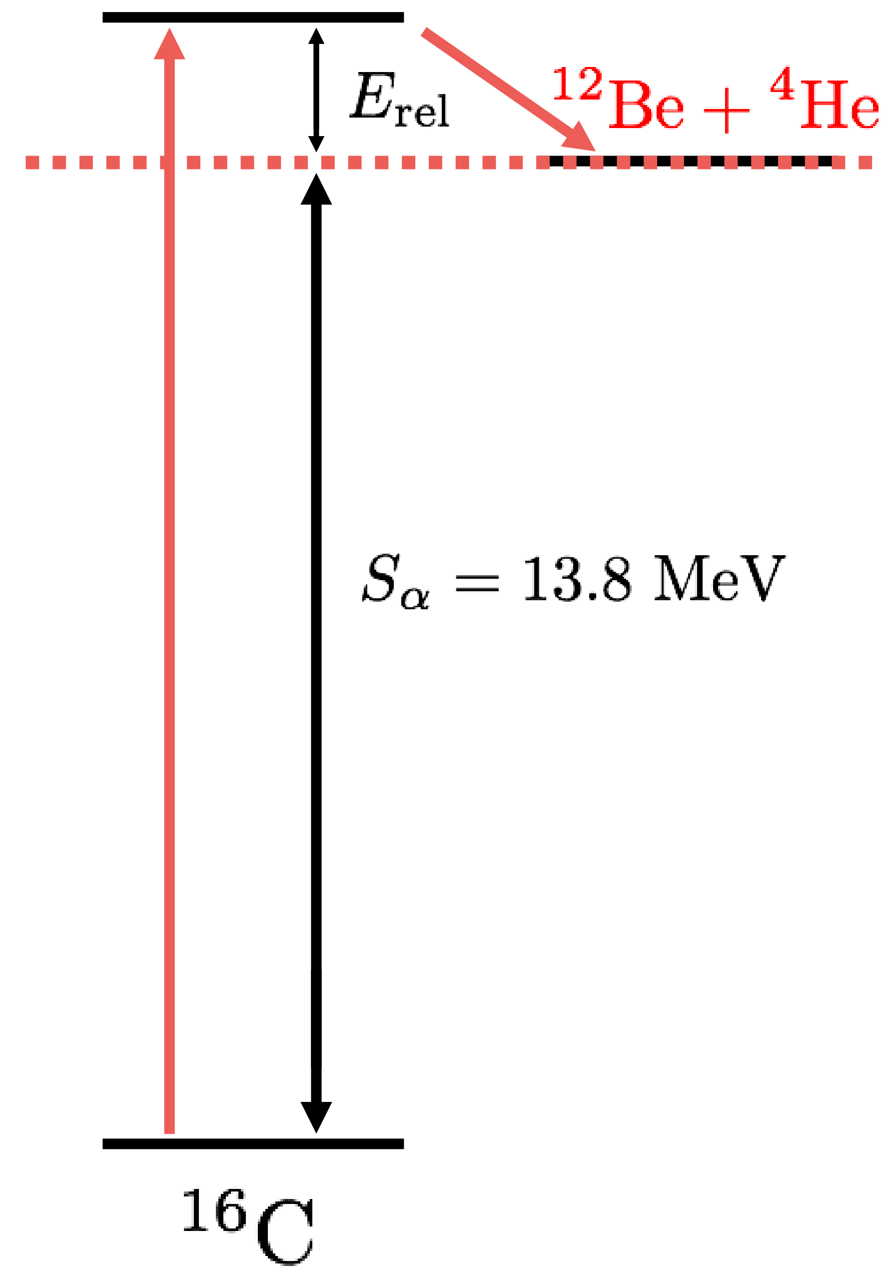
Relative Energy Spectrum

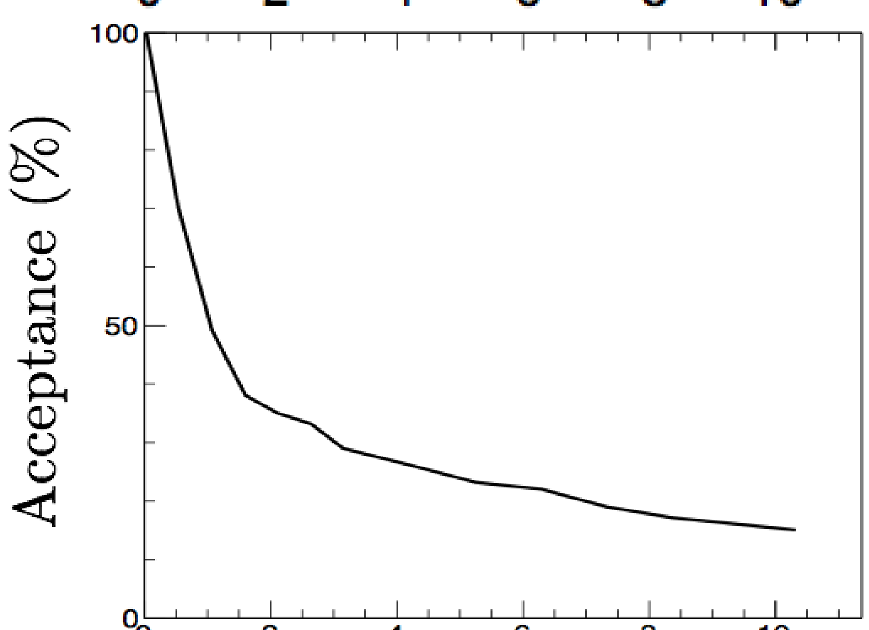




Relative Energy Spectrum



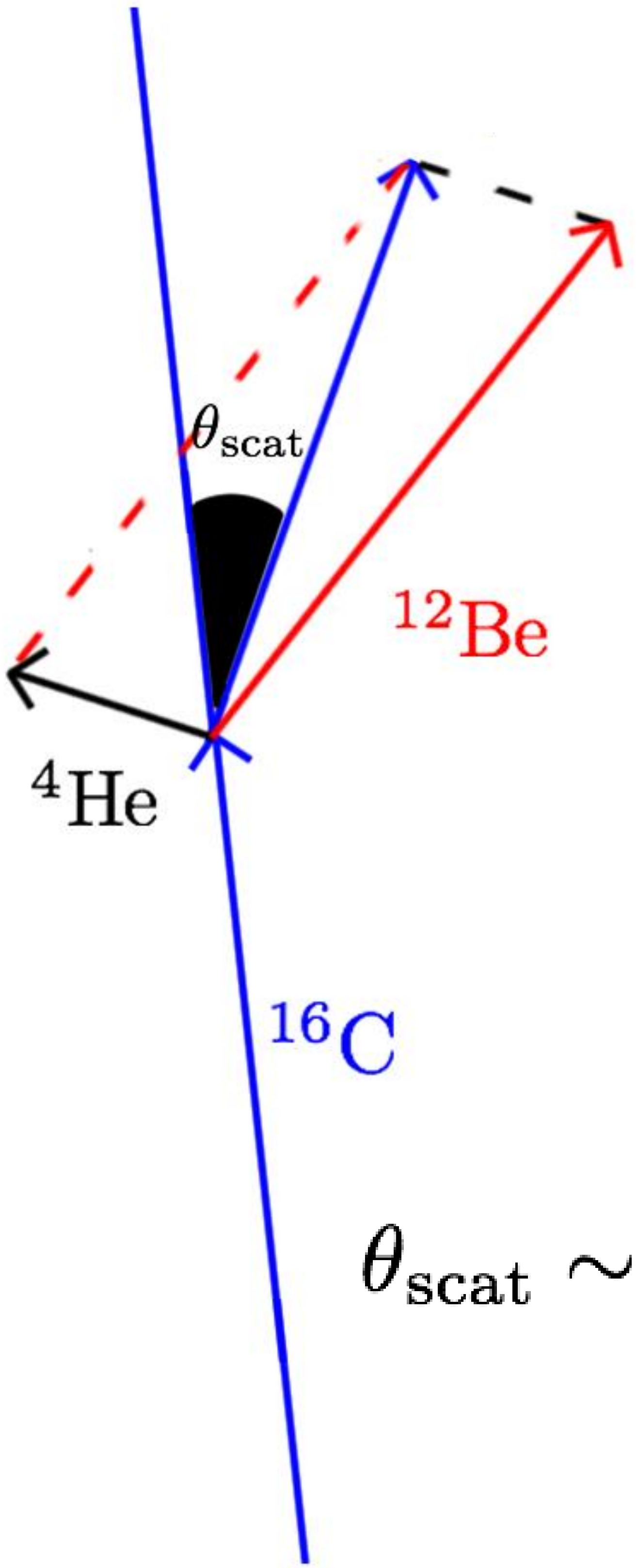




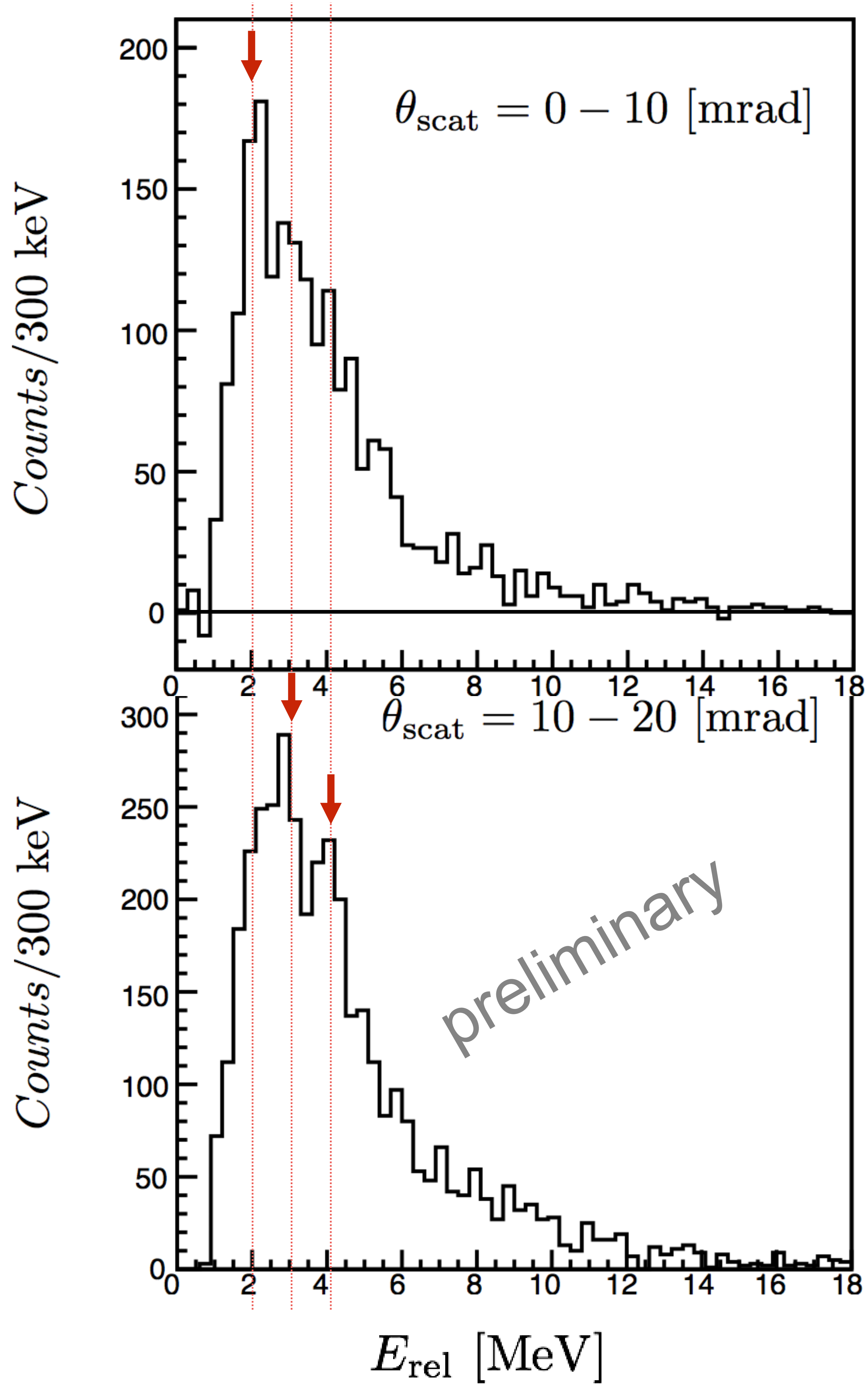
resolution

$$\sigma\ (E_{\mathrm{rel}})\ [\mathrm{MeV}] \simeq 0.1 \times \sqrt{\mathrm{E_{rel}}\ [\mathrm{MeV}]}$$

Scattering Angle



$\theta_{\rm scat} \sim \Delta L$



Fitting

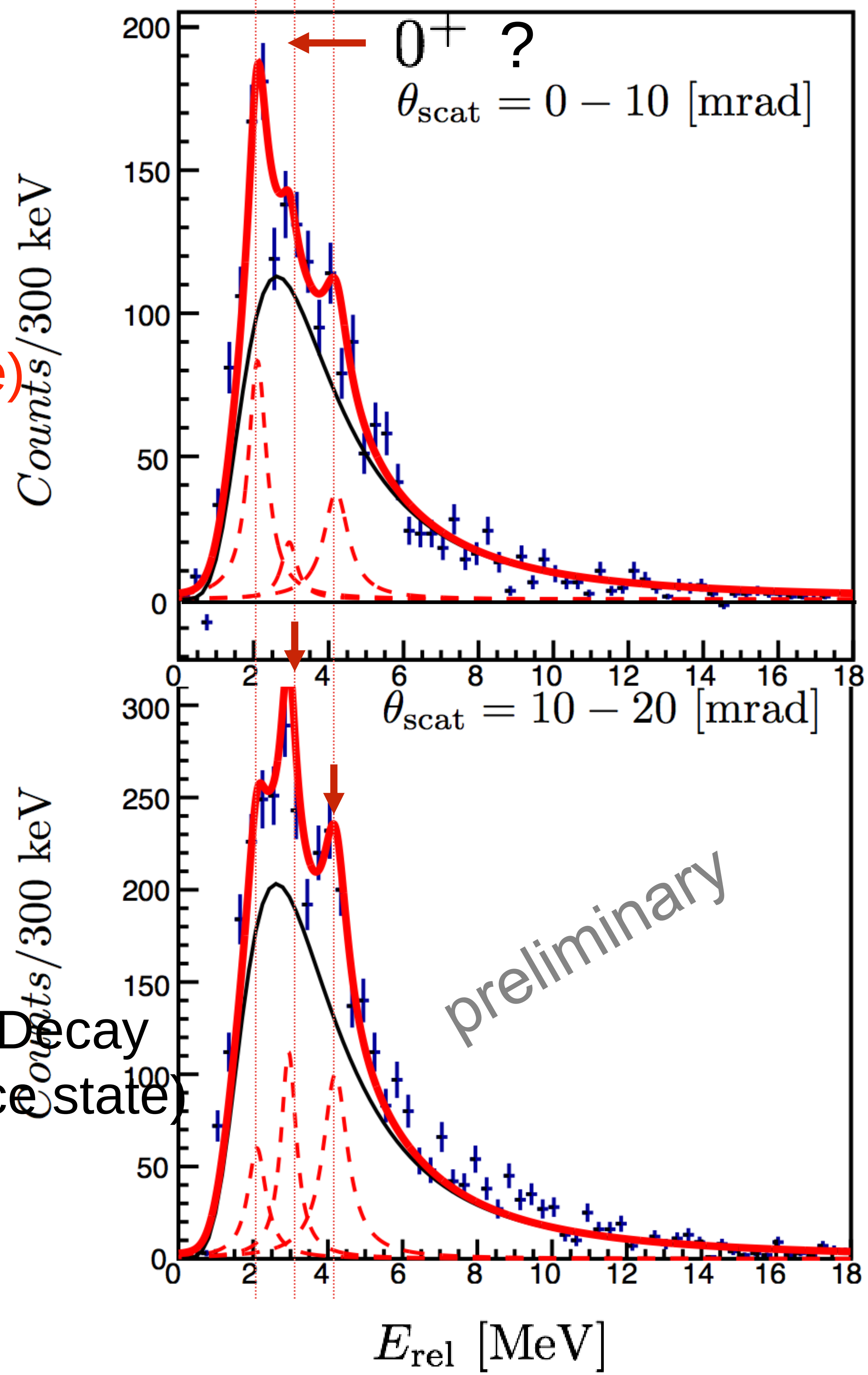
$S_\alpha = 13.8$ MeV

Lorentzian
(resonance state)

2.2 (2)MeV
2.9 (2)MeV
4.2 (2)MeV

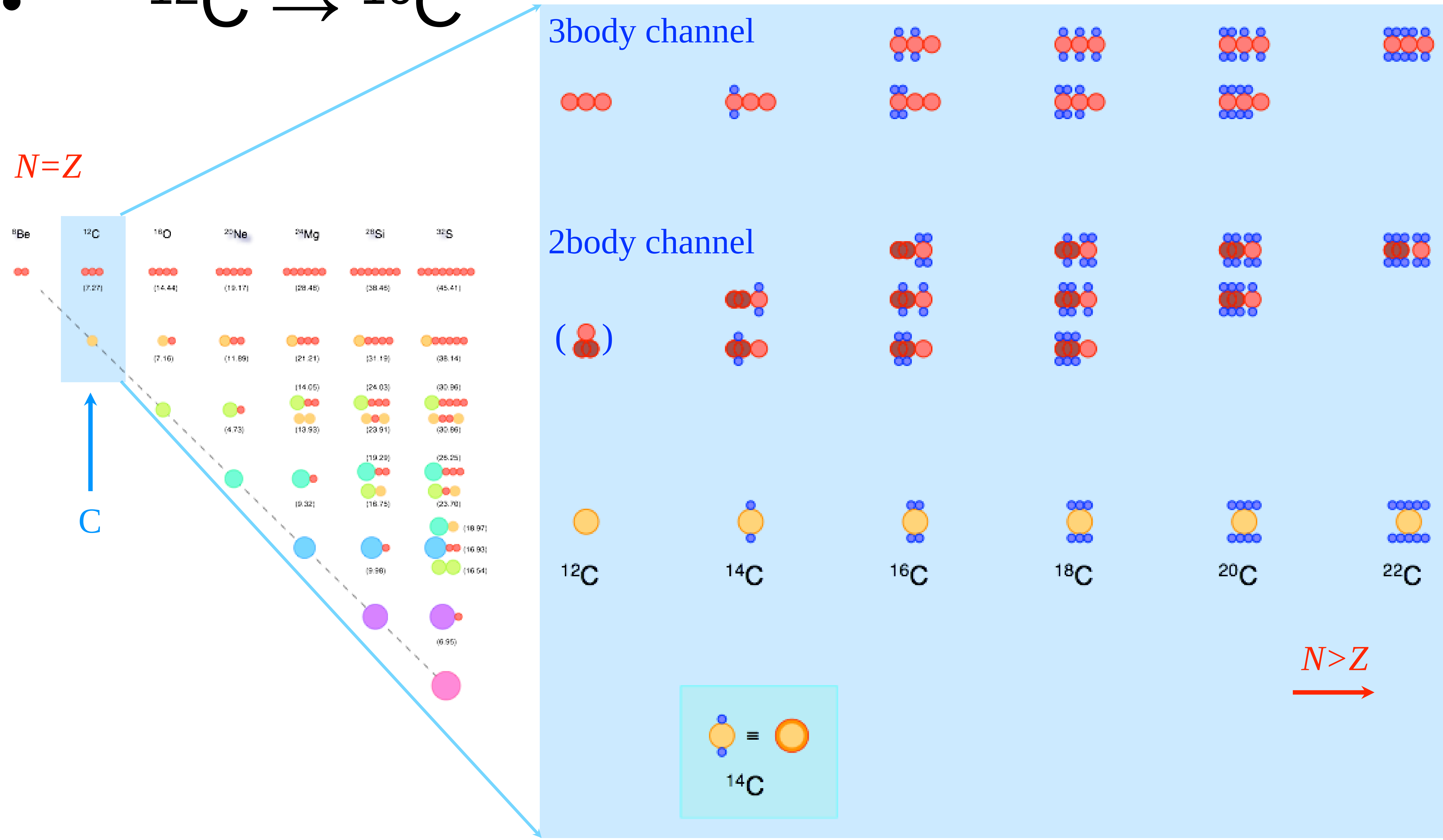
+

Phase Space Decay
(non-resonance state)

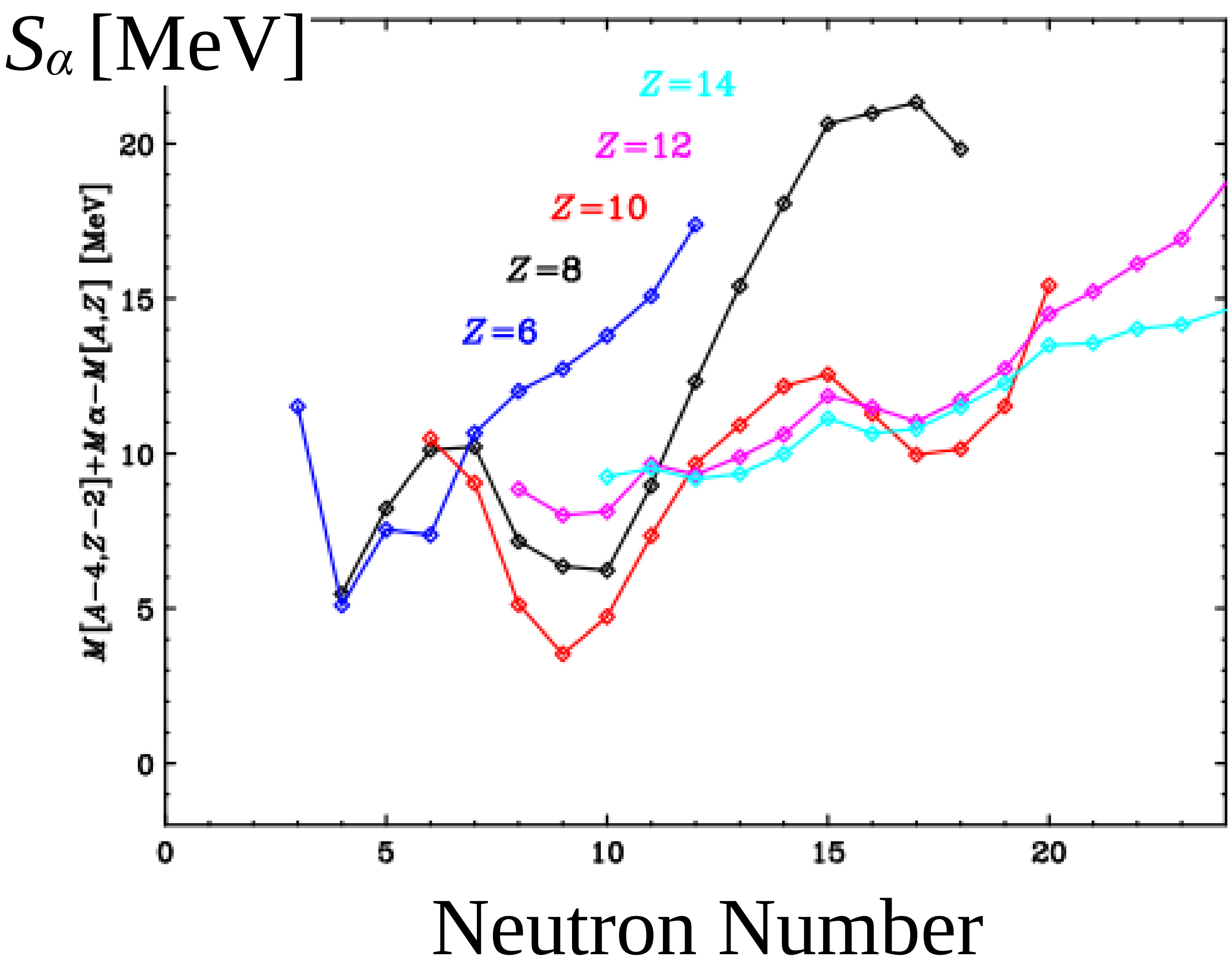


Beyond the Ikeda Diagram toward n-rich direction

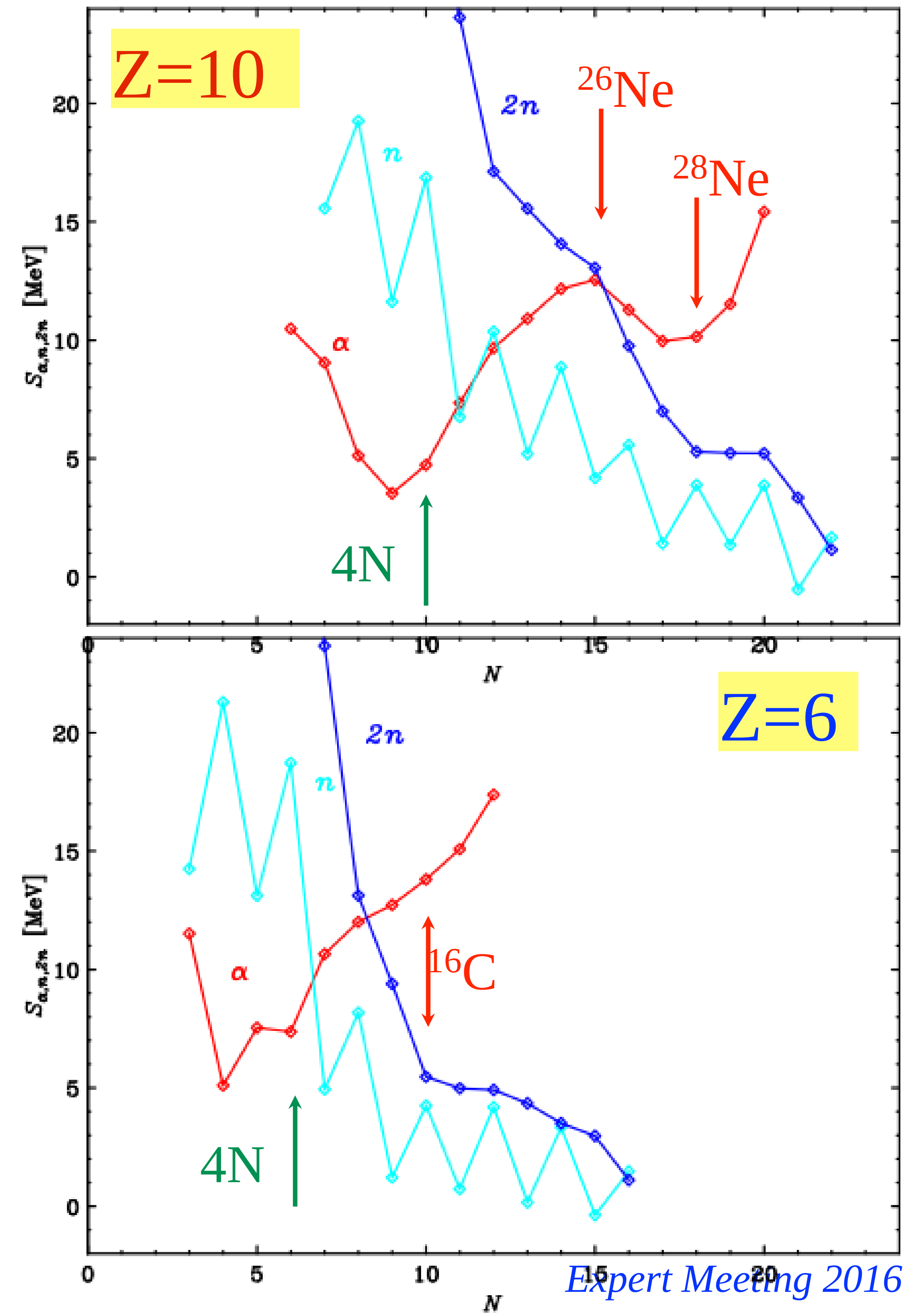
- $^{12}C \rightarrow {}^{16}C$



S_α tendency at $Z = 6 \sim 14$ and comparison with S_n and S_{2n}



- Z=10 tendency is SPECIAL
  2 dips : ^{16}O and $\underline{^{24}\text{O}}$
- $S_\alpha > S_n, S_{2n}$ @ n-rich region
  c.f. $S_\alpha < S_n, S_{2n}$ @ 4N region



Observation of α cluster

Invariant mass measurement with inverse kinematics
induced by nuclear break up by ^{4}He target (Liq.)

$^{16}C \; + \alpha \rightarrow$ $^{12}Be + \alpha$ $\; + \; \alpha'(X)$

(beam) (target) (beam rapidity) (target rapidity)

Mass :

$M_{INV}^2 = (\Sigma E_i)^2 - (\Sigma \vec{p}_i)^2$

$E_x = M_{INV} - m_0$; $E_{rel} = M_{INV} - \Sigma m_i$

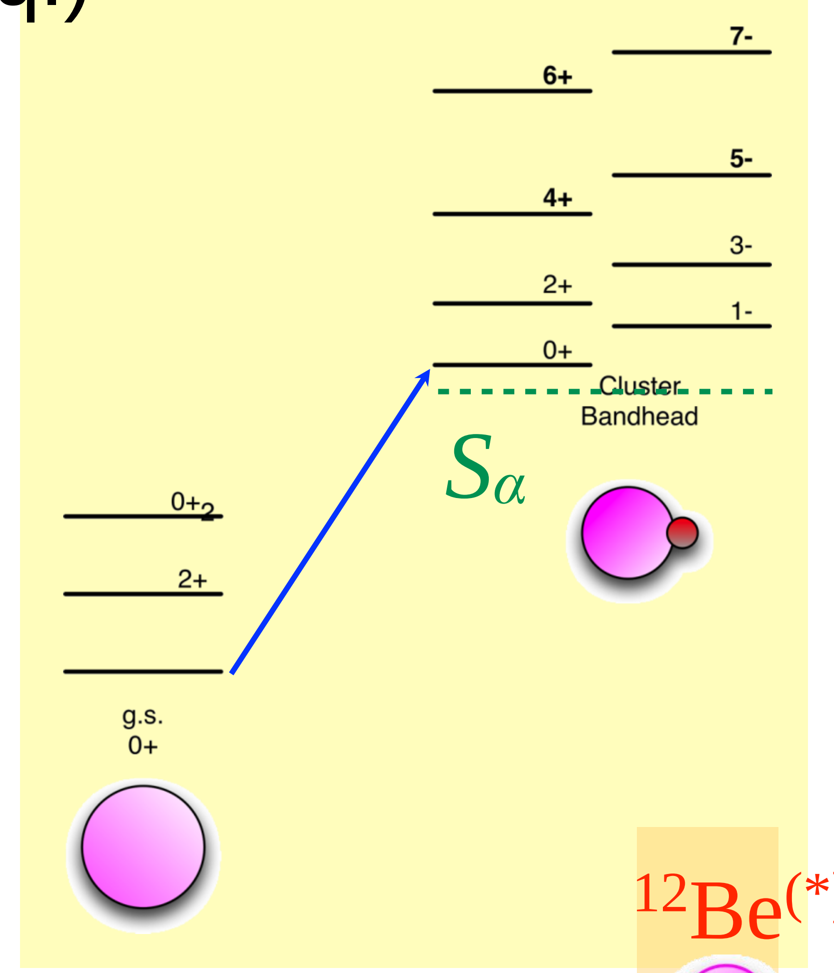
Momentum :

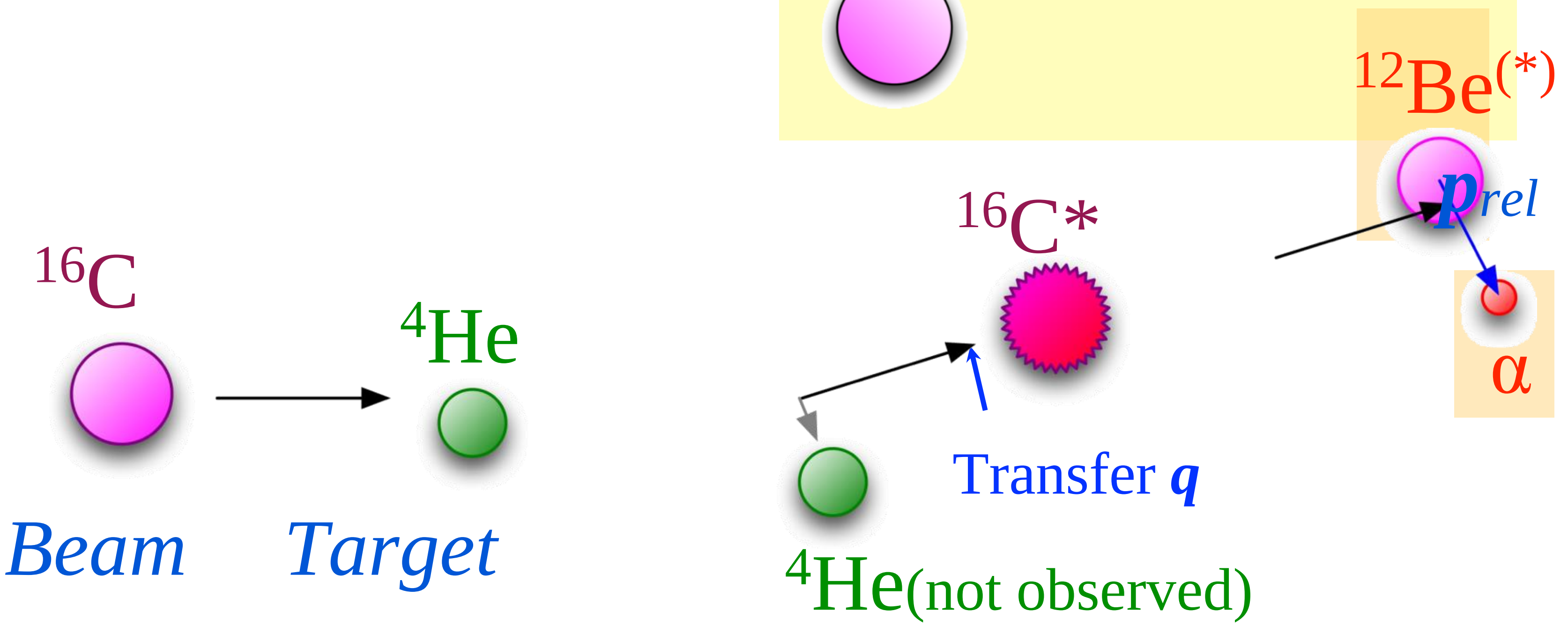
$\boldsymbol{q} = \Sigma \boldsymbol{p}_i - \boldsymbol{p}_{in}$

$\boldsymbol{p}_{rel} = \boldsymbol{p}_\alpha - \boldsymbol{p}_{12Be}$

reaction plane $\leftarrow \boldsymbol{q}$

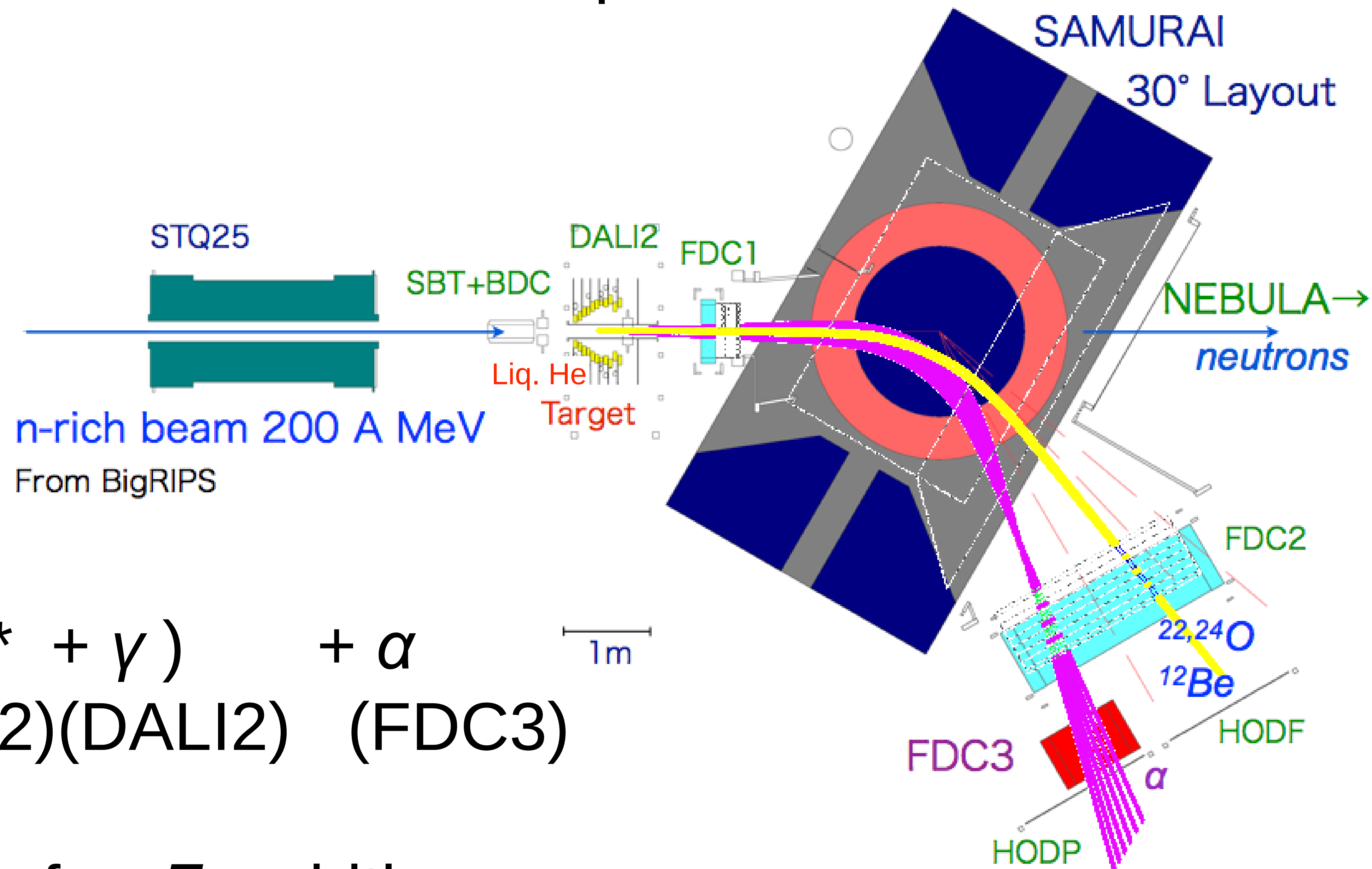
$L(J^\pi) \leftarrow d\sigma/dp_{rel}(E_{rel})$





Experimental setup

Add FDC3 on standard SAMURAI detector setup
to restore track information for Z=2 particles



$^{16}C(\alpha,\alpha')^{16}C^*$

$\rightarrow$ $^{12}Be(^* + \gamma)$ $+ \alpha$

(FDC2)(DALI2) (FDC3)

$\rightarrow$ $^{15}C+n$ for Γ_n width

RUN on Apr., 2013

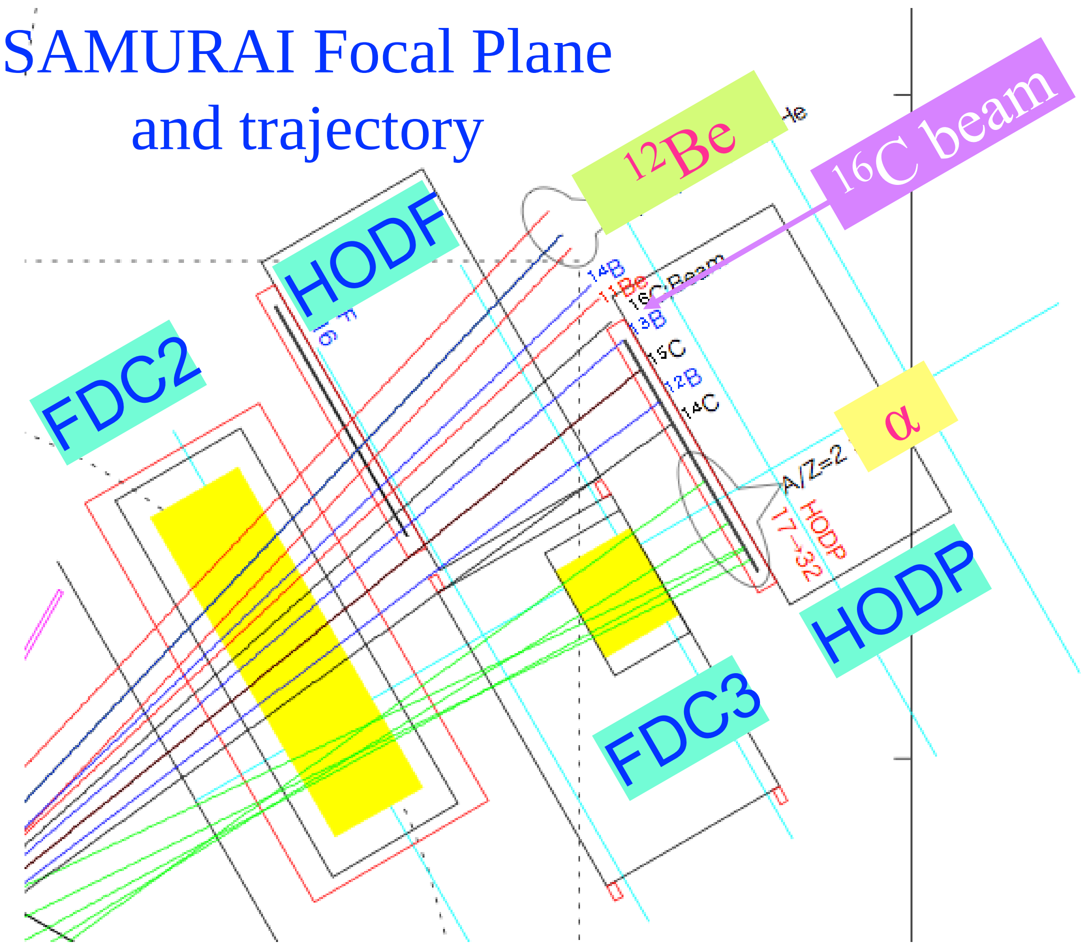
Event for n emission channel can be obtained with same setup simultaneously.

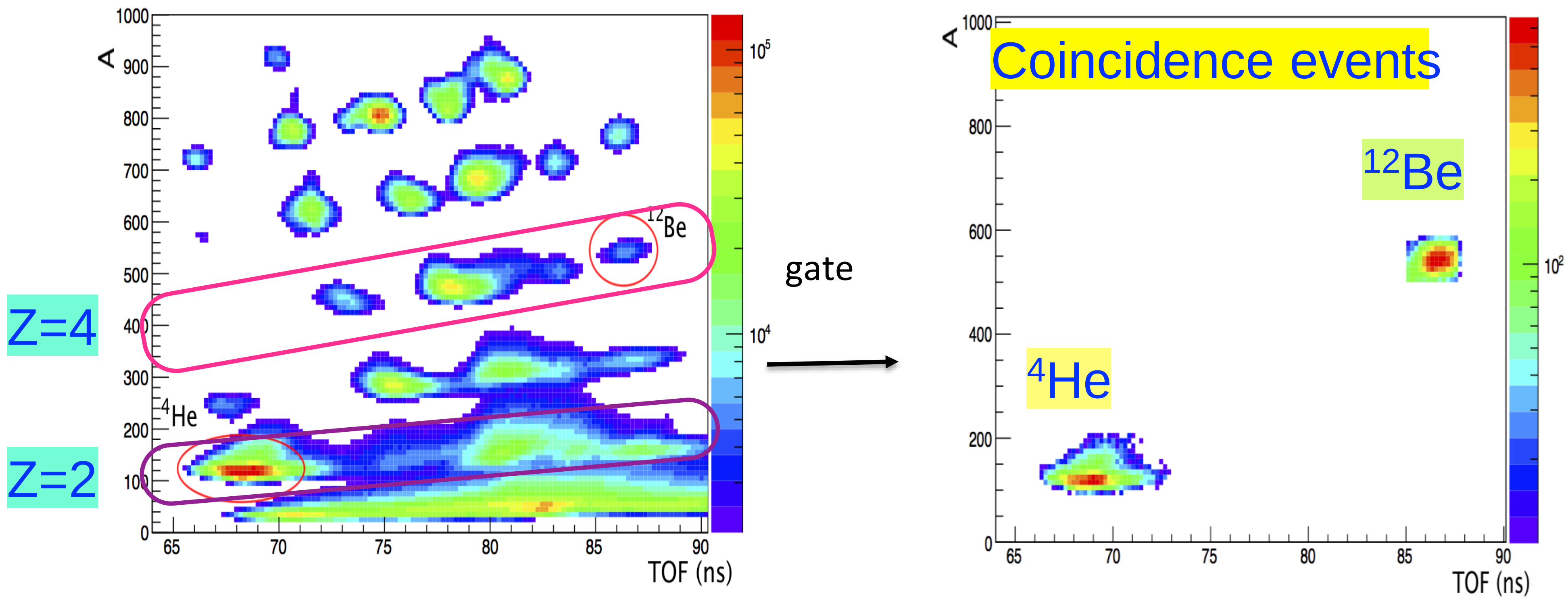
PID spectra @ SAMURAI FP

- α + Be coincidence @ SAMURAI FP

  Unbiased PID on HODF/HODP from FDC2 tracking

- FDC2 : Z>3 optimized

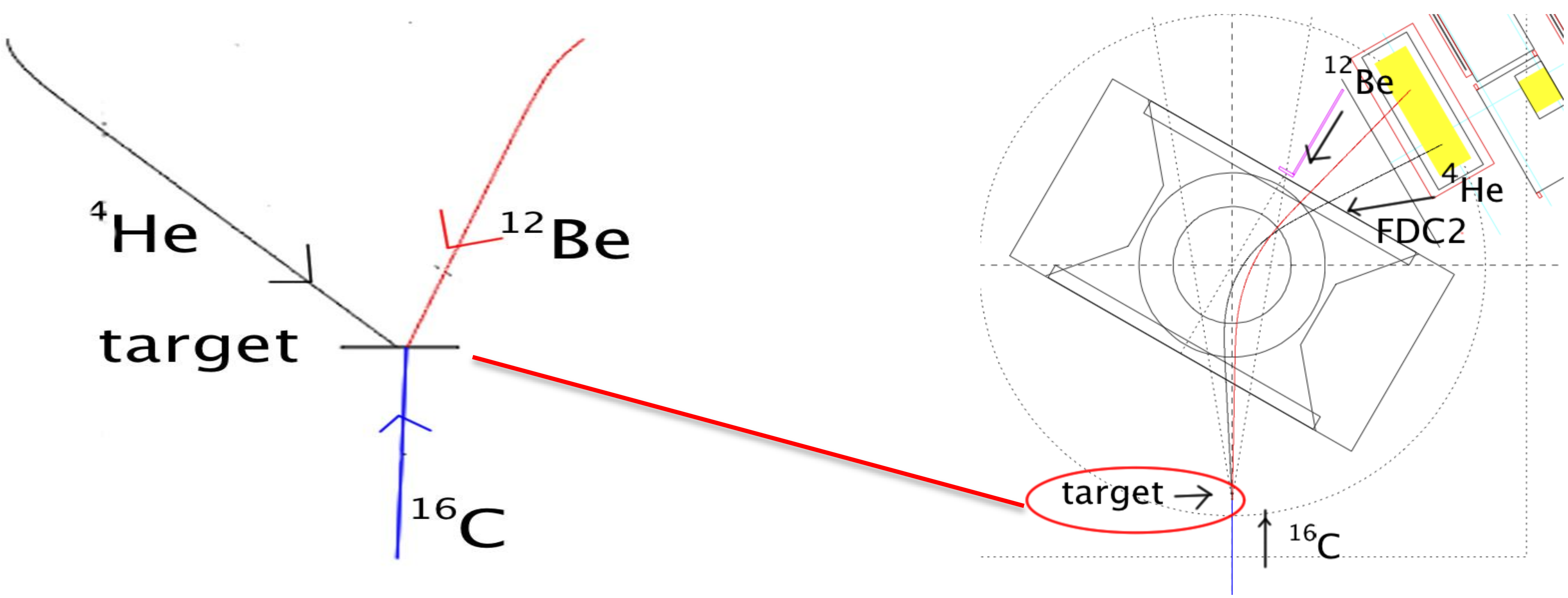




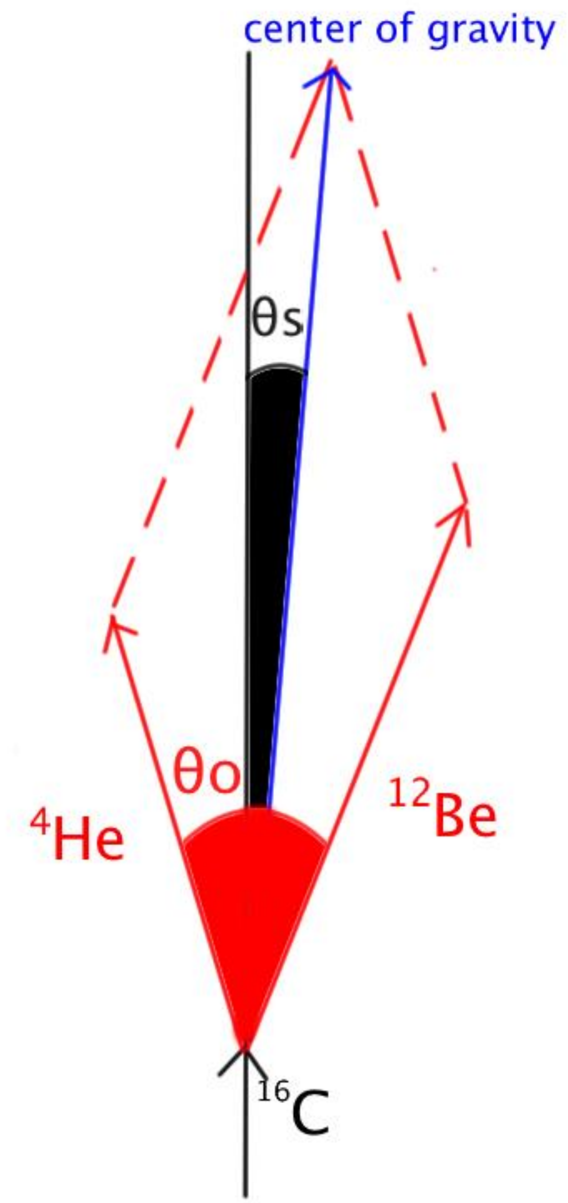
16C Slat : HODF14 masked

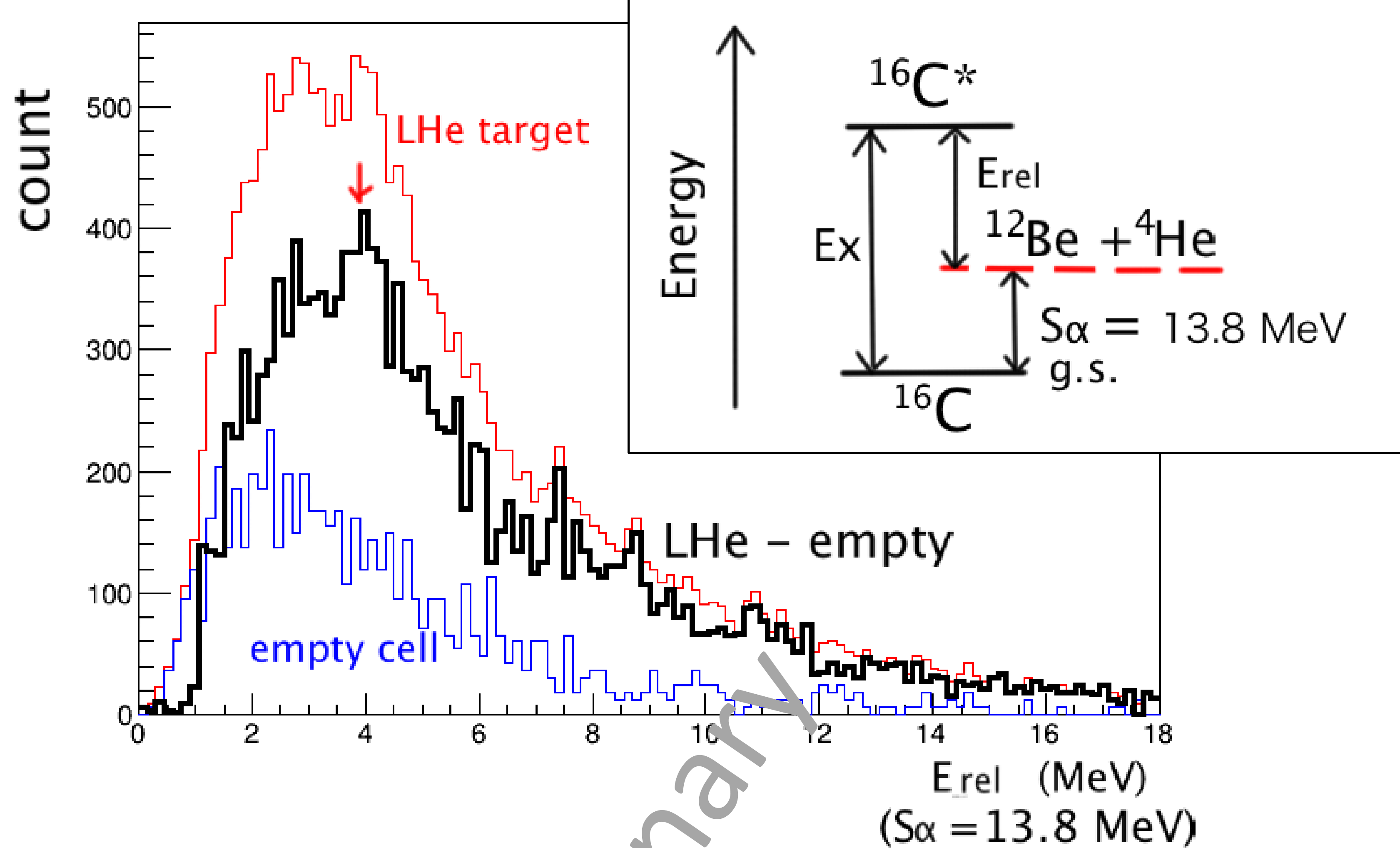
Momentum analysis (1)

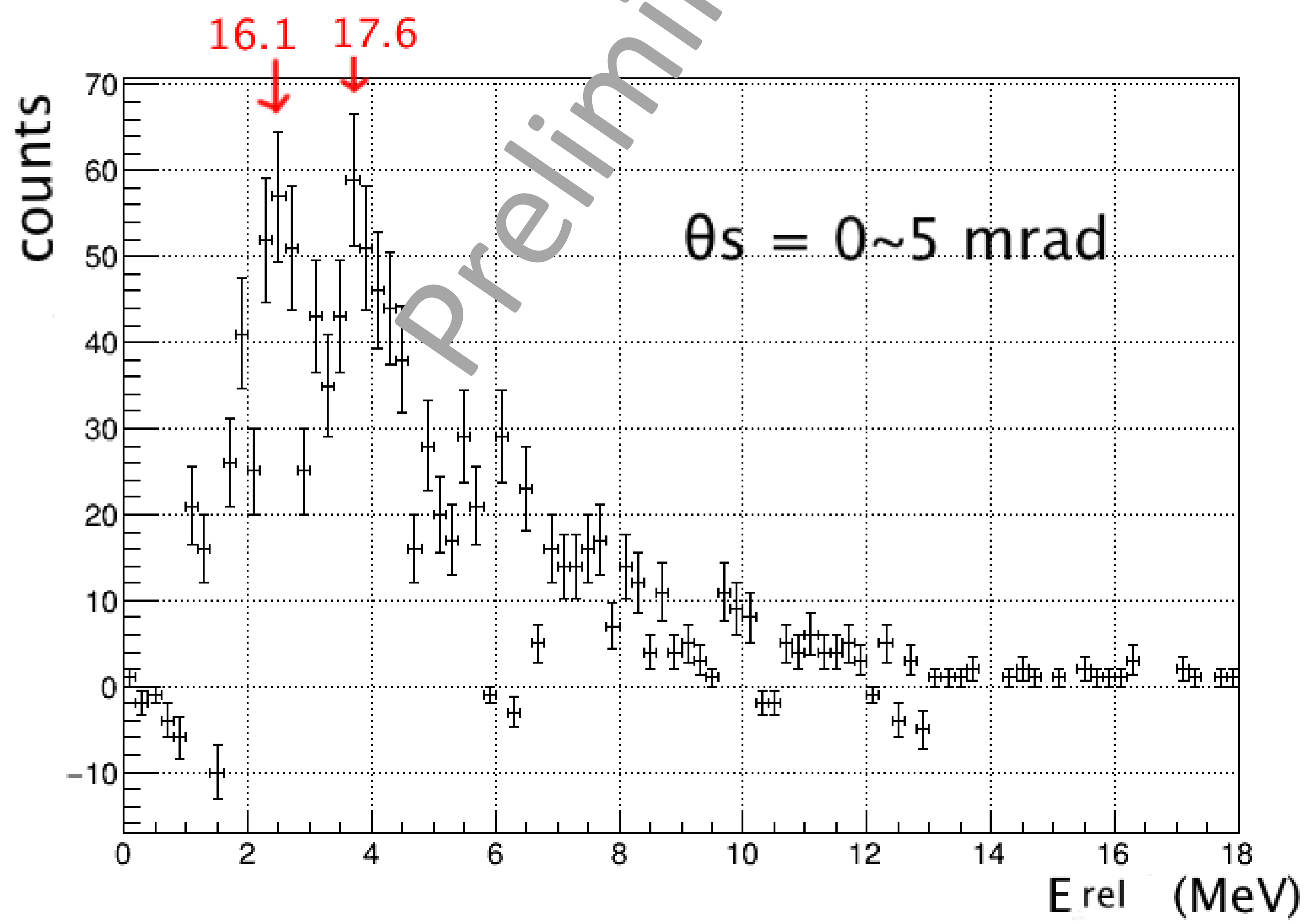
- Trace-back
  - Reaction point on the target <- BDC1&2
  - Positions and angles of ^{12}Be and ^{4}He downstream of magnet <- FDC2 & FDC3 (for ^{4}He)
  - Momenta of ^{12}Be and ^{4}He <- parameters
  - Momentum adopted when $x_{C16} = x_{frag}$ on target



Invariant mass



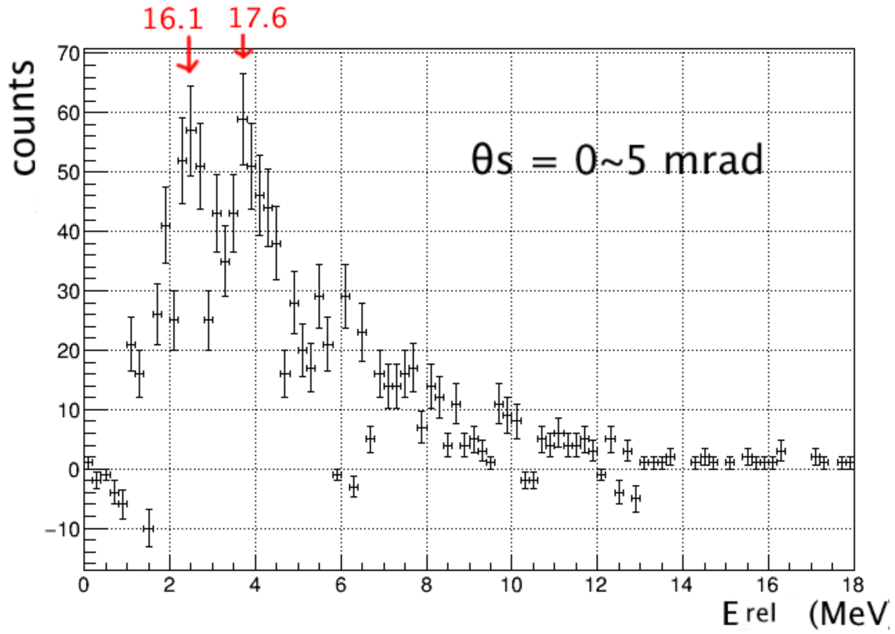


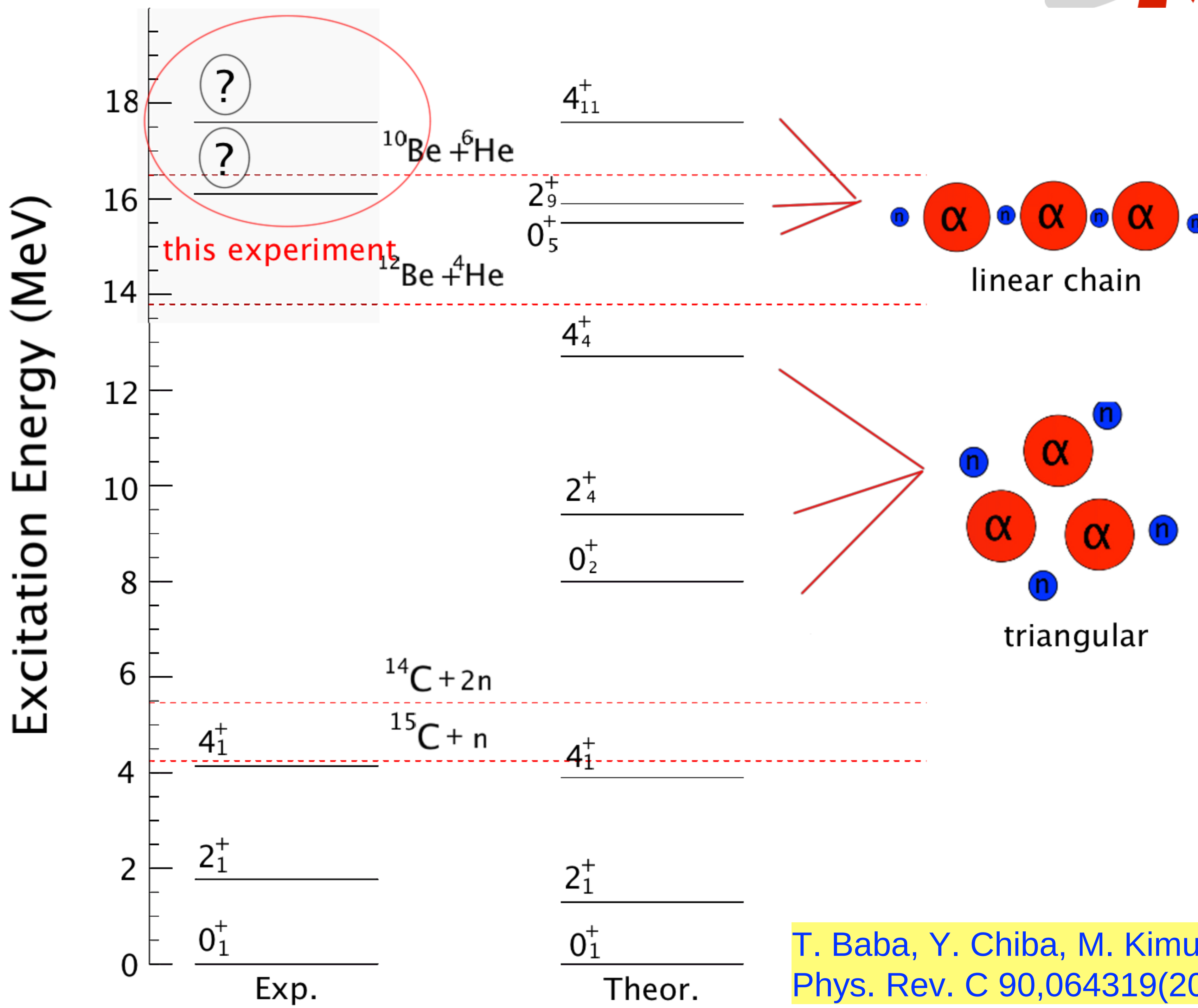


θs: scattering angle ~ ΔL

θo: opening angle ~ Erel

discussion



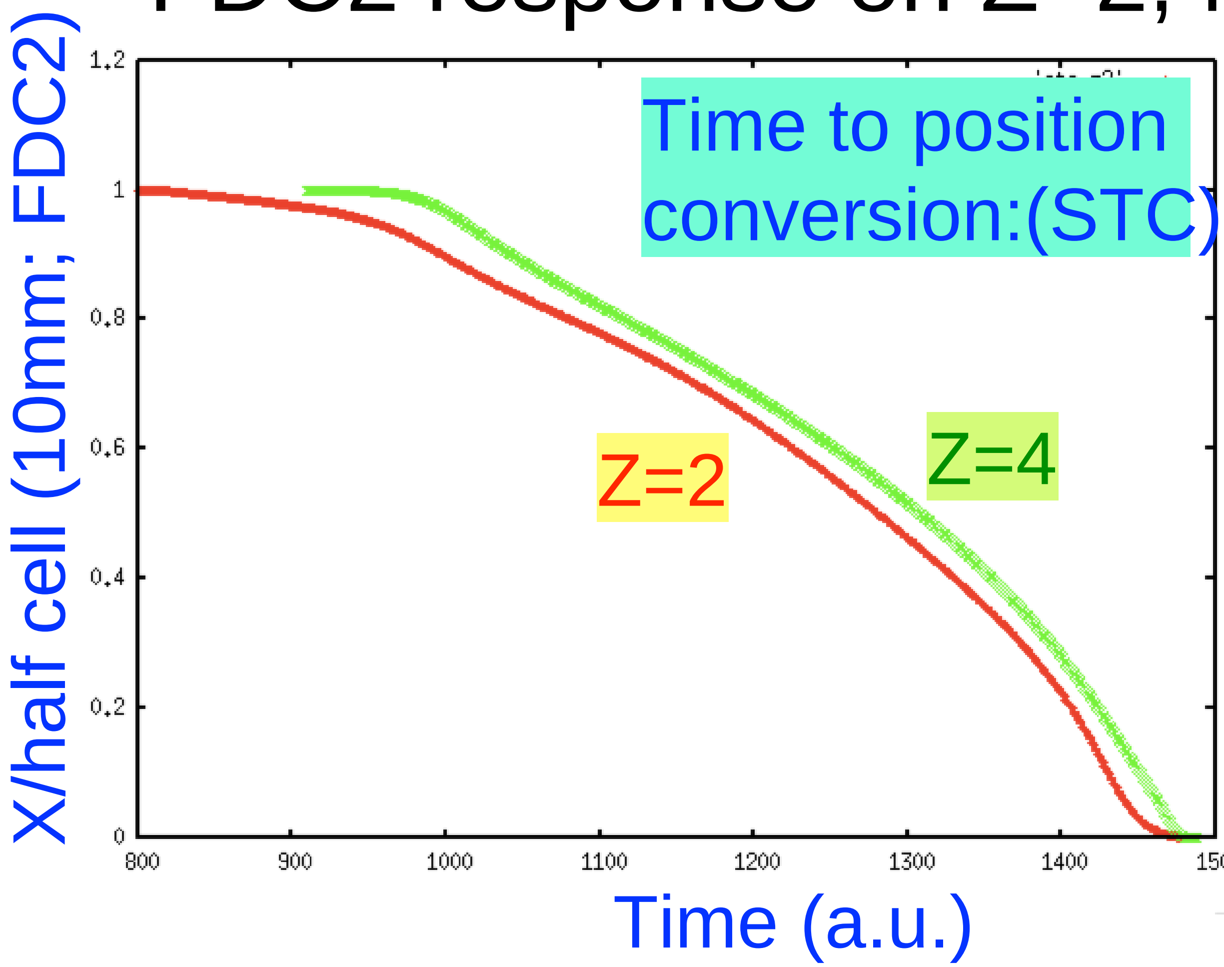


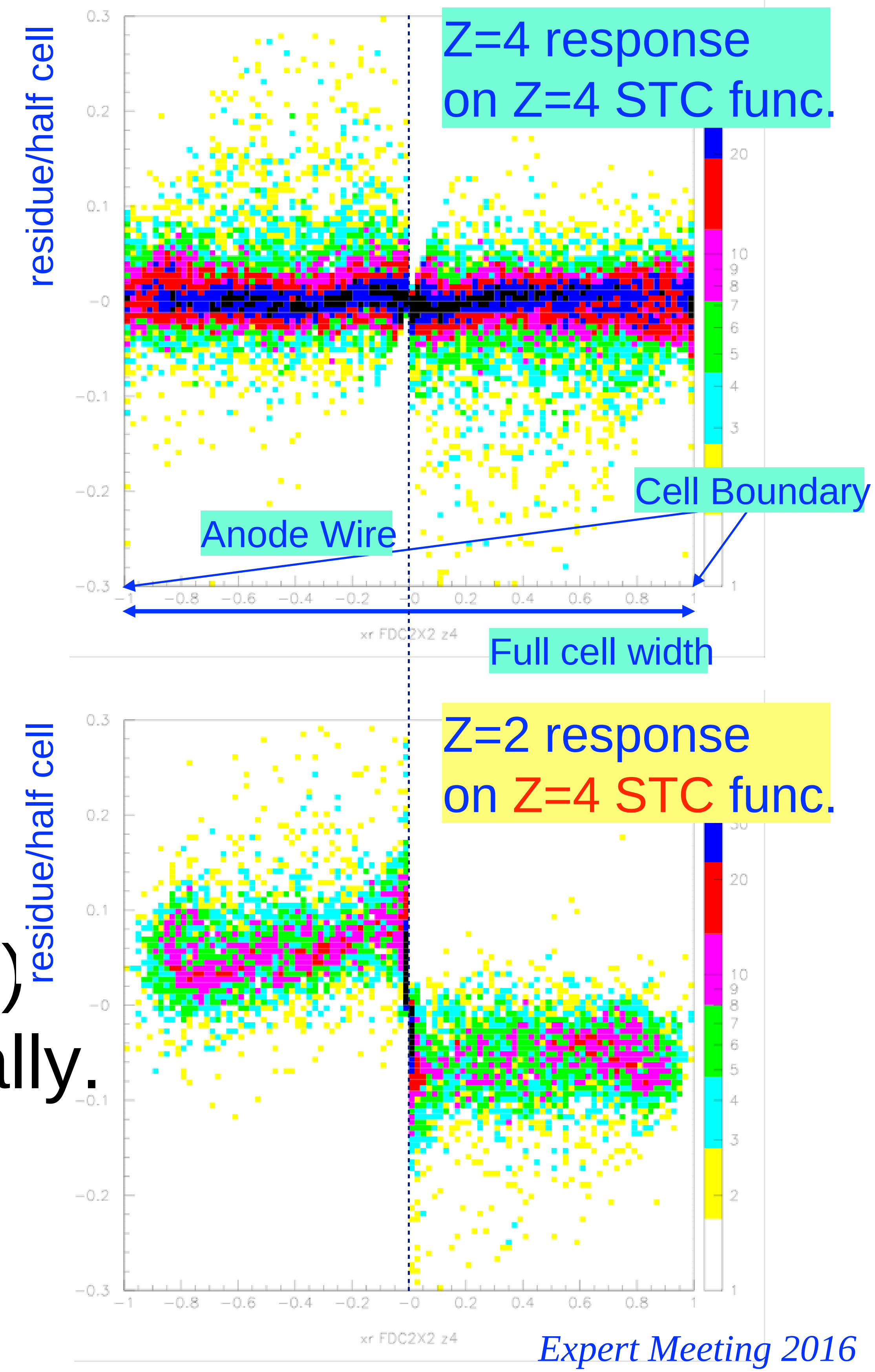
T. Baba, Y. Chiba, M. Kimura, Phys. Rev. C 90,064319(2014)

- Information needed for confirming cluster state
  - J^{π} <- Scattering angle (θ_s) distribution・angular momentum transfer
  - Iso-scalar monopole transfer strength <- cross section

Drift Chamber response

- FDC2 response on Z=2,4





- Max. 0.1 unit cell (1 mm on FDC2) would be mis-tracked systematically.
- Z=2 should be treated separately with Z=4.

Summary
of SAMURAI08 exp.

- SAMURAI08 exp.
- ^{16}C cluster structure by the (α,α') inelastic scattering
- Invariant mass by 12Be + α detected at FP on SAMURAI
  - Cluster structure candidates are observed.
  - Preferable on lower L states

- Technical point of view
  - Different Z (Z_1~2/Z_2~4 on Z_{beam}=6) detection properly / simultaneously on SAMURAI
  - by treating carefully of responses of DCs. 4 times difference on pulse height

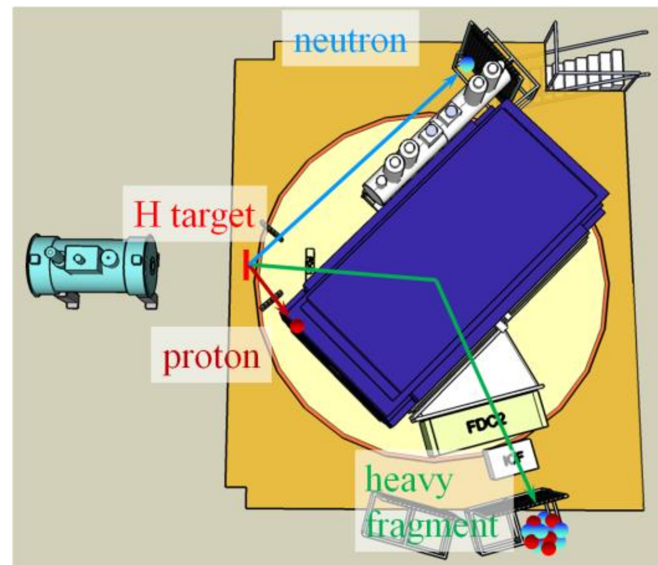
- Future plan with SAMURAI
  - ^{28}Ne → ^{24}O+α, ^{32}Mg → ^{24}O+2α : α cluster degree of freedom
  - α evaporation on heavier system
  - ^{32}Mg → ^{16}C+^{16}C : search for symmetric cluster decay on *n*-rich

SAMURAI versatile usage+1 required by approved programs

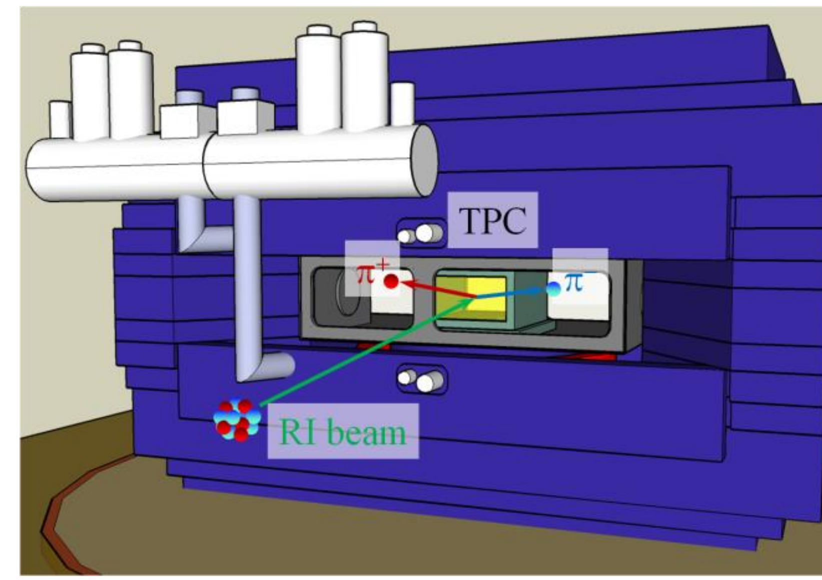
x*n*+HI (neutron-rich side)
(©, *n*), unbound nuclei…

Commissioning RUN:
Day-one/two (02,03,04, 08,10)

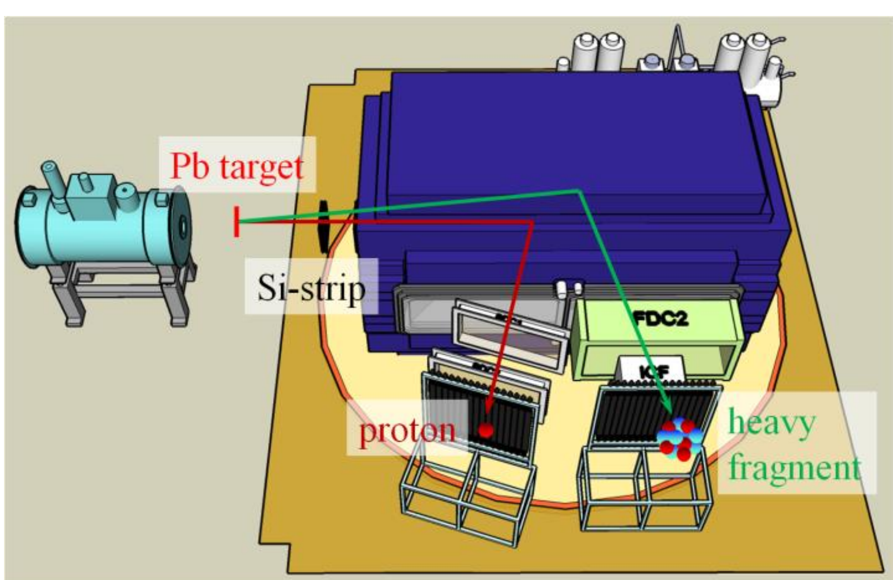
***p*,*n*(target frame)+HI**
(*p*,*p*'), (*p*,2*p*), (*p*,*pn*), …



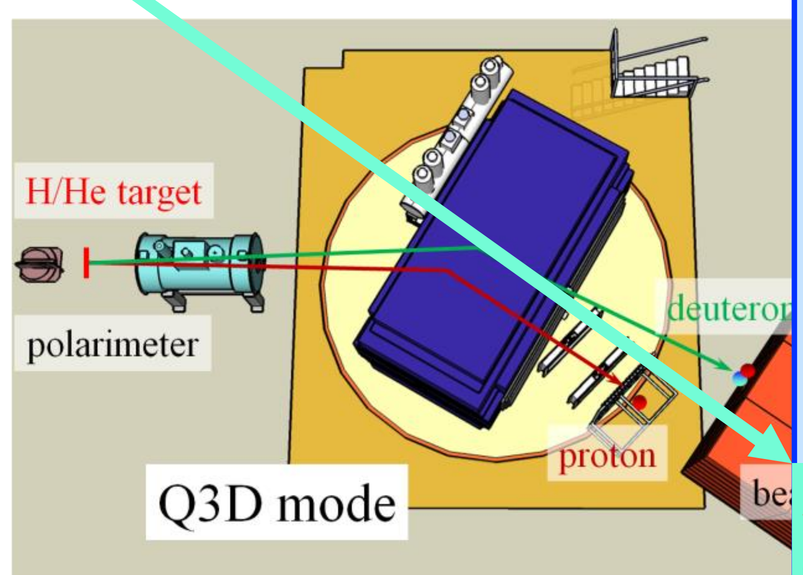
EOS measurement



***p*+HI (proton-rich side)**
(©, *p*) reaction,…



pol. *d*-induced reaction



α+HI (both n-rich, p-rich side)
Cluster degree of freedom,...

New!

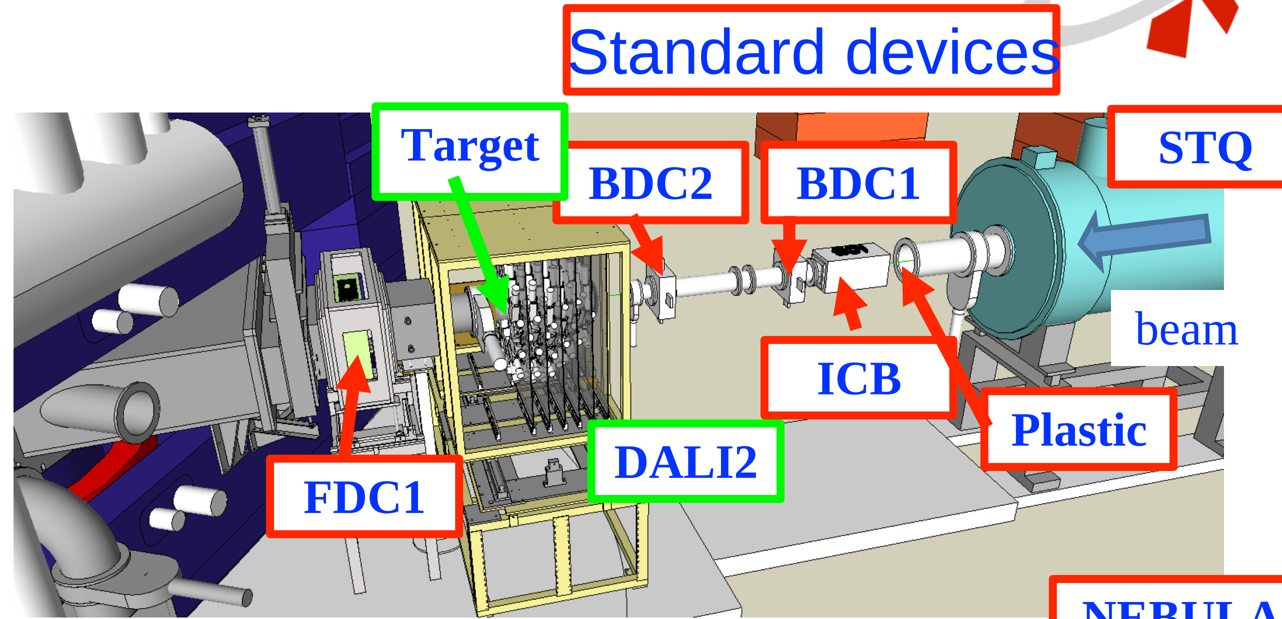
SAMURAI08
Cluster Study

Operation phase
for RIBF users

Operation phase

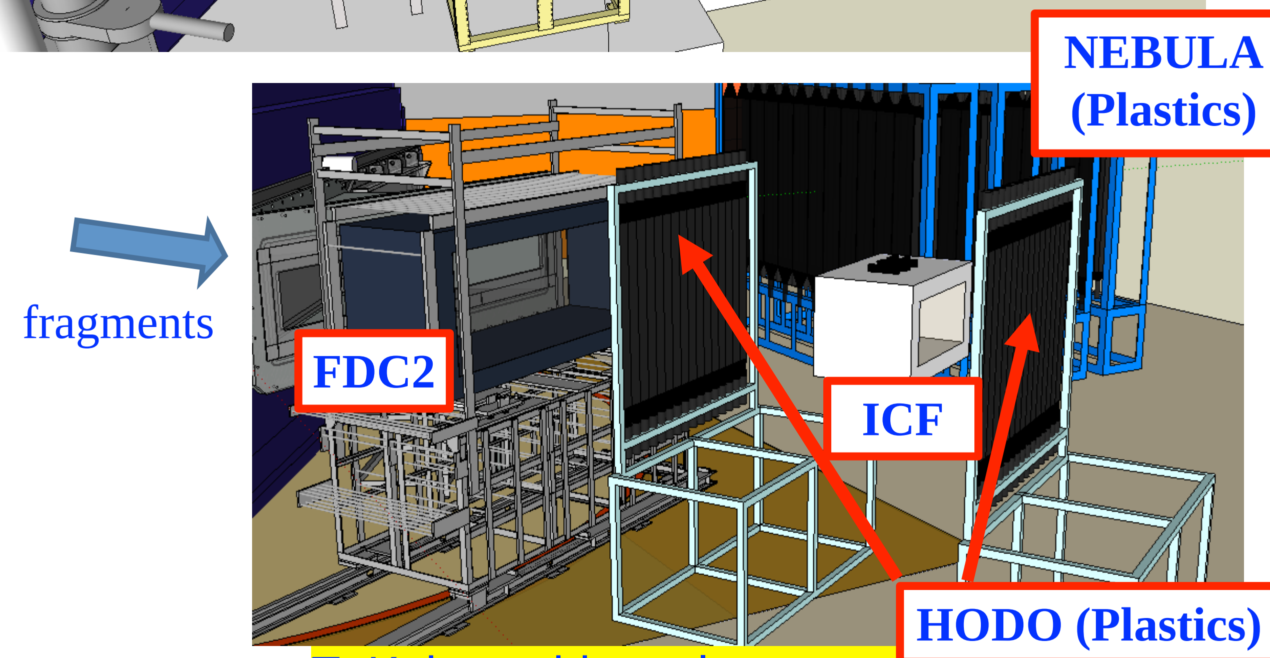
1) Maintenance and upgrade of "standard devices"

Who supplies their spares in accidents?



2) User devices
DALI
WINDS
TPC
MINOS
neuLAND
...

Who takes care of their protocols?



T. Kobayashi et. al., NIMB317(2013)294, presented on EMIS2012

3) Magnet+Detector Configuration
HI-p program : 90 degree
TPC program : 0 degree

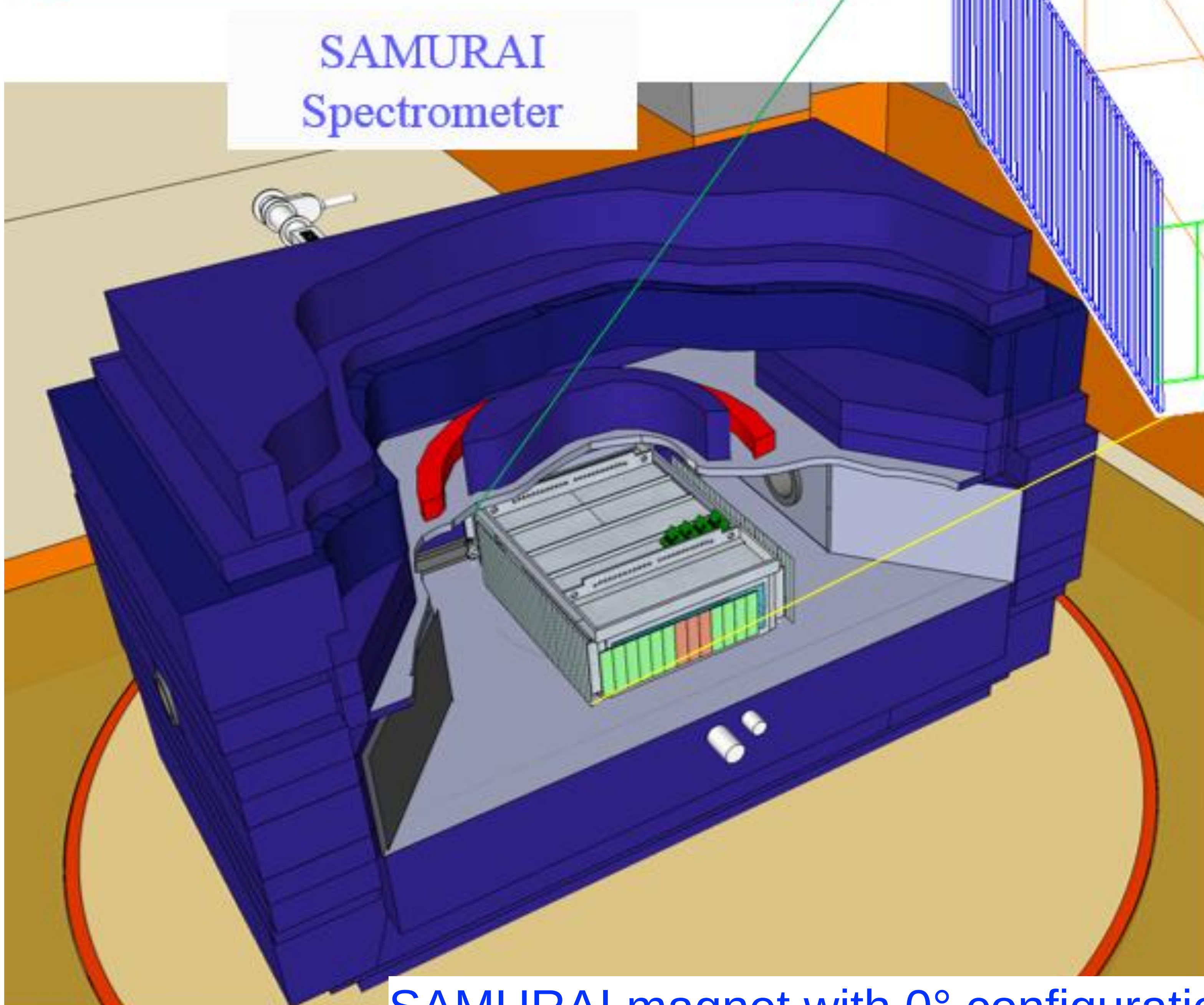
Who takes care of their engineering intelligence and man powers?

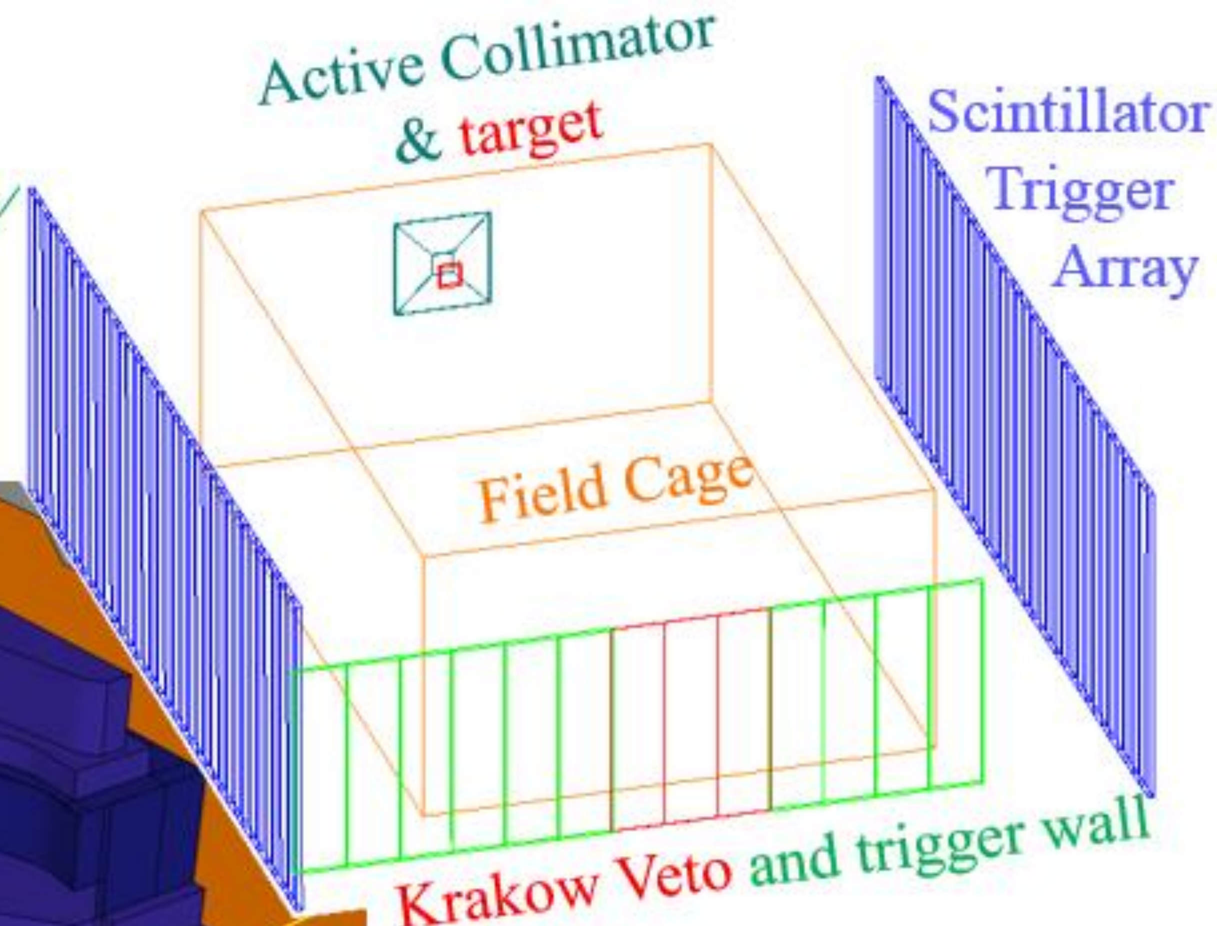
MT request on 2015 Autumn/2016 Spring

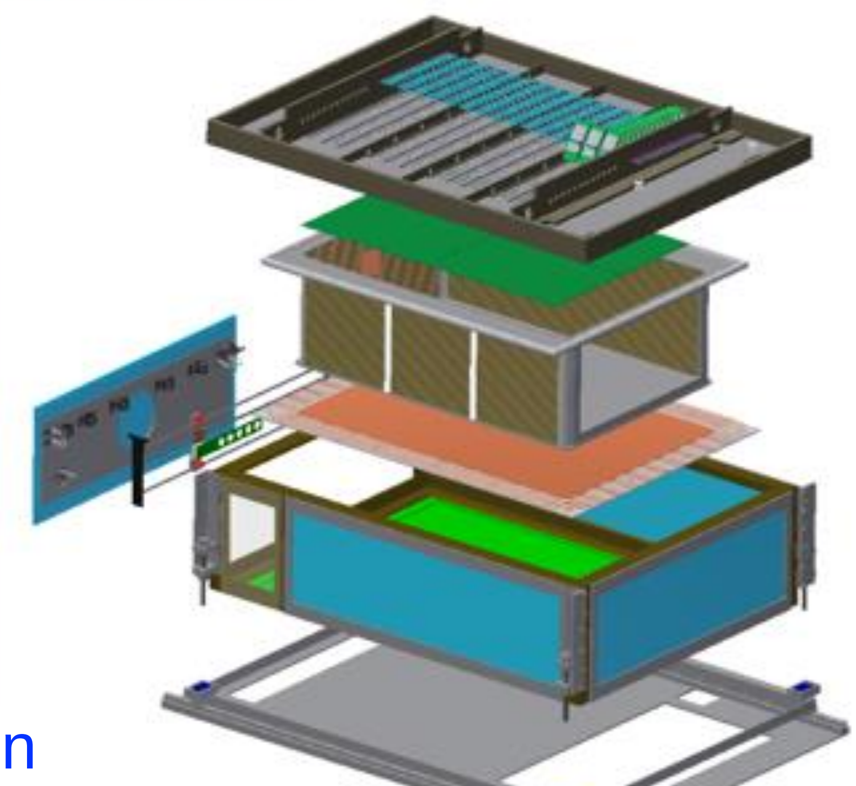
0 ° configuration for EOS experiment

Given by W. Lynch in this conference

SAMURAI TPC
Day-one Experiment





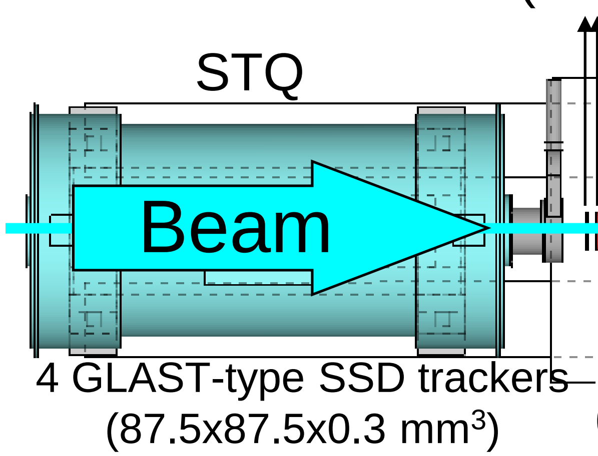


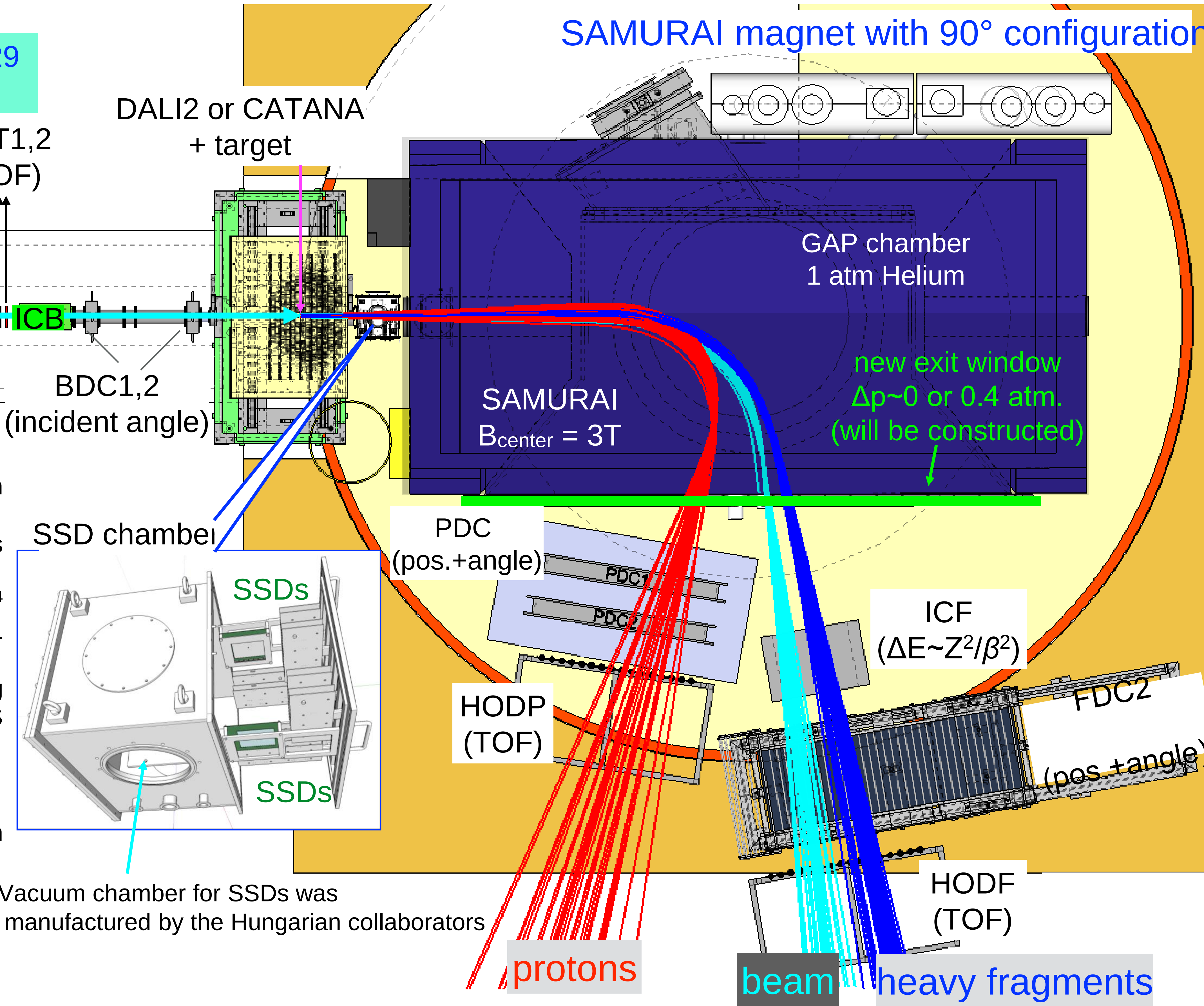
SAMURAI magnet with 0° configuration

90° configuration for HI-p experiments

Slide by V. Panin

SAMURAI24, 25, 28, 29
Astrophysical interests





- Coincident HI-proton tracking
- ASIC dual-gain preamplifiers were developed in RIKEN
- Wide dynamic range ~10^4 (dE from 200 keV to ~1 GeV)
- High-density processing circuit HINP by the US group
- Strip pitch 684 um
- Angular resolution ~2 mrad
- Tested @ HIMAC in February 2015

Relative HI-p angle

HI-p experiments

beam time request on
2015 Autumn/2016 Spring

- Key devices
  - GLAST-type SSD trackers(87.5 x 87.5 x 0.3 mm^3)
    - for Opening angle determination between HI and proton
    - 684 μm pitch : σ(θ) ~ 0.6 mrad
    - Wide dynamic range of 10^4 needed (0.2 MeV - 1000 MeV of ΔE) Tested at HIMAC on 2015/02
    - ? Cross talk on high gain output by large energy deposit strip (beam of HI fragments)
    - ? How to manage triggering

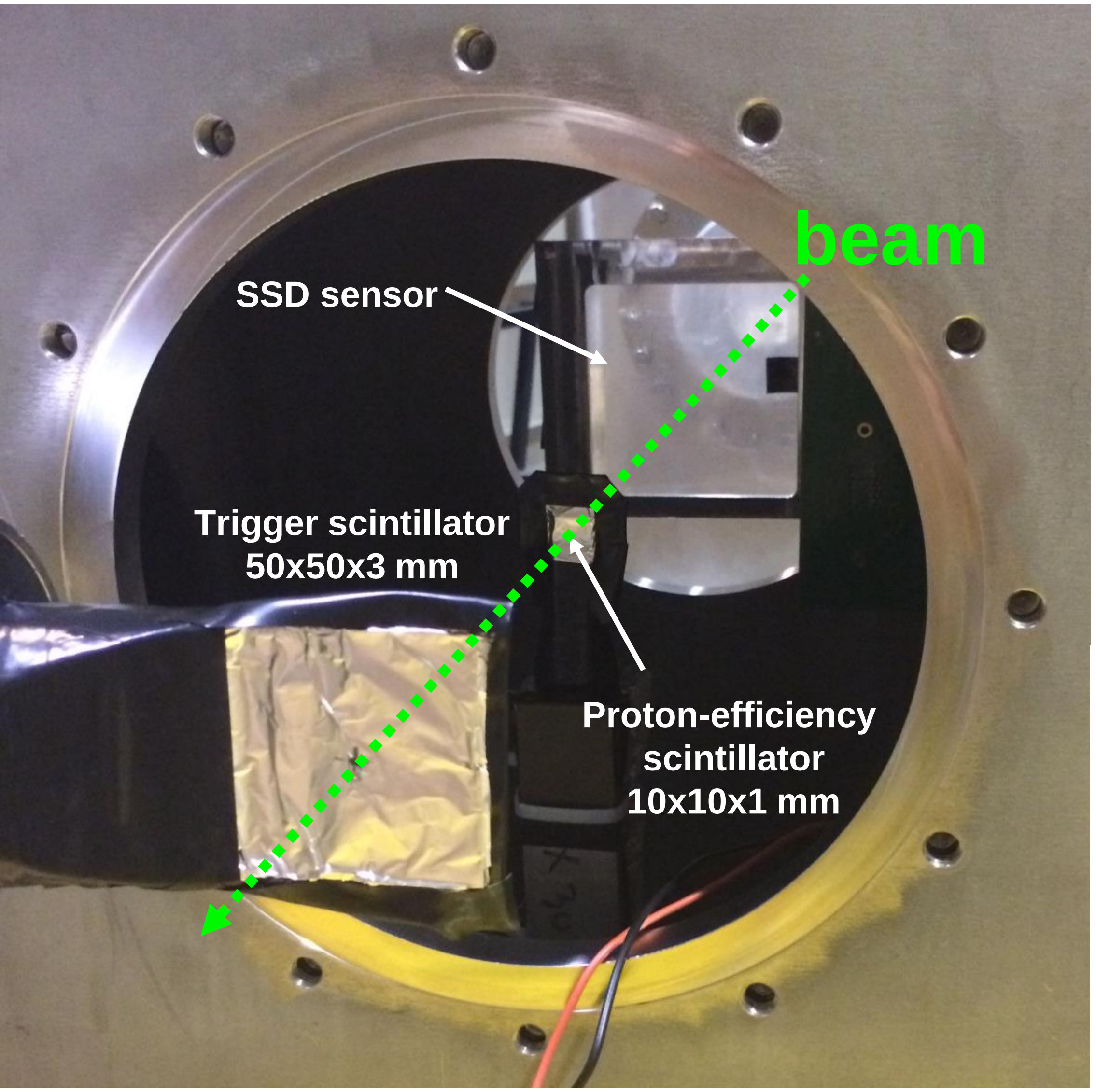
    as "standard device" supported by Tohoku U.
  - PDC (:= Proton Drift Chamber) Tested at HIMAC and parasitic run on SAMURAI18 exp.
    - Cathode readout (U(+45°),X,V(-45°)) with 1700x800 of effective area
    - for recoil particle detection only : beam should be passed thru outside of this device.
    - Position and angle determination for protons → momentum determination
- Peripheral techniques to be finalized
  - Si vacuum chamber Vacuum is not yet tested.
  - He filling window 3m width window will be tested on 2015 summer
    - 7 x 0.8 m^2 of area have to be covered ; vacuum separation was given up.
  - Stands of CATANA/DALI2, Si vacuum chamber On designing
    - ? How to layout them around the target region
    - ? position determination of the SSD

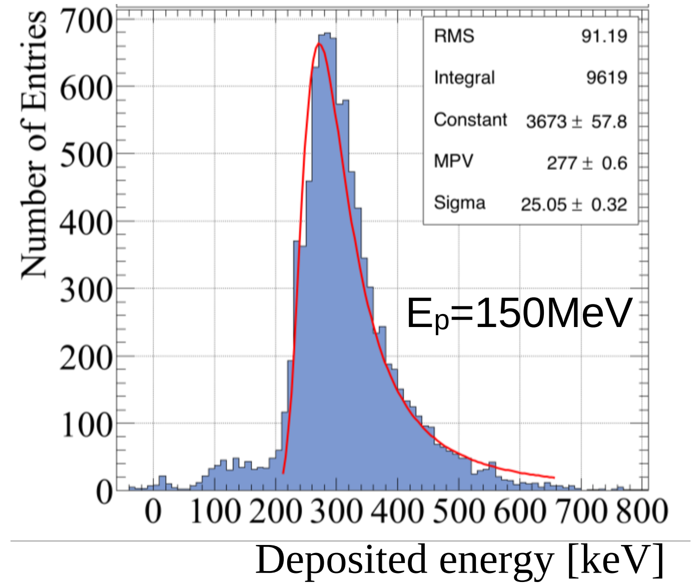
    Required engineering for protocols
  - How to layout "standard detectors" on Downstream of SAMURAI

Performance test of the SAMURAI Si-detection system @ HIMAC, February 2015

- Irradiation in air: protons (E=150->230MeV), ^{12}C(400MeV/u), 132Xe(primary and secondary A/Z=), 84Kr (400MeV/u)
- Water-cooling, installation in the new vacuum chamber (constructed in Atomki, Hungary)
- In total 32 strips of one sensor were readout

Slide by V. Panin





- Energy response to energetic protons (150->230 MeV):

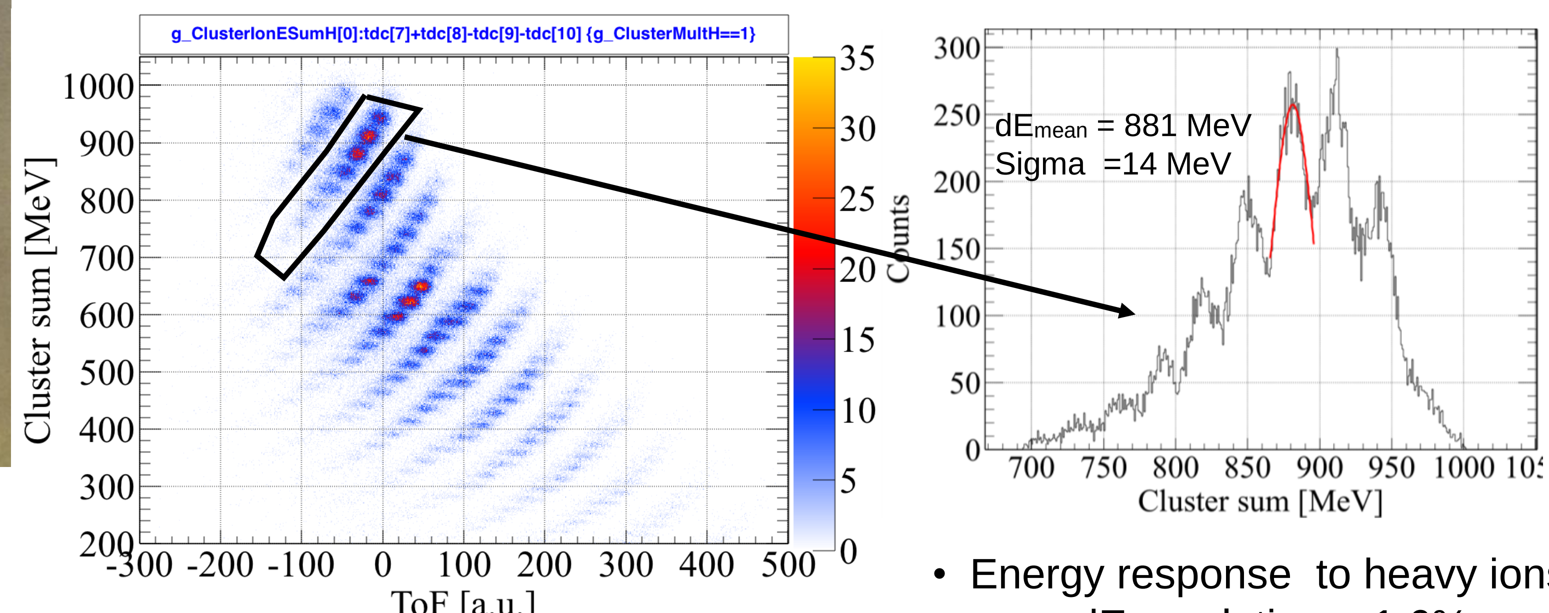
  dE resolution ~ 8%

- Proton detection efficiency:

  > 97%

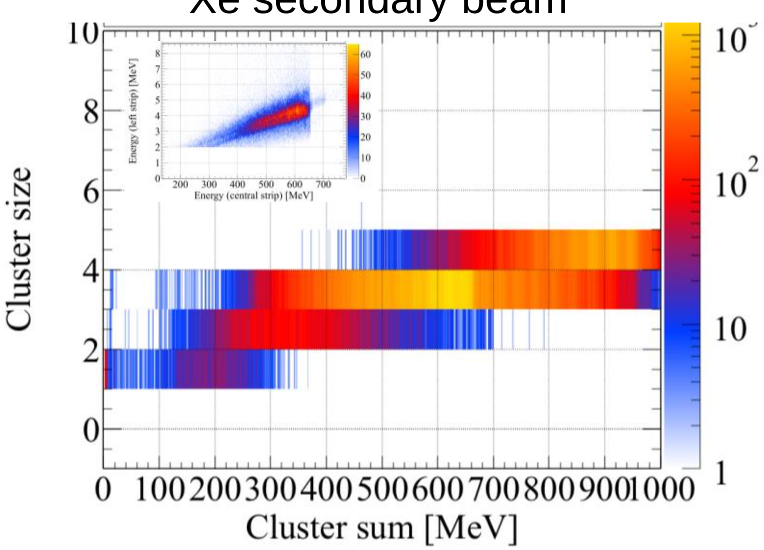
- Checked the linearity of the High-Gain readout

Xe secondary beam



- Energy response to heavy ions: dE resolution ~ 1.6%

Xe secondary beam



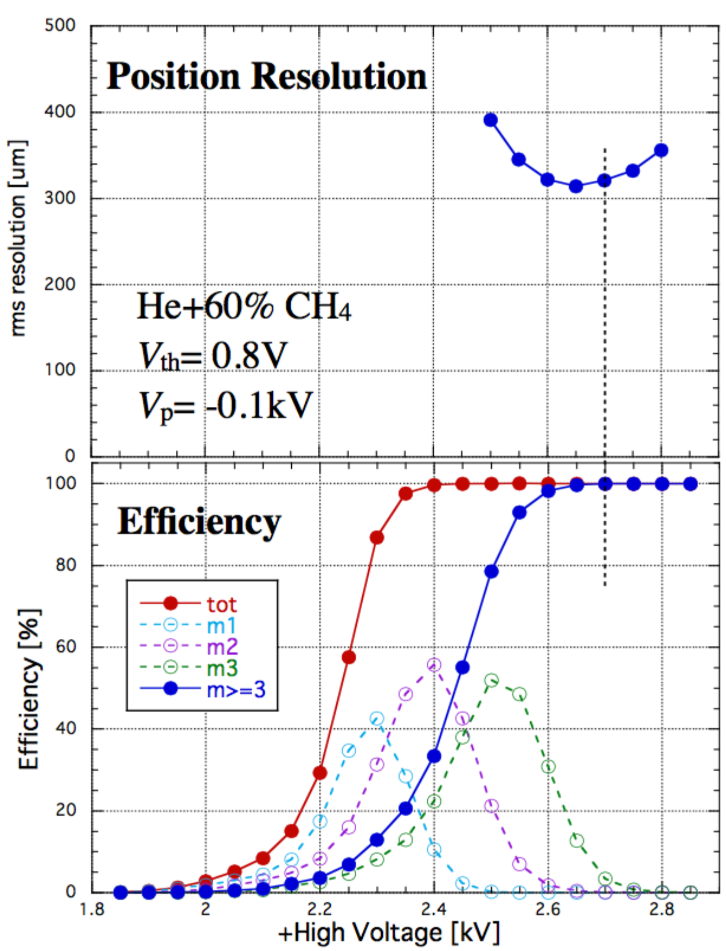
- Observed cross-talk ratio: ~1%
- Max. cluster size: 5-6 strips for dE>500 MeV (not harmful for the real experiments)

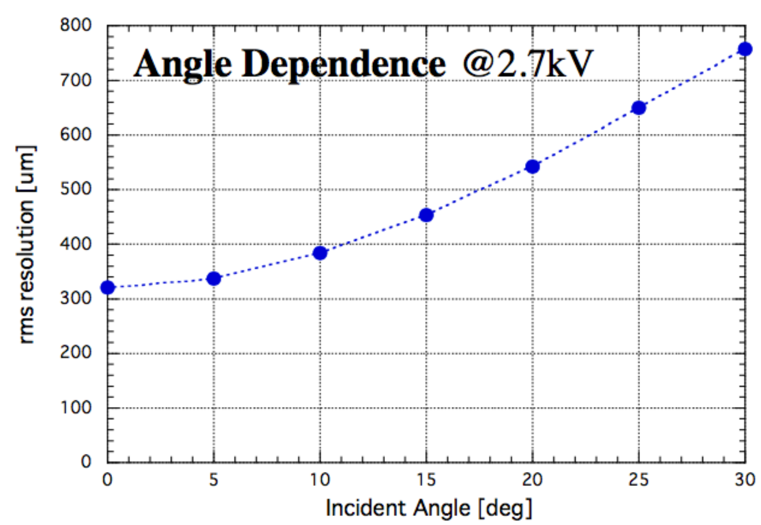
- **Good performance of the new sensors and dual gain preamplifiers**
- **Confirmed detection range for the deposited energy from 200 keV up to 1 GeV**

PDC readiness

Slide by T. Kobayashi

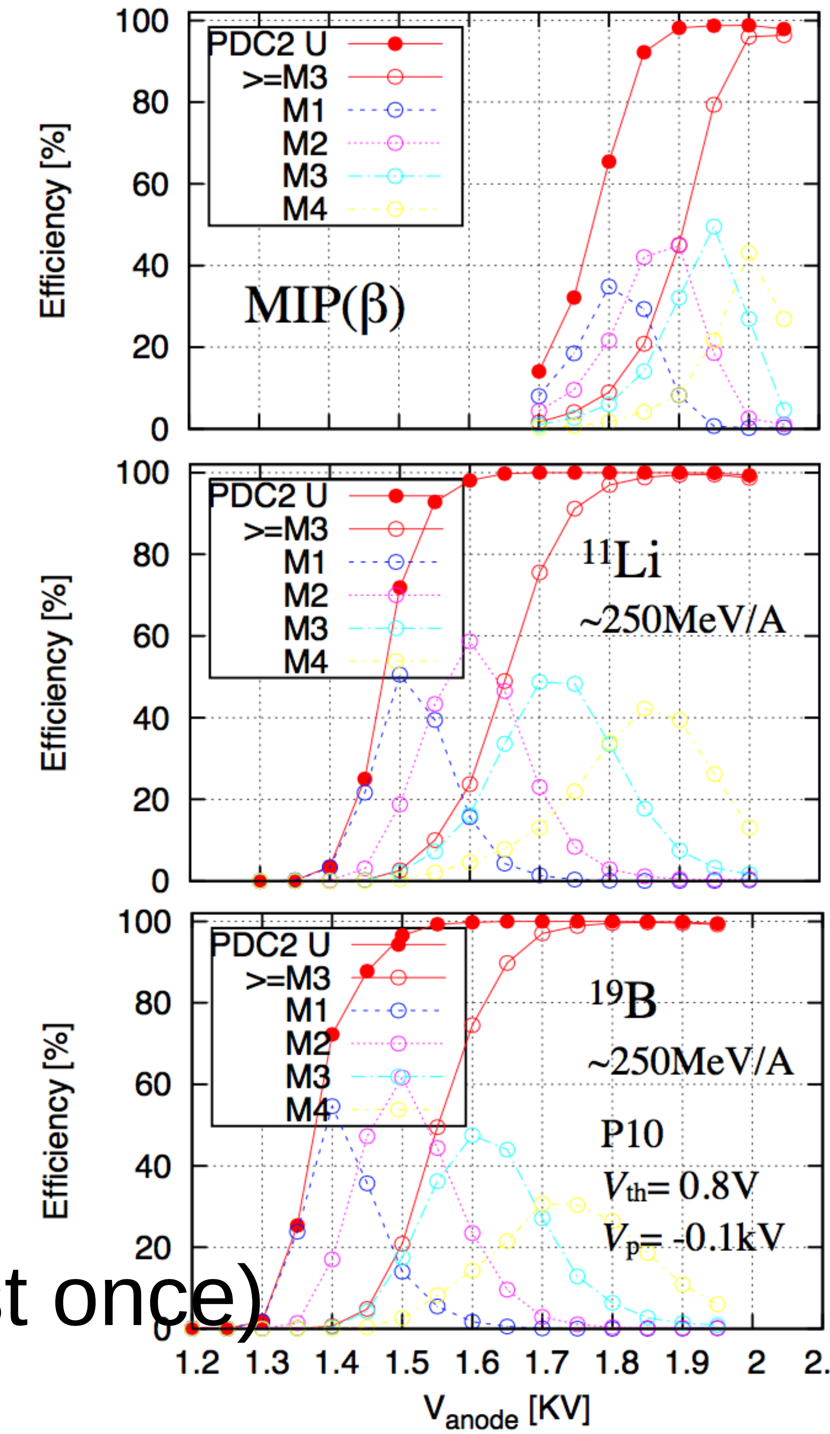
- proton response tested at HIMAC on 2013/11
- Z=3~ response tested as parasitic run on SAMURAI18 on 2014/12
- neighboring 3ch TOT(width) responses are used.





p 230 MeV at HIMAC
with reference chamber

Cathode wire : 3mm pitch
4 wires or-ed as one strip → 12mm pitch
3 hits are required to determine the position
$\sigma(x)$ = 320μm at 0°



- Analysis method : to be optimized
- Reference chamber runs are needed (at least once)

HI-p experiments

beam time request on 2015 Autumn/2016 Spring

- Key devices
  - GLAST-type SSD trackers(87.5 x 87.5 x 0.3 mm^3)
    - for Opening angle determination between HI and proton
    - 684 μm pitch : $\sigma(\theta) \sim 0.6$ mrad
    - Wide dynamic range of 10^4 needed (0.2 MeV - 1000 MeV of ΔE) Tested at HIMAC on 2015/02
    - ? Cross talk on high gain output by large energy deposit strip (beam of HI fragments)
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    as "standard device" supported by Tohoku U.

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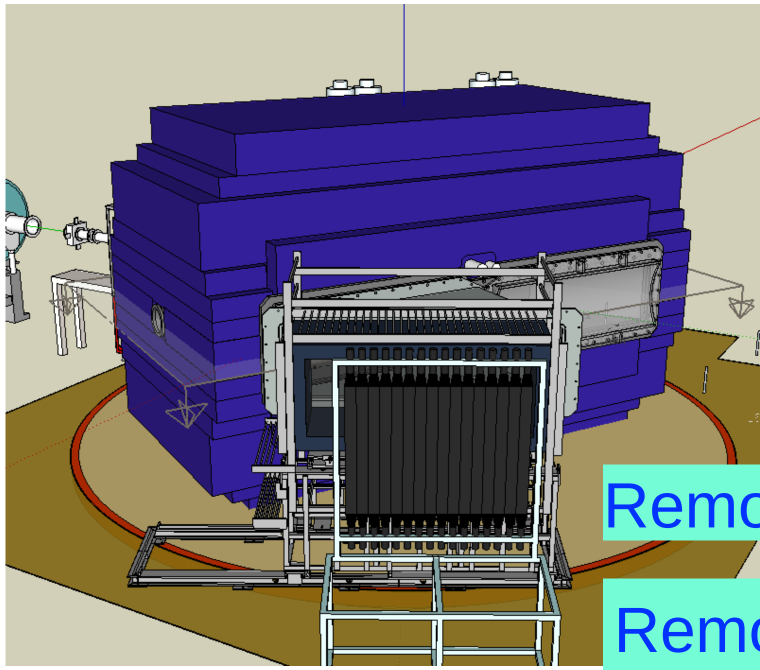
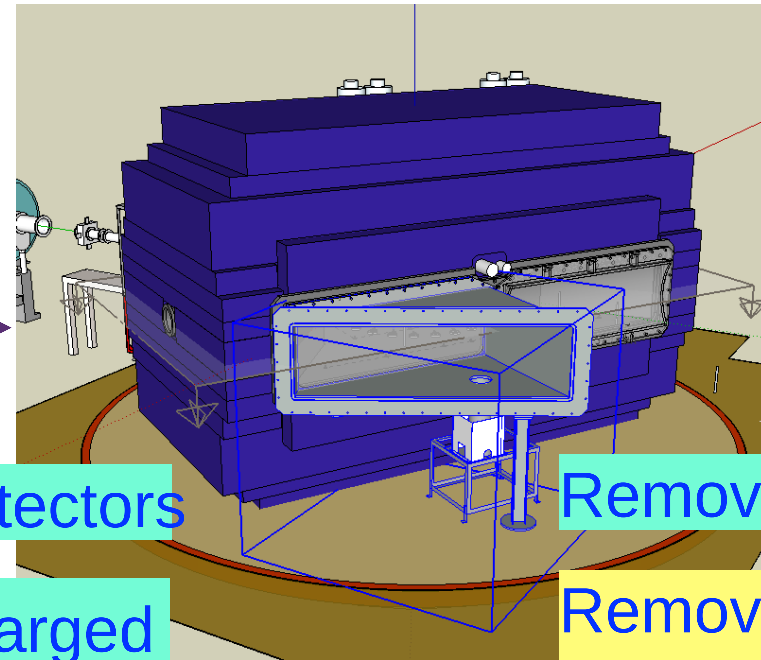
    - 7 x 0.8 m^2 of area have to be covered ; vacuum separation was given up.
  - Stands of CATANA/DALI2, Si vacuum chambe[r] On designing
    - ? How to layout them around the target region
    - ? position determination of the SSD

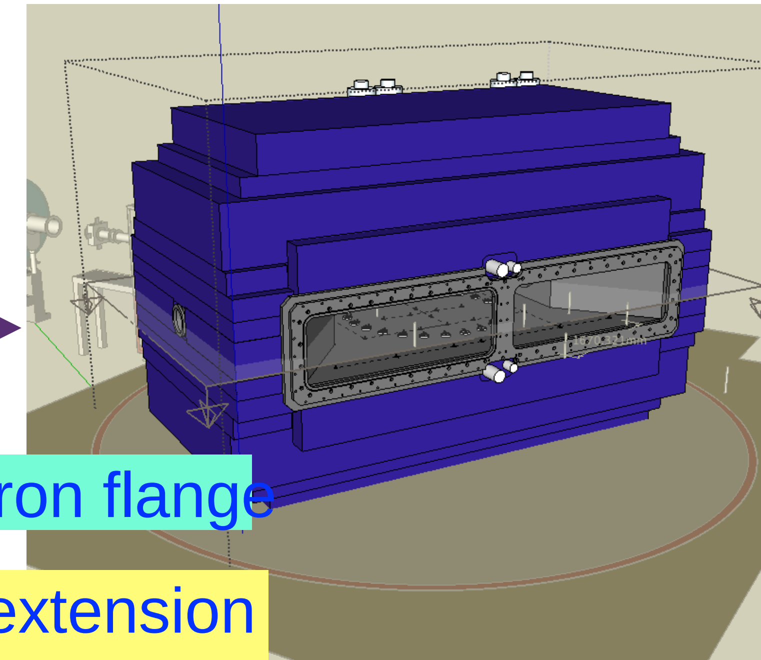
    Required engineering for protocols

  - How to layout "standard detectors" on Downstream of SAMURAI

Tasks for 0° / 90° configuration







Remove Detectors

Remove charged particle flange

Remove neutron flange

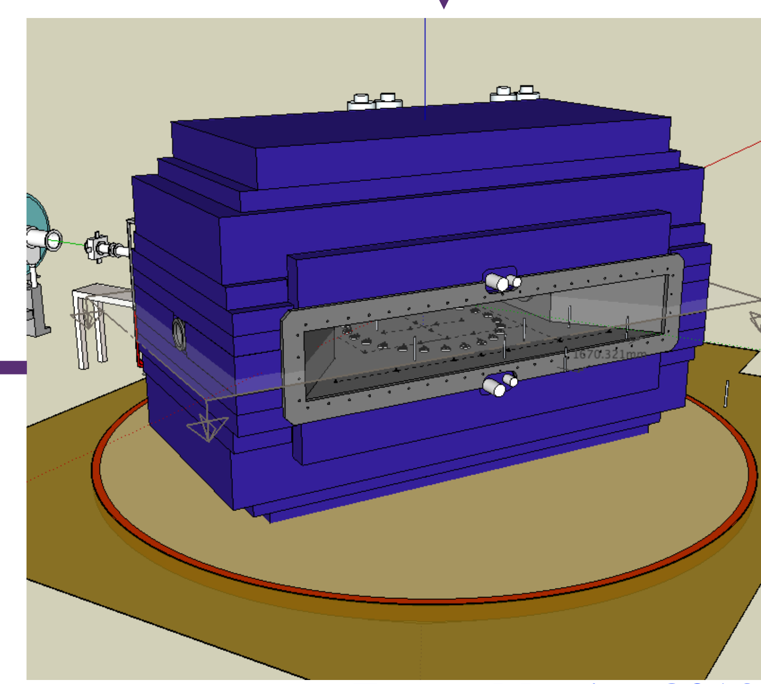
Remove 30° extension duct (2.5t, balancing)

Remove "Glass shape flange" (0.9t)

Operation with experiences

Operation w/o experiences

10 days in rough estimation



Rotate magnet to 0° or 90°

Connect beam line

Slide STQ25 if needed

Layout devices at FP

Layout devices around target

...

unexpected incidents

User's Operation

Facility Side but Collaboration base operation

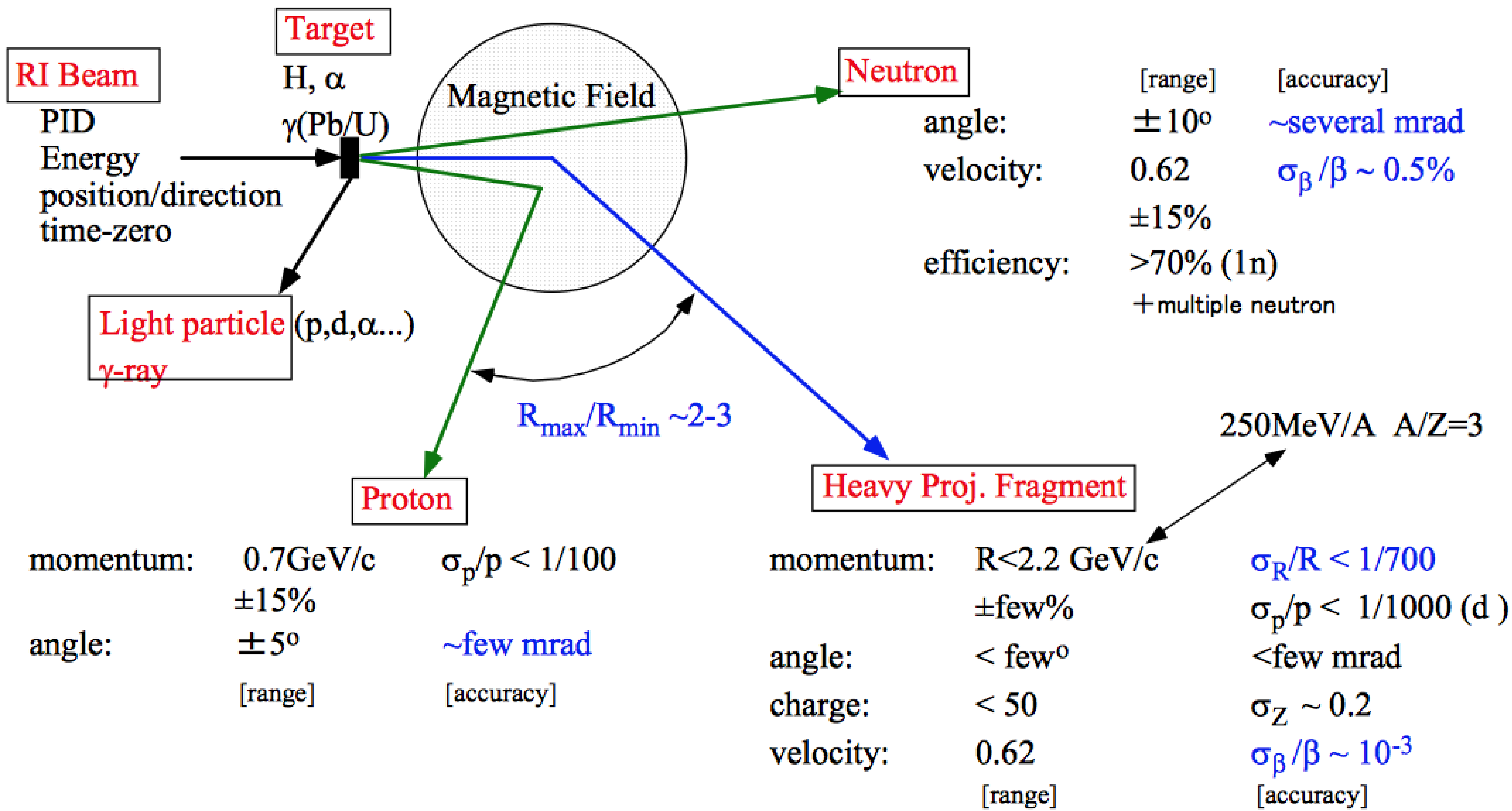
Thank you for your attention.

Commissioning Experiment March 2012

Backup Slides

Designing phase

- Broadband type spectrometer was originally designed as key device in RIBF project from the beginning (~ 1997).



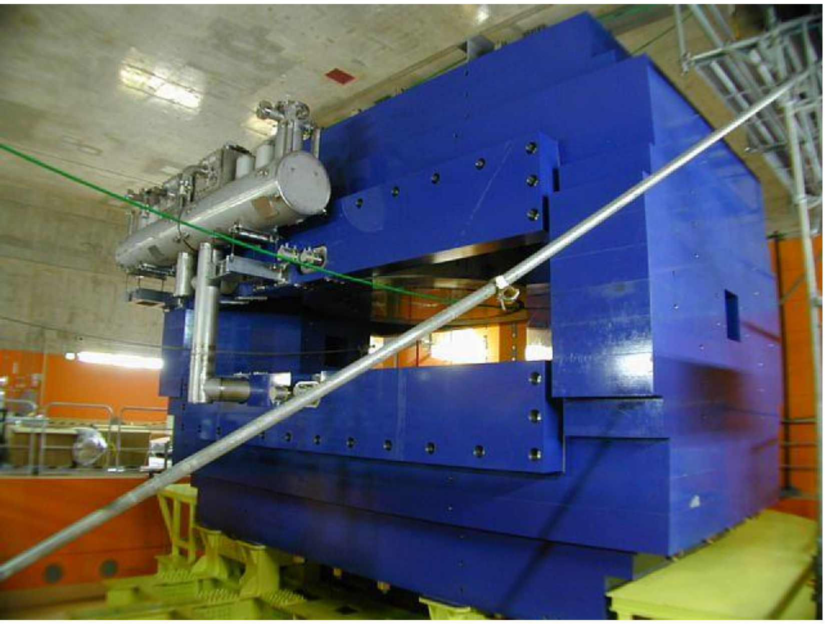
T. Kobayashi, TAC report, Fig. 1-3, 2004

Magnet construction

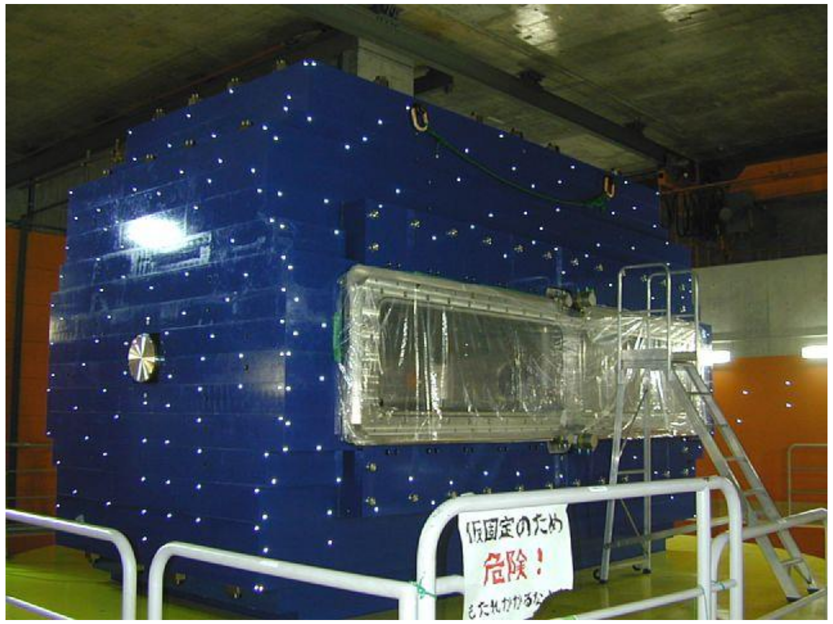
Rails for rotatable base

Rotatable base with the first layer

Magnet yoke with poles



Coils with cryostats, LHe vessels



Vacuum chamber

COMPLETED 2011/03

Spectrometer on RIBF

- SAMURAI : large/huge acceptance broadband type
  - Planned on RIBF design (~1997 ?)
  - Construction completed : 2011
  - First beam : 2012
  - dδ/δ~1/1500 (achieved value), 1/1000 (designed value)
  - Rmax/Rmin : 2~3
  - Vertical acceptance : 170mrad (± 5°) designed → 140mrad
  - Horizontal acceptance (for n) : 340 mrad (± 10°)

- ZeroDegree : extension of beam line from BigRIPS
  - Planned on RIBF design (~1997 ?)
  - Construction completed : 2007
  - First beam : 2008
  - dδ/δ=1/1240 (Large acceptance mode : 6%, H/V 90/60 mrad)
  - dδ/δ=1/4000 (Dispersive spectrometer mode : 4%, H/V 40/60 mrad)

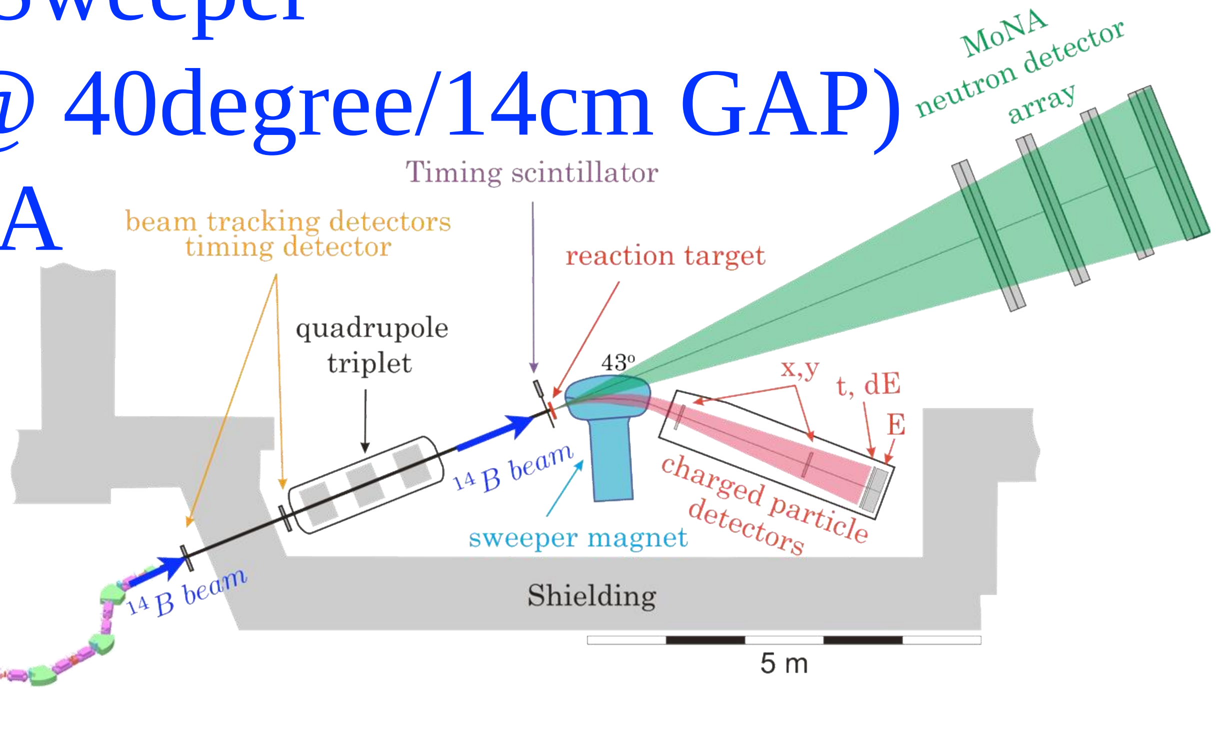
Spectrometer on RIBF

- ZeroDegree : extension of beam line from BigRIPS
  - Planned on RIBF design (~1997 ?)
  - Construction completed : 2007
  - First beam : 2008
  - dδ/δ=1/1240 (Large acceptance mode : 6%, H/V 90/60 mrad)
  - dδ/δ=1/4000 (Dispersive spectrometer mode : 4%, H/V 40/60 mrad)

- SHARAQ : high resolution spectrometer for RI beam by CNS
  - Kick off on 2004(?)
  - TAC : 2005
  - Construction completed : 2009
  - First beam : 2010
  - dδ/δ=1/15000

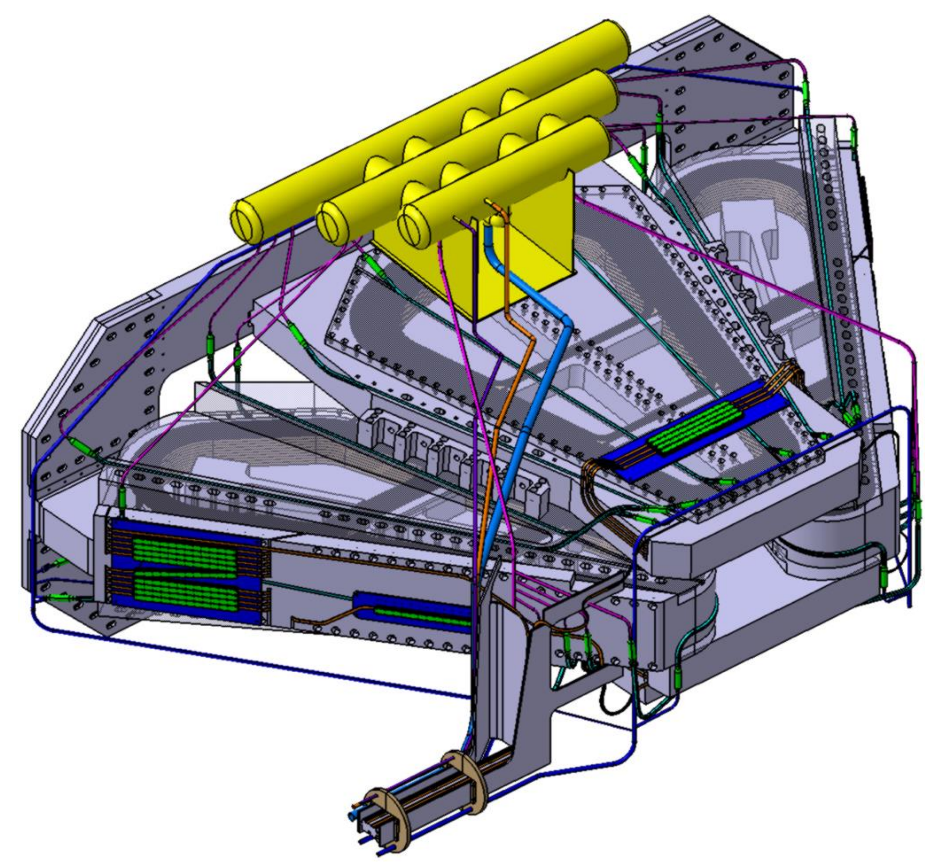
Large Acceptance magnetic spectrometer for RI experiments in the world

NSCL Sweeper
(4Tm @ 40degree/14cm GAP)
+ MoNA

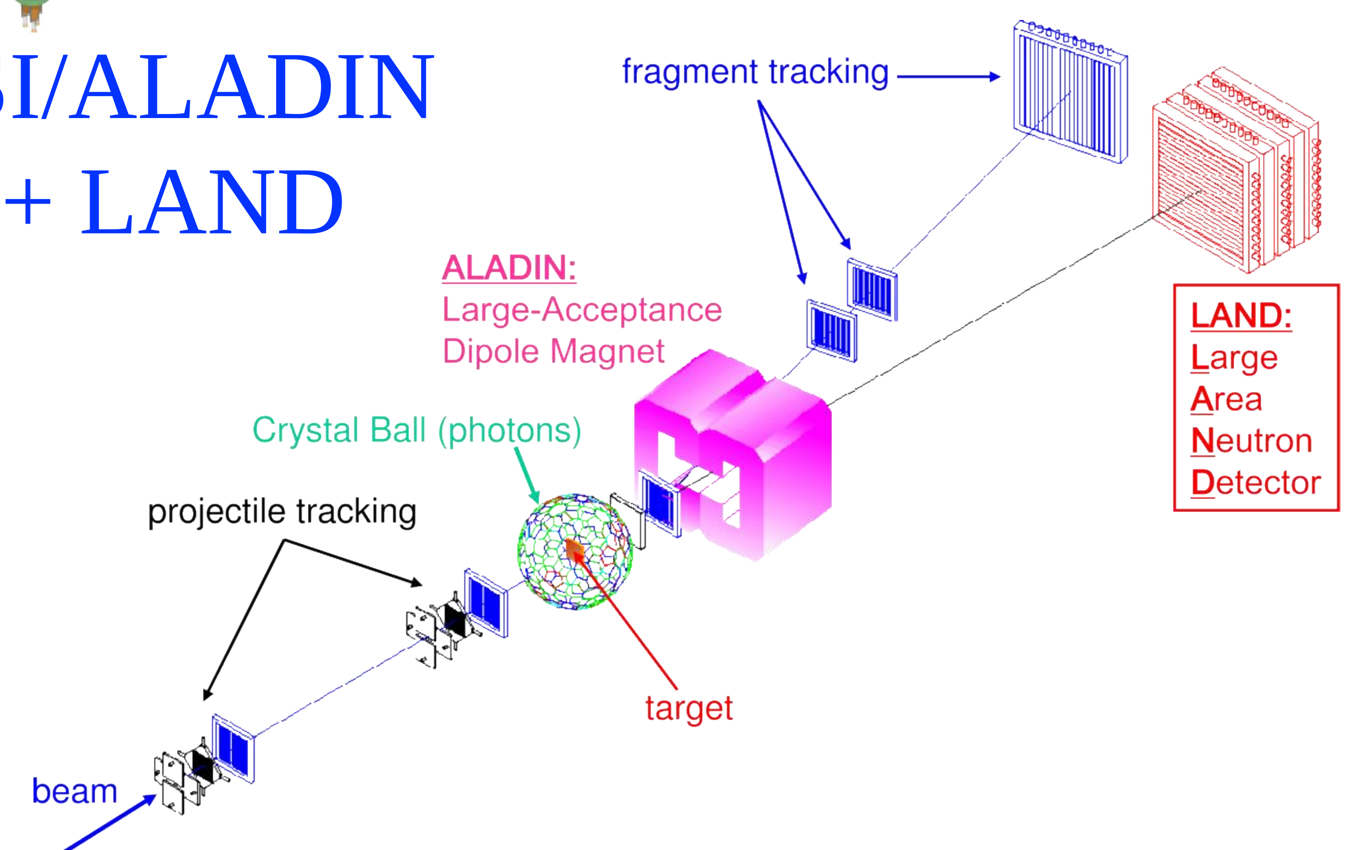


R3B-GRAD
GSI/FAIR
5Tm, ±80 mrad for n
under construction

+ neuLAND

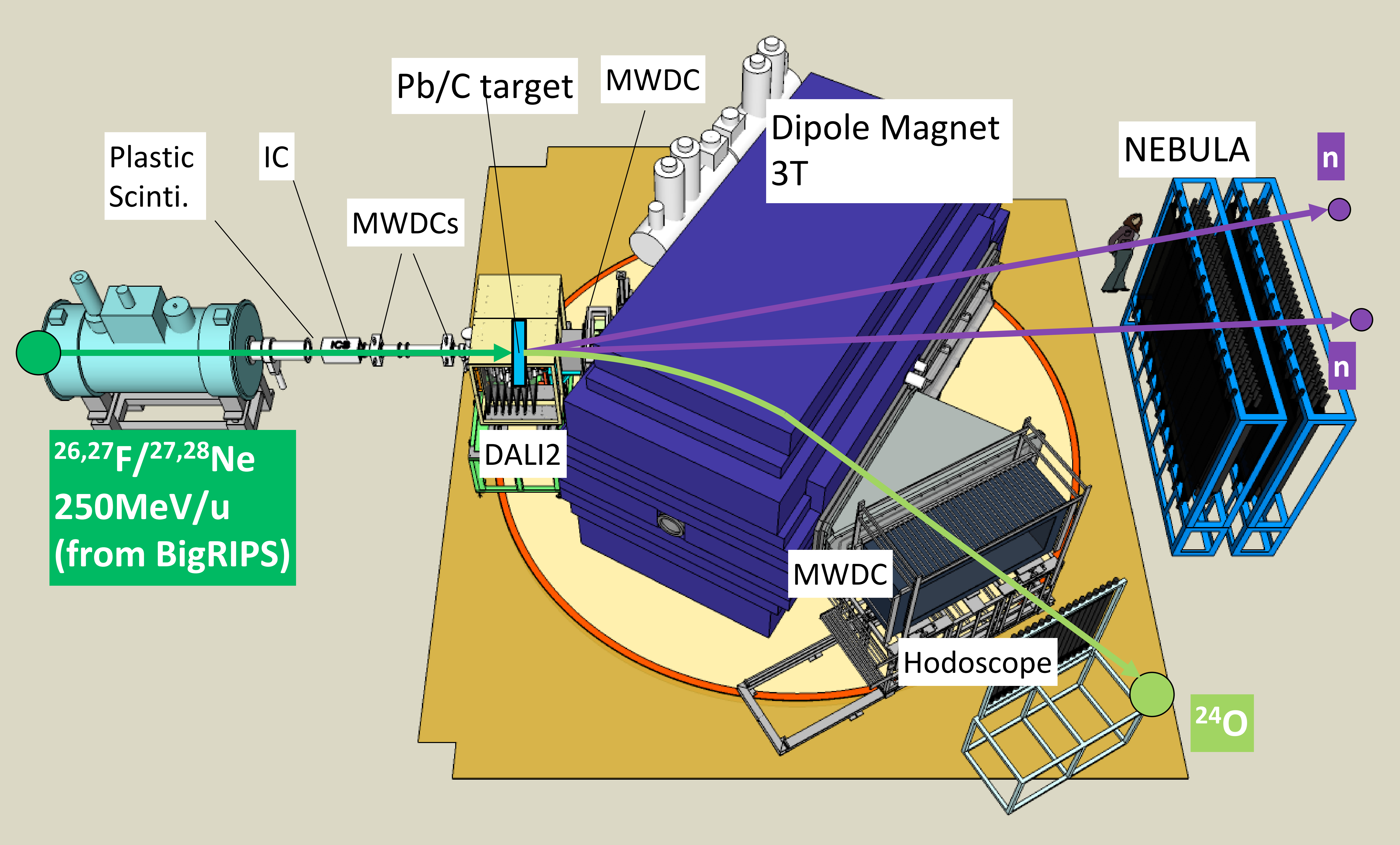


GSI/ALADIN
+ LAND



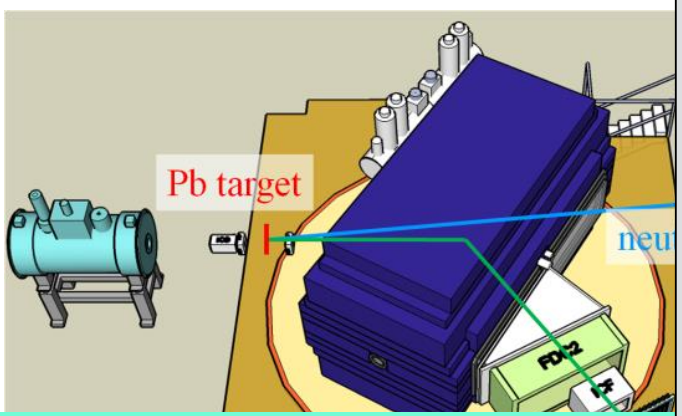
SAMURAI
Properties/Constituents

Typical n-HI measurement Experimental setup



Approved programs and SAMURAI setup modes

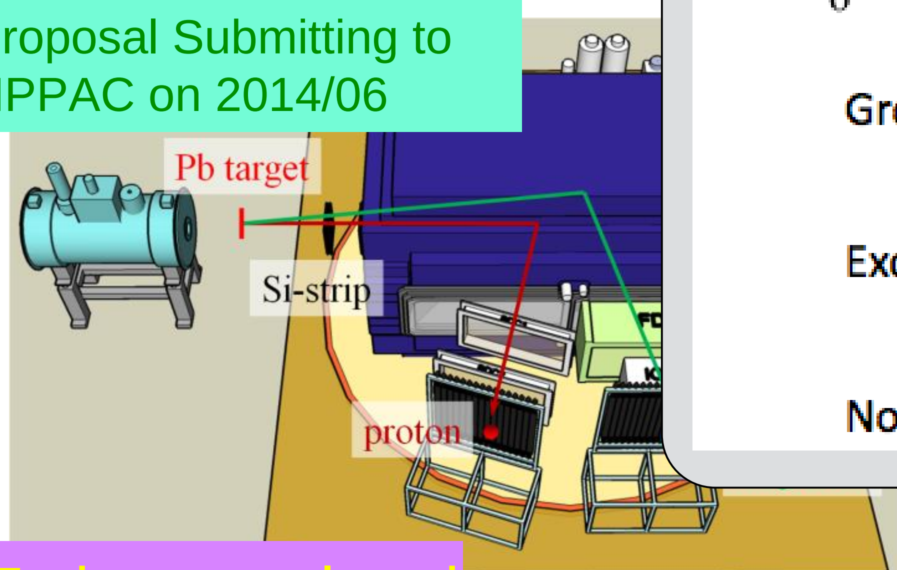
xn+HI (neutron-rich side)
(©, n), unbound nuclei…



Commissioning RUN:
Day-one/two
SAMURAI21(S grade): ^{28}O
SAMURAI20: ^{26}O life
SAMURAI09: Pigmy Dipole

(©, p) reaction,…

Proposal Submitting to
NPPAC on 2014/06

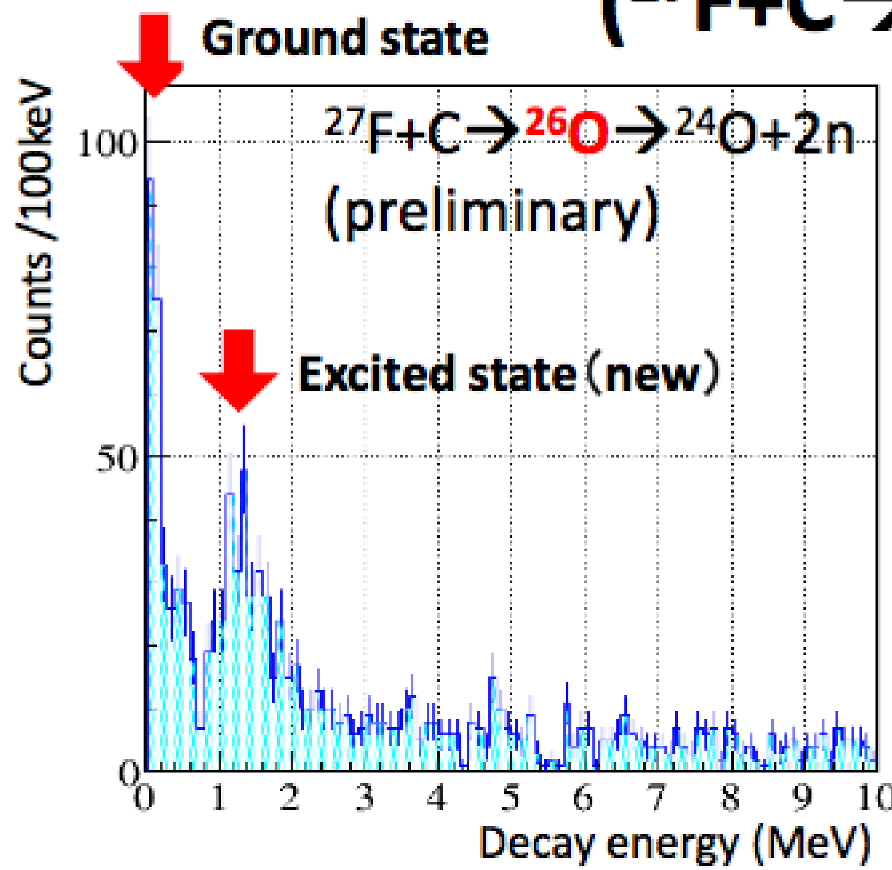


To be completed

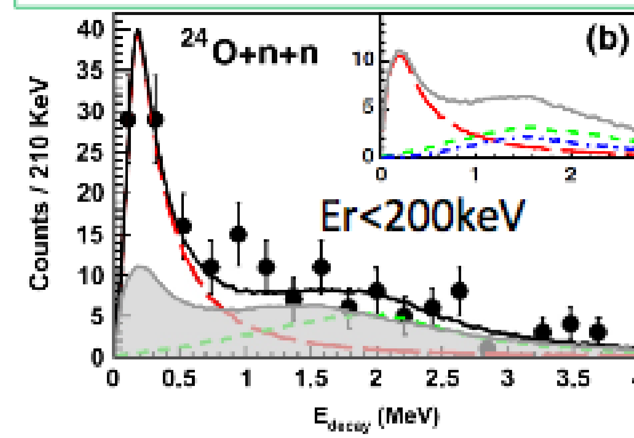
To be completed

Slide by
Y. Kondo(Tokyo Tech)

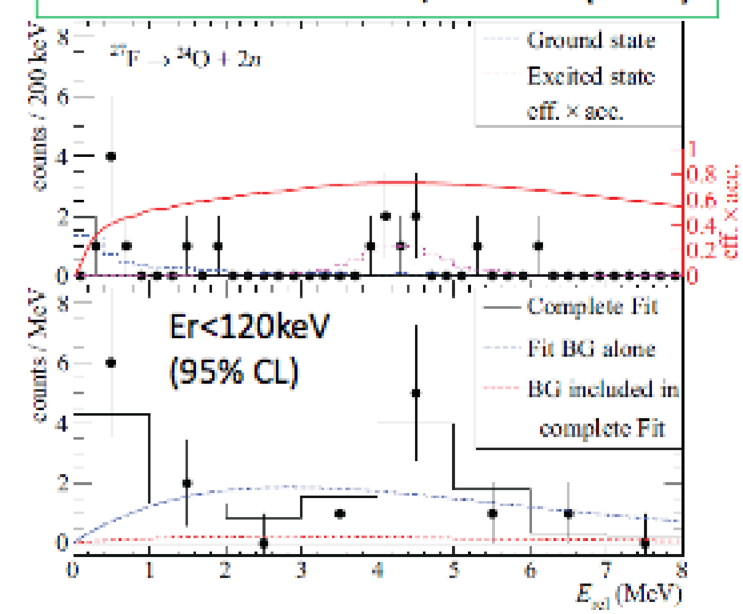
Decay energy spectrum
(^{27}F+C→^{26}O→^{24}O+2n)



E. Lunderberg et al.PRL108, 142503 (2012)



C. Caesar et al.PRC88, 034313 (2013)



Ground state
- 5 times higher statistics
- →better determination of energy

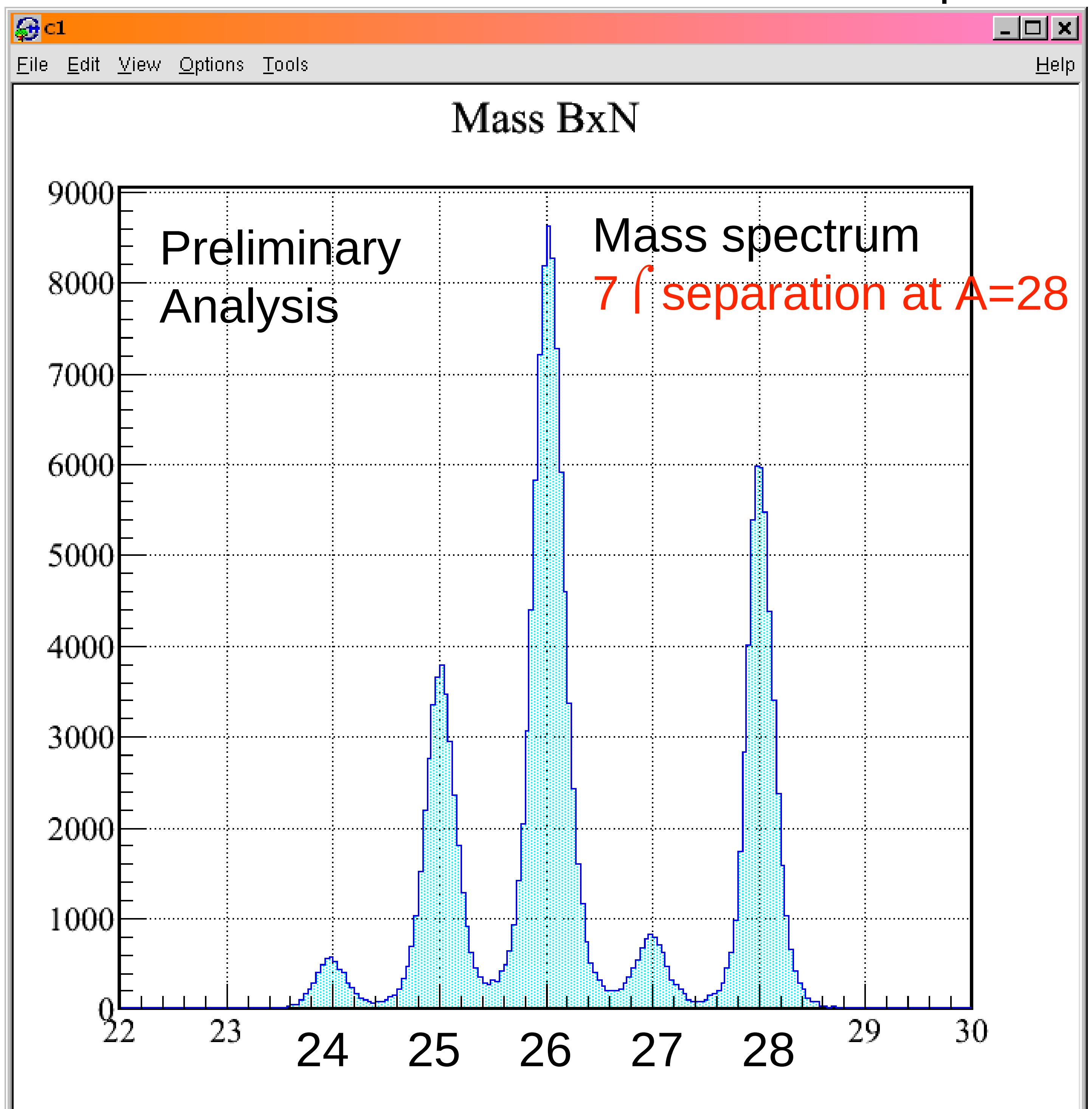
Excited state at ~1.3MeV
- First observation
- Most probably 2$^+$

No peak at ~4.2MeV

Particle Identification Spectra at SAMURAI

(May, 2012, SAMURAI/RIBF, Kondo et al)

^{28}Ne → ^{A}Ne+X On-line Spectra



Courtesy of Y.Kondo

neutron trigger

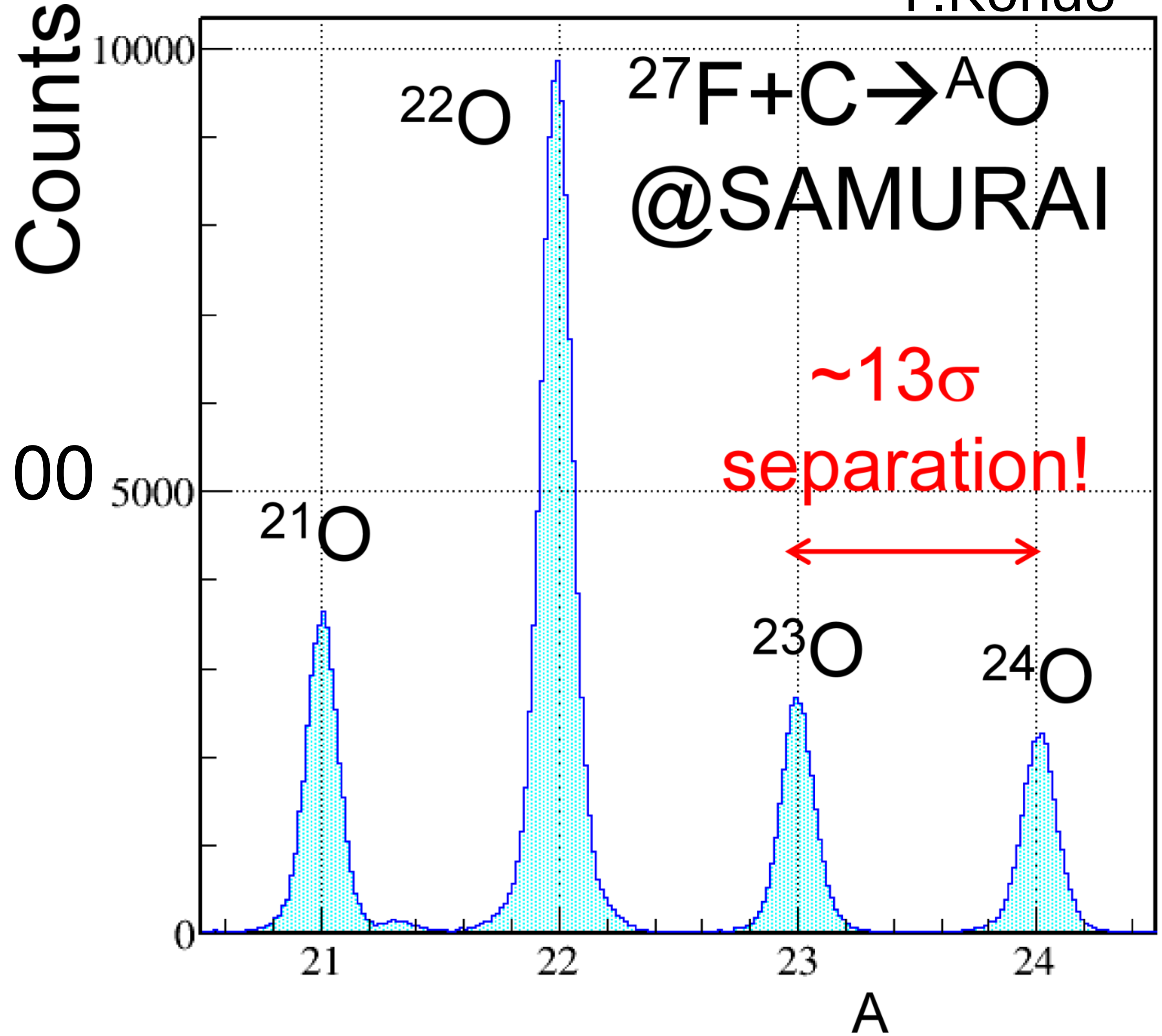
Offline analysis : much better than those of on-line phase.

Courtesy of Y.Kondo

- On-line : 7σ separation

↓

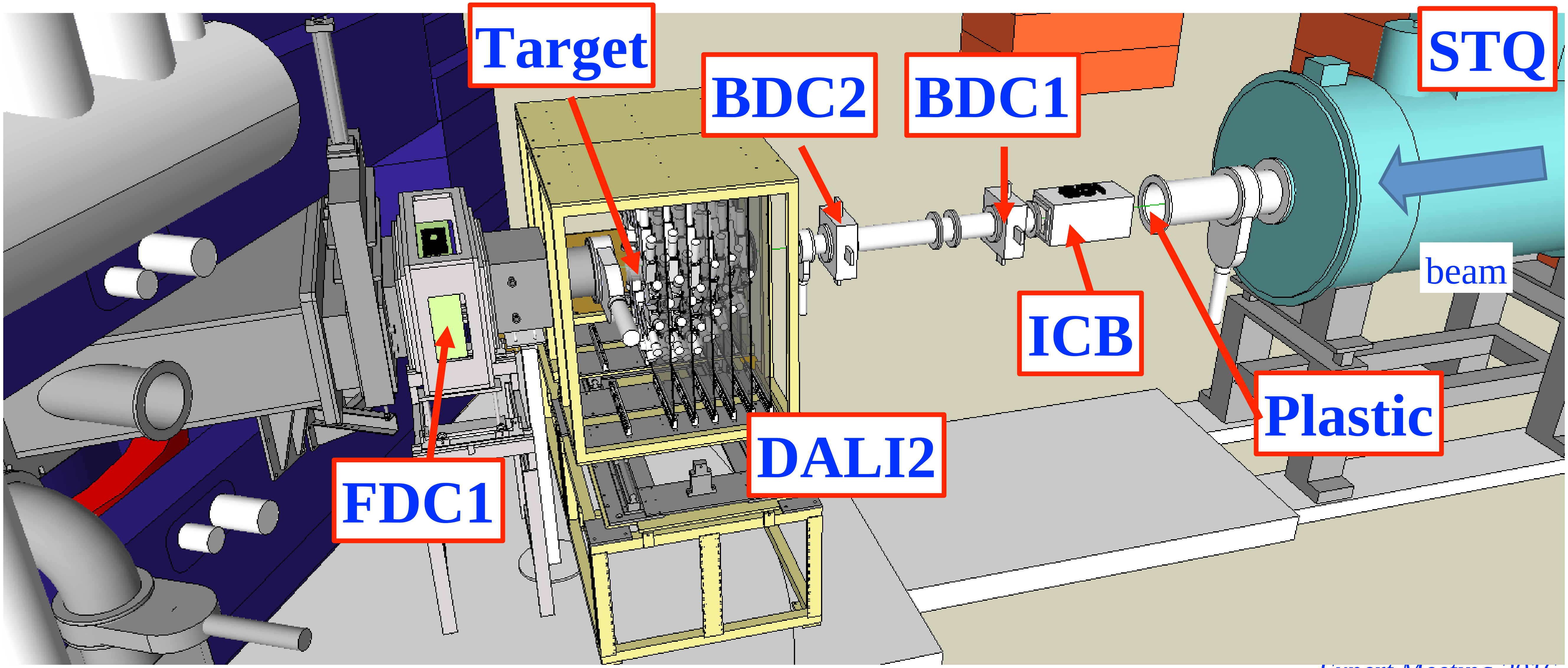
- 13 σ separation @ A~25
  → 3σ separation @ A~100 (expected)



Clear Particle identification!
→ High resolving power of SAMURAI

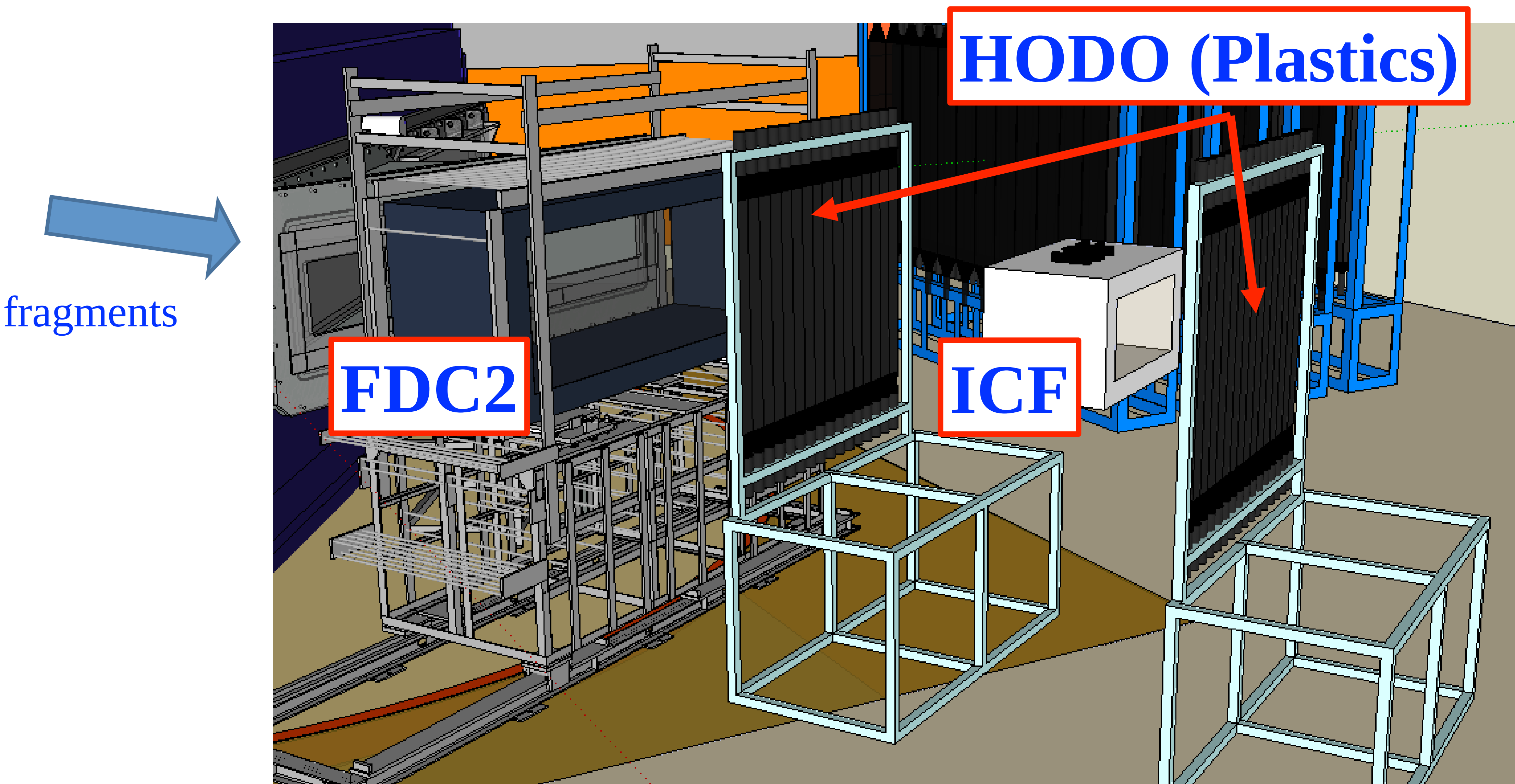
SAMURAI beam line detectors

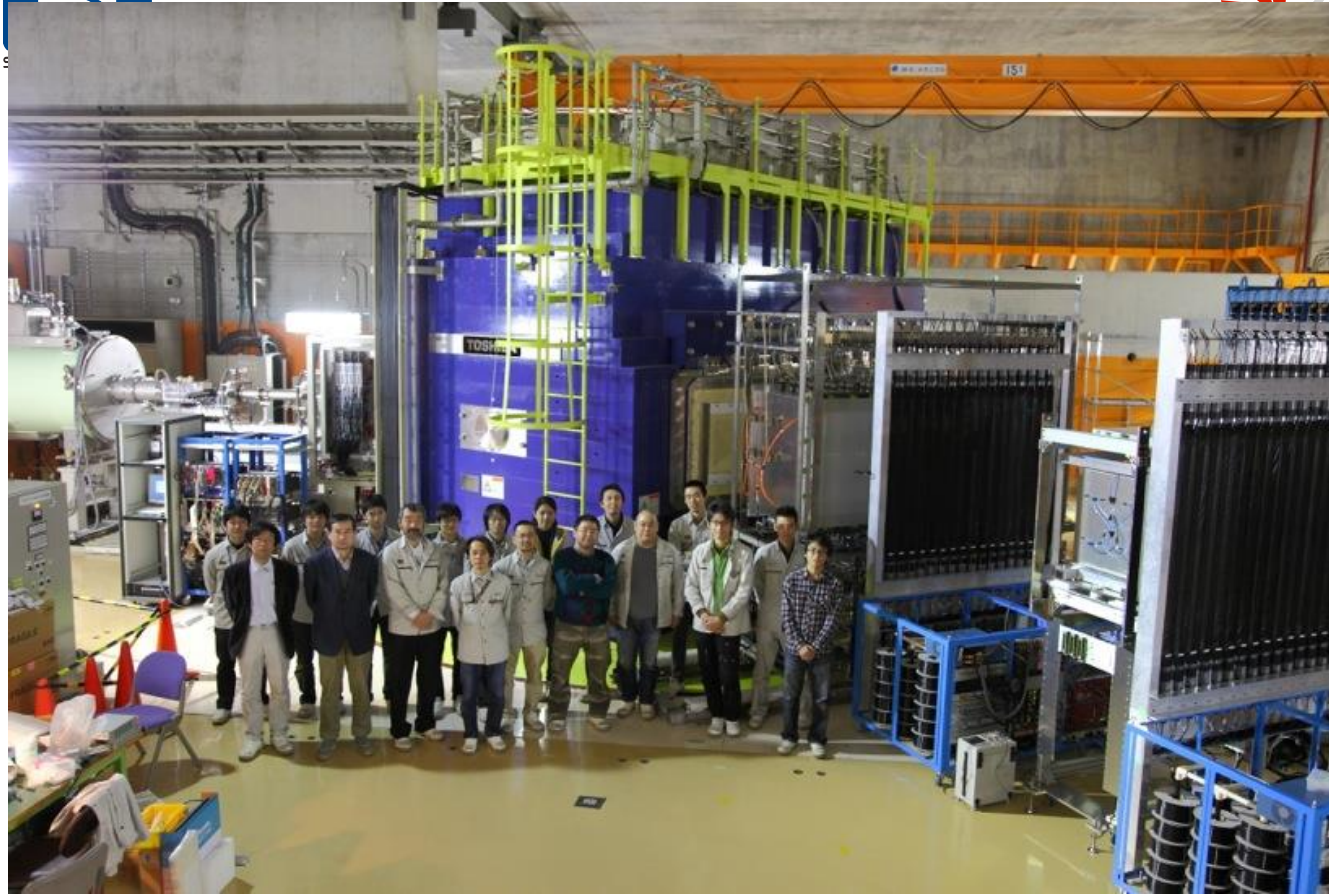
- Detectors for incoming beams: beam position (BDC), PID(Plastic and ICB), ©(DALI2) and tracking detector(FDC1) for electro-magnetic spectroscopy at SAMURAI.



SAMURAI Focal plane detectors

- Detectors for fragments: FDC2 for tracking, HODO for ⊗E and TOF, ICF for ⊗E.
- Proton drift chamber (PDC), CsI total energy detector (TED), and total internal reflection Cherenkov (TIRC) will come in the future.





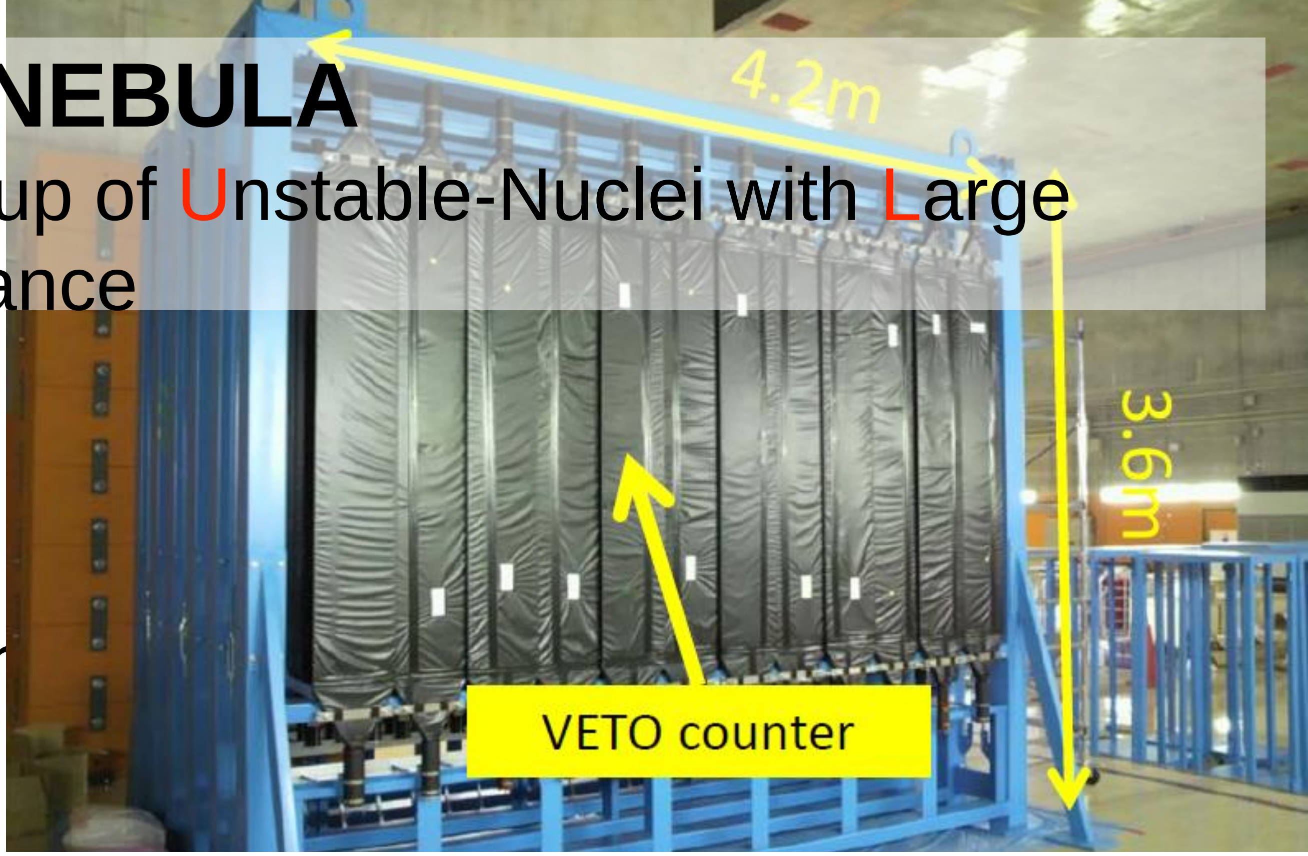
Commissioning Experiment March 2012

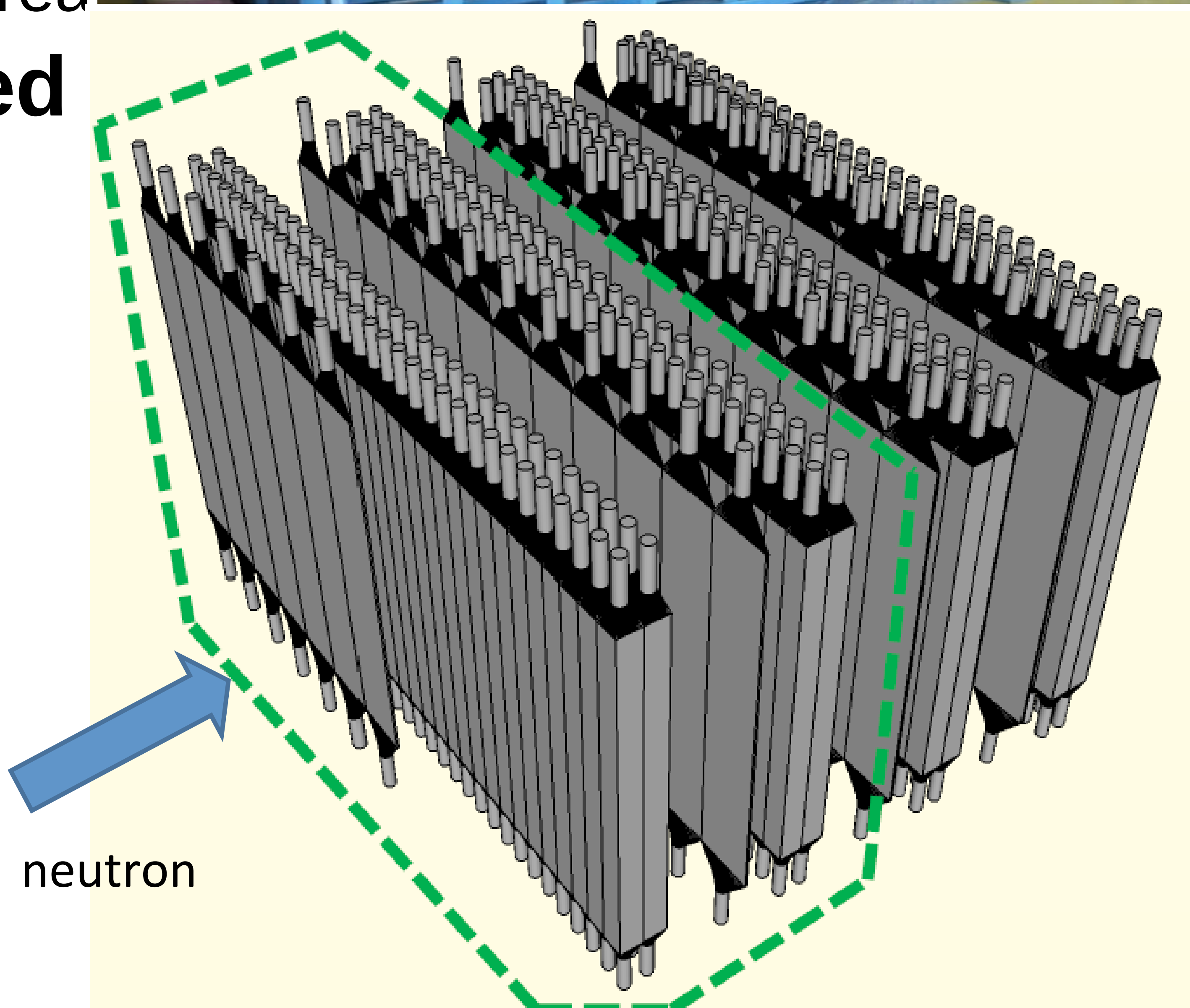
SAMURAI-NEBULA

Neutron-detection system for Breakup of Unstable-Nuclei with Large Acceptance

- Design
  - 240 Neutron counters
  - 48 VETO counters
  - arranged into 4 stacks
- Detection efficiency~40% for 1r
- Large acceptance
  - 3.6m (H) x 1.8m (V) effective area

Half(120 modules) is funded

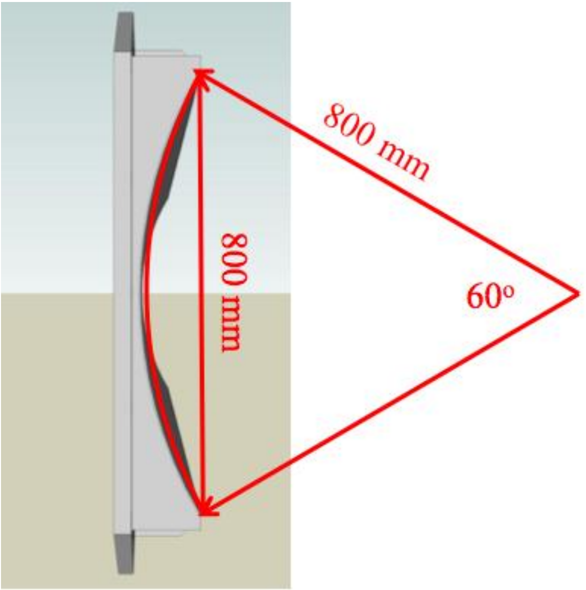


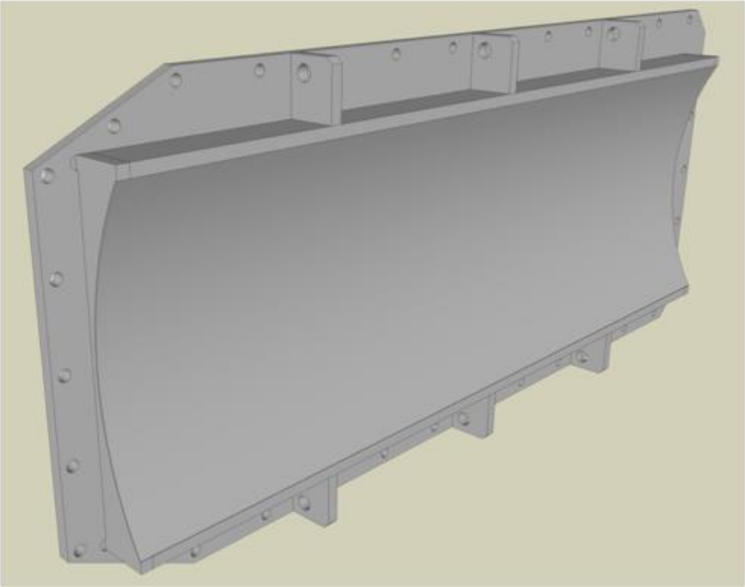


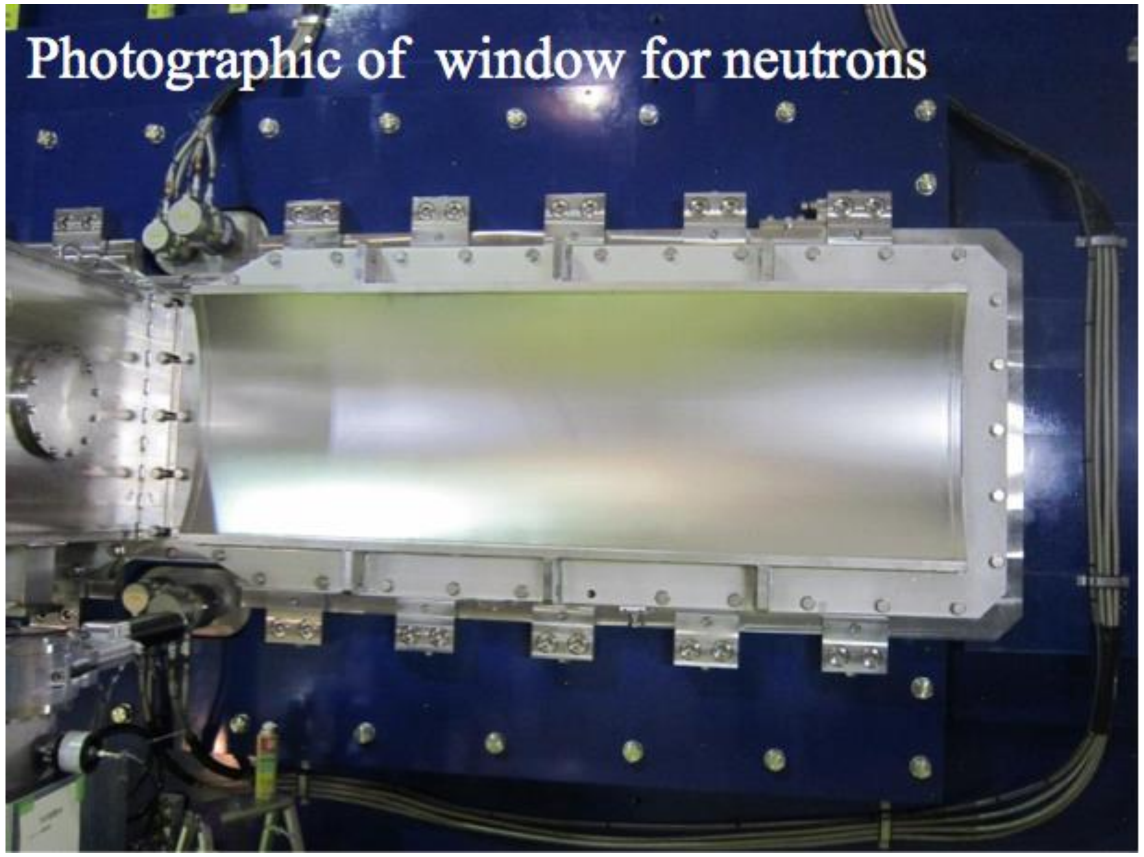
SAMURAI Vacuum Window

- Neutron window : SUS 3mm^t : 2430 × 800 mm^2
  - for neutrons ~ 250 MeV to pass through
  - De-dimension configuration applied
    Estimated by ANSYS calculation → Deformation is reasonably small

CONCEPT: De-dimension
2D geometrical degree of freedom
→ approximately restricted to 1D deformation







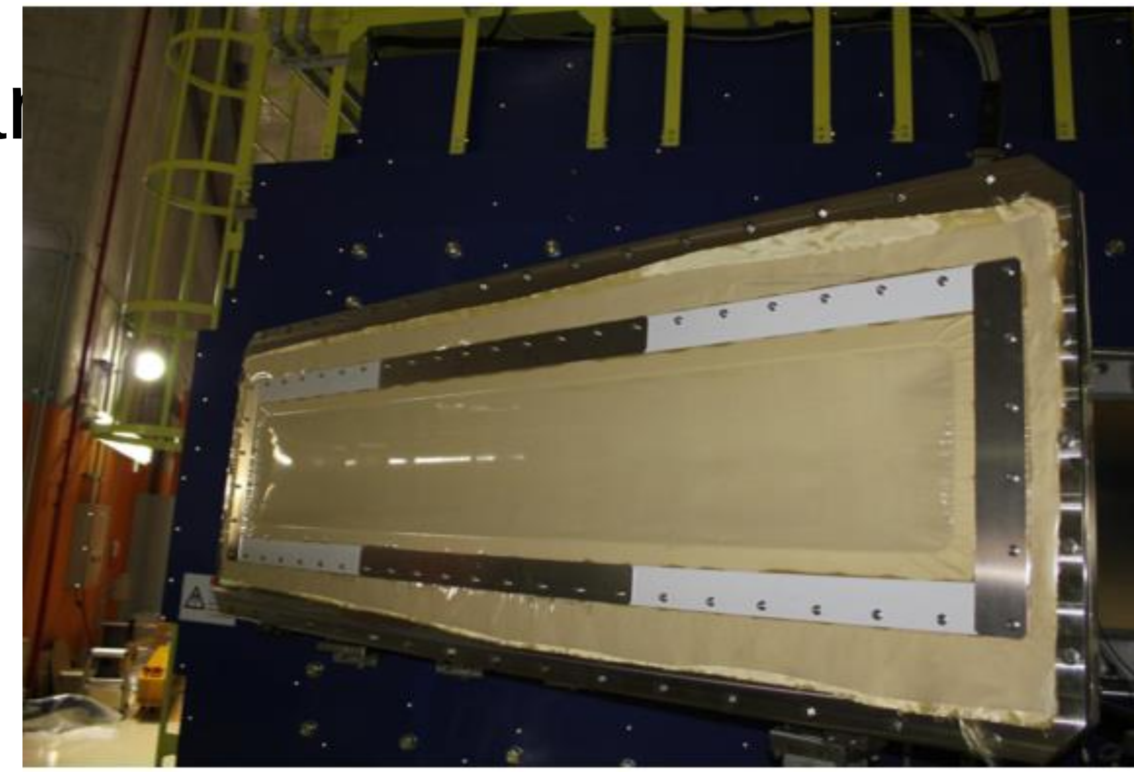
Calculation results:
Deflection : 0.22 mm
Stress(Max.) : 29 MPa

Y. Shimizu, EMIS2012 proceedings, to be published on NIM

SAMURAI Vacuum Window

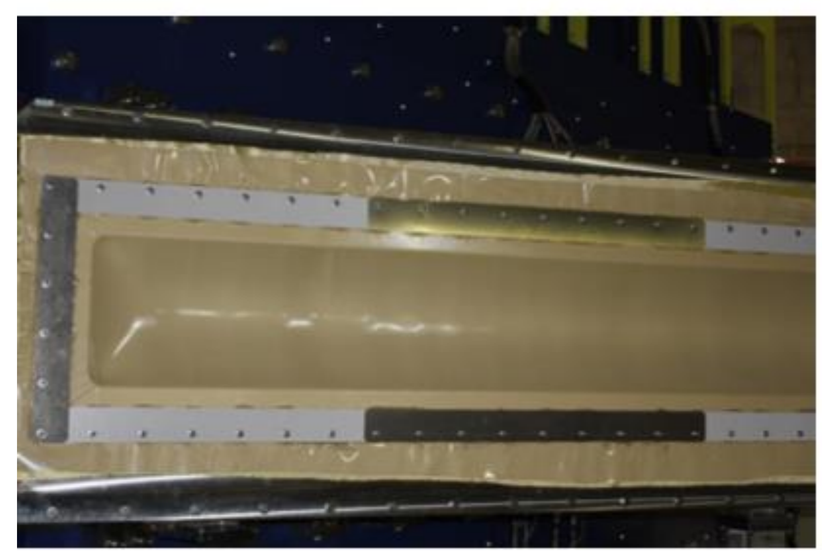
- Charged particle window : 2940 × 800 mm^2
  - for HI ~ 250 MeV to pass through

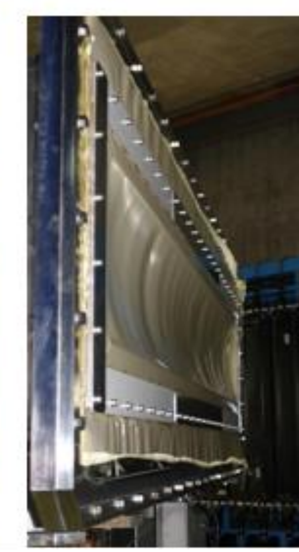
- For Commissioning(2012/03) ar
  Dayone exp(2012/05),
  we decided to use
  only 400mm height aperture
  for HI for SAFETY.



Membrane configuration :

Mylar 75 μm for separating vacuum
Kevlar(K49) 0.28 mm^t for support stress
by pressure
Glued by Araldite(TM) with 70mm width



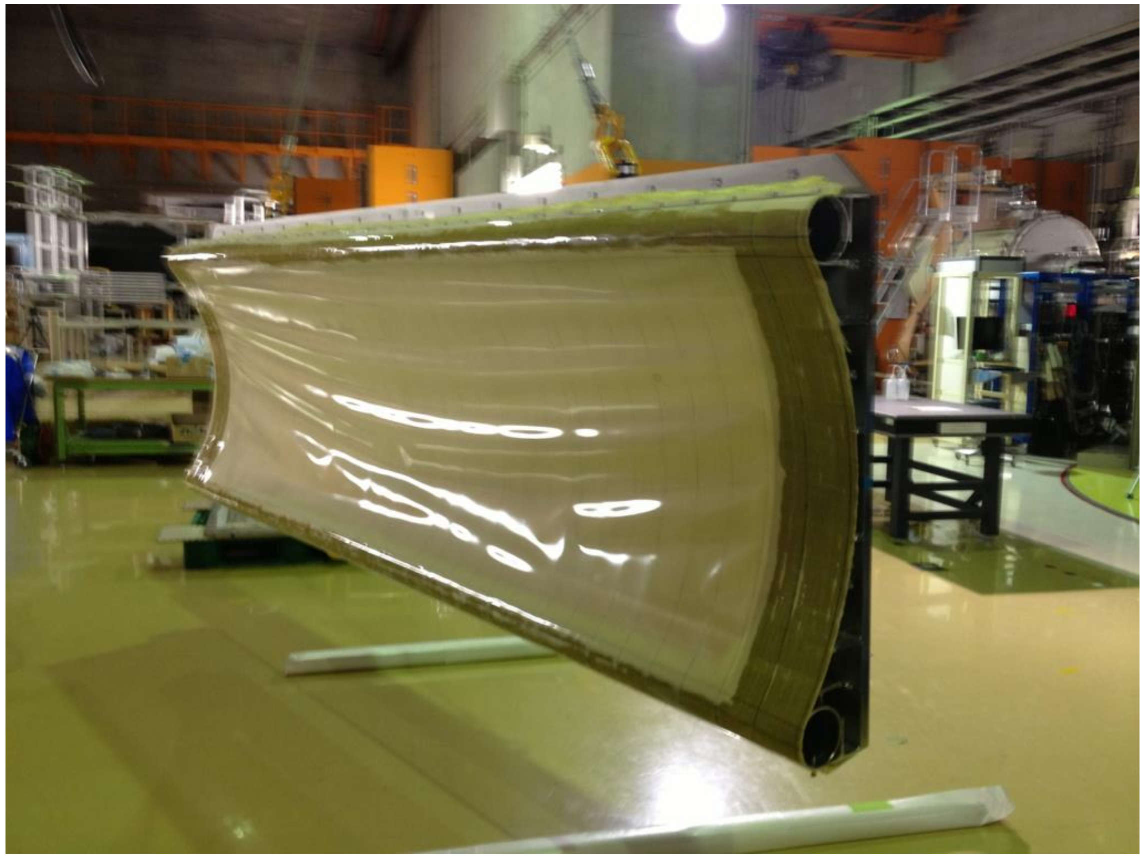


Y. Shimizu, EMIS2012 proceedings, to be published on NIM

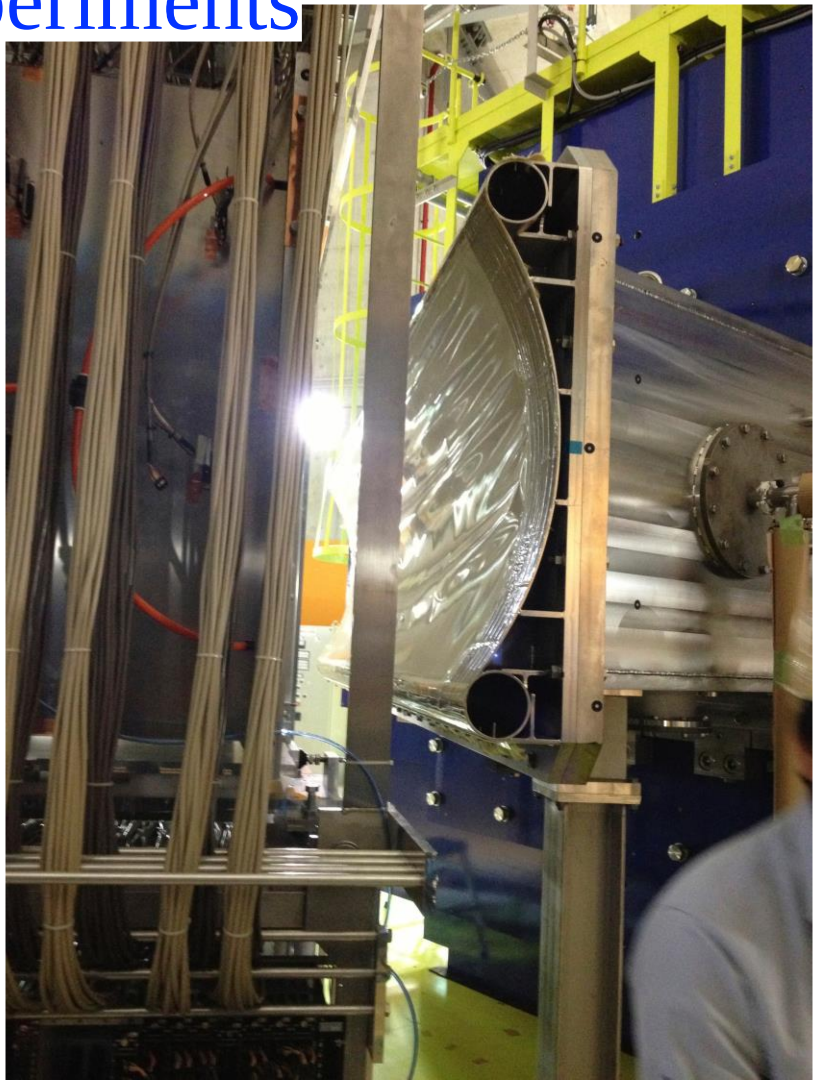
SAMURAI Vacuum Window

- Charged particle window : 2940 × 800 mm^2
  for HI ~ 250 MeV to pass through
- 400mm → 800mm
  by De-dimension concept successfully introduced on n-window

Put to the practical usage on 2013/01 for Day-2 experiments



Membrane configuration : (same)
Mylar 75 μm / Kevlar(K49) 0.28 mm^t



If large window would be broken...

- Downstream
  - FDC2 : all wire inside will be blown.
    : support structure will be also damaged.
  - HOD : possibly damaged or folded.

- Upstream
  - FDC1 : all wire inside will be damaged
  - All vacuum separation windows will be blown
  - Possibly User's devices are damaged
- NEBULA : no damage (?)
- Machine time
  - have to be postponed around 1 or more years...

- Total damage estimated (w/o MT): 0.25 - 0.75 M$ (?) or more...

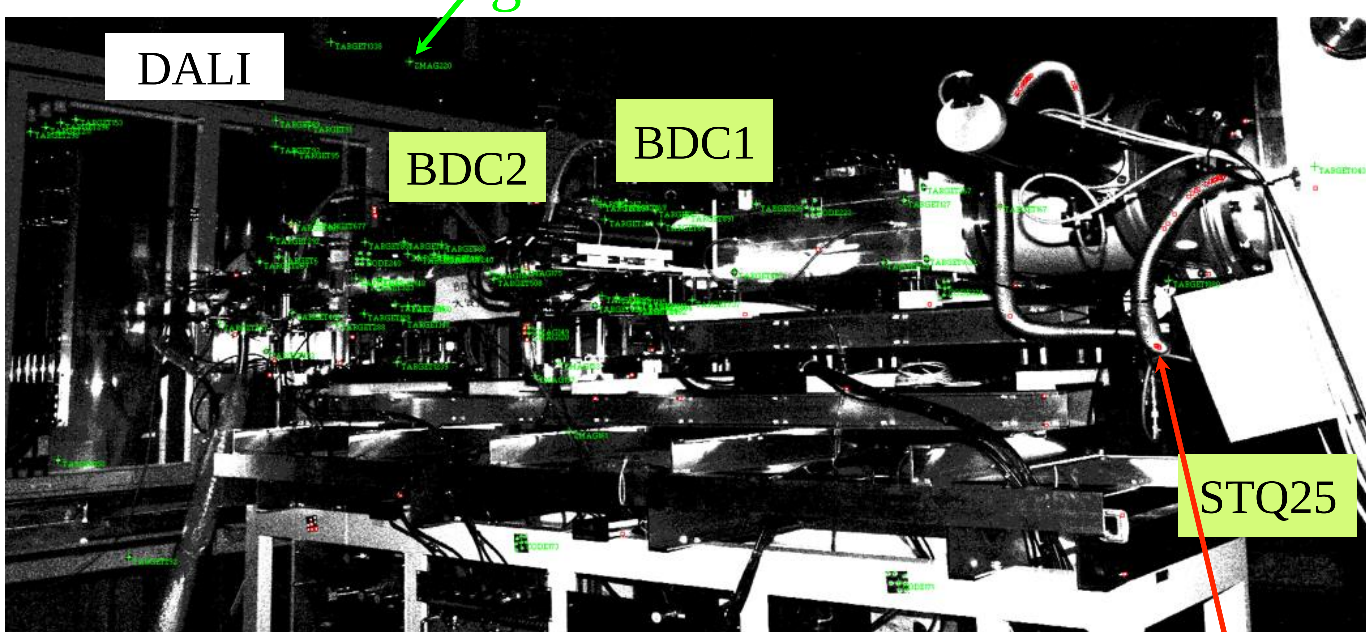
*) Construction budget for SAMURAI : 15M$

Position determination of devices upstream and downstream of the magnet

- Photo Grammetry System (PGS)
  - as RIKEN Common usage device , FY2010

1. Paste target markers on devices
2. Take pictures surrounding from the devices

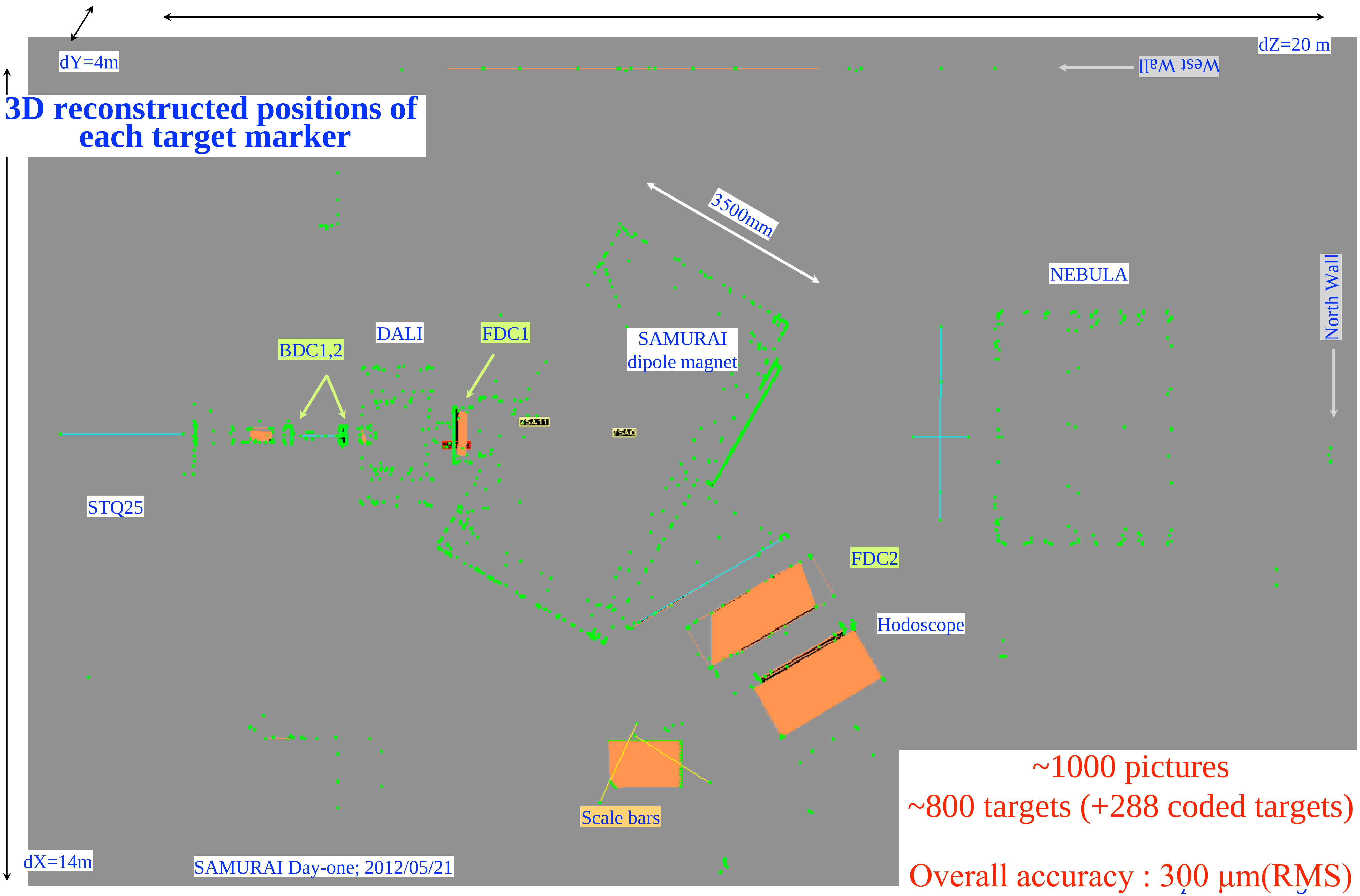
Every target is identified as a green marker.



Spurious reflections are noted as red markers

Reconstruct to 3D position by dedicated software (VStars)

Establishment of position measurement by PGS unbiased by human experiences or eyes



~1000 pictures

~800 targets (+288 coded targets)

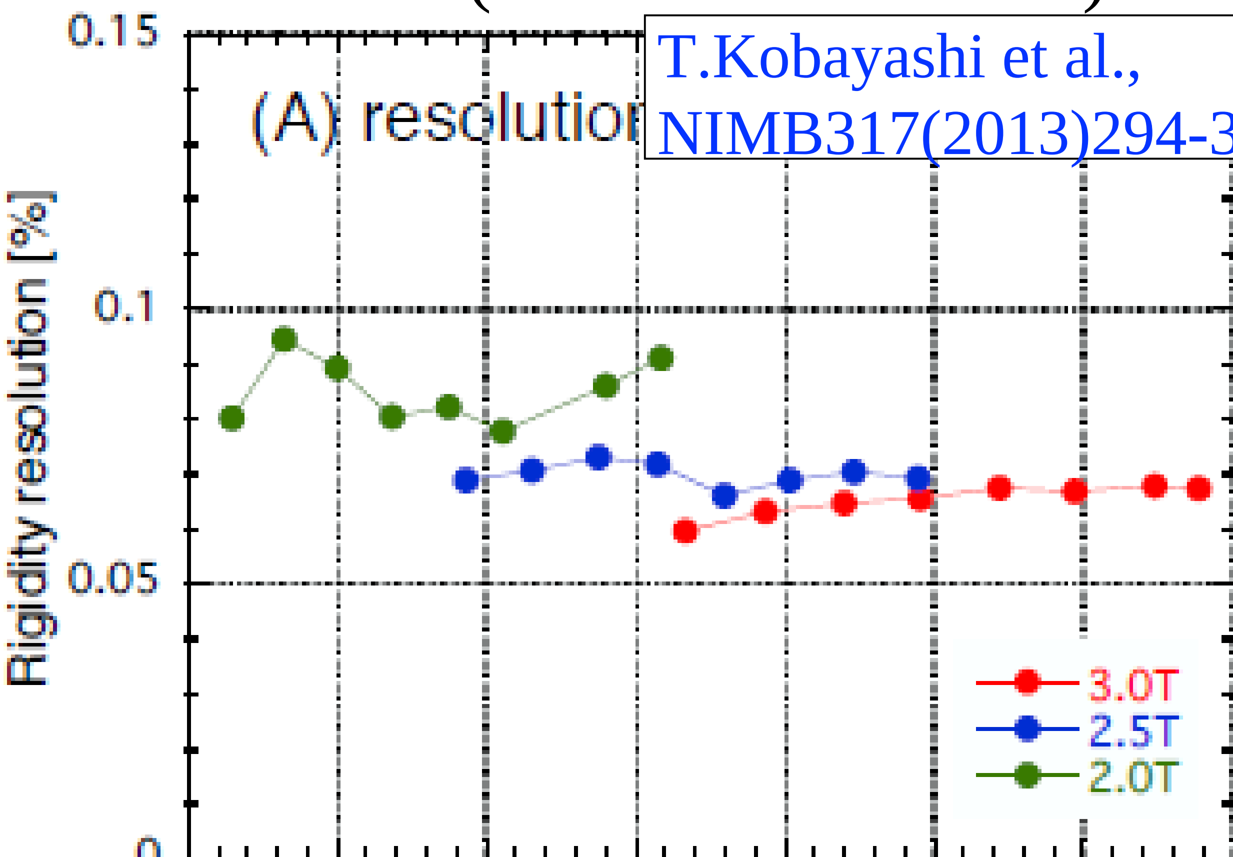
Overall accuracy : 300 μm(RMS)

Results of precise position determination

Each detector position (and angle) are determined within 150μm(RMS)
→ Successfully reduce the large contribution of systematic error on momentum analysis

Absolute momentum analysis
from BDC1,2 – FDC1,2 tracking
+ B field(TOSCA calculation)

T.Kobayashi et al., NIMB317(2013)294-304



Scattering Angular Resolution

→0.9mrad (rms)

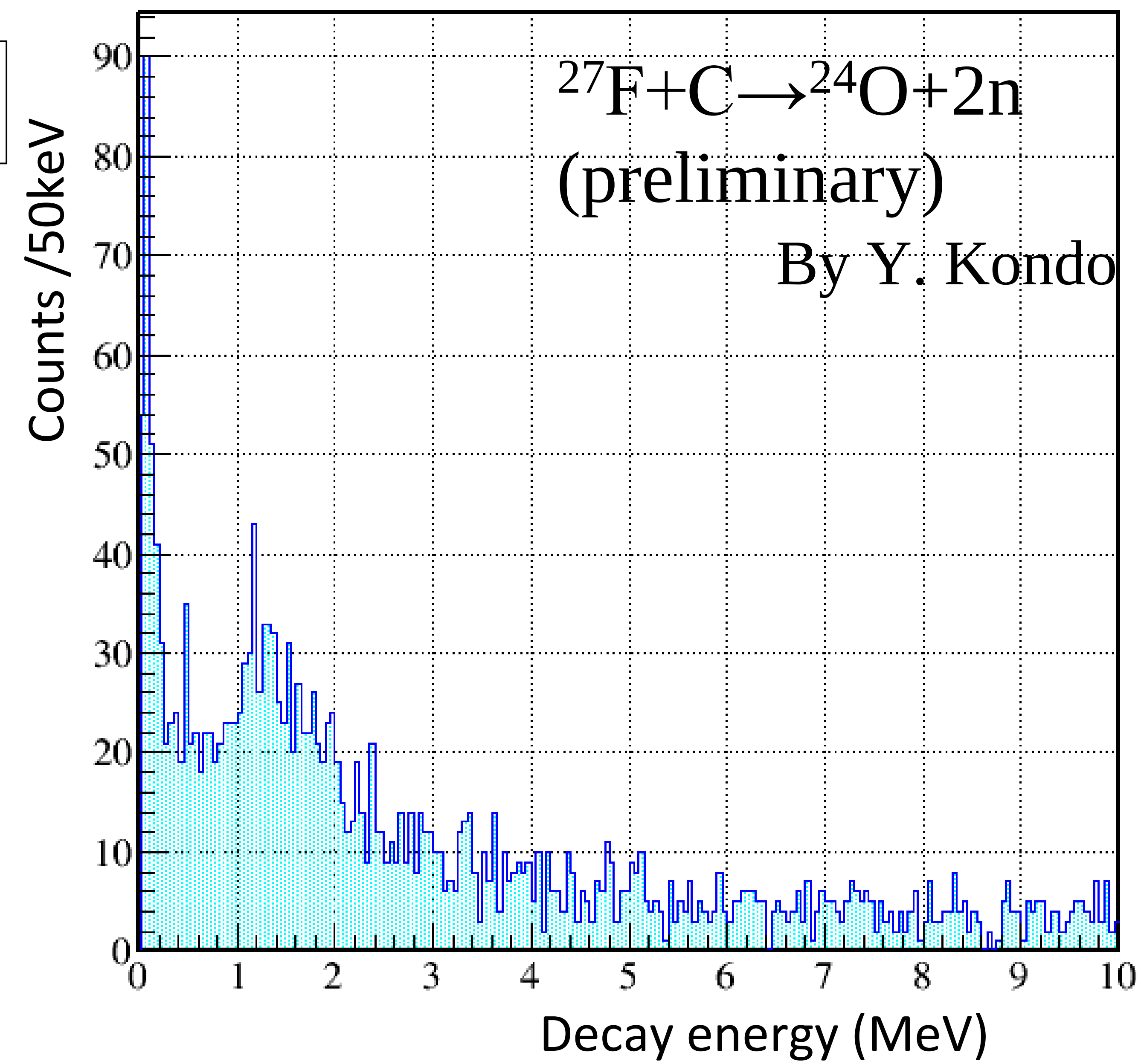
B〉 Resolution

→1/700 (one-path analysis)

→1/1500 (sophisticated) Here

→5 ⌠ mass resolution for A=100

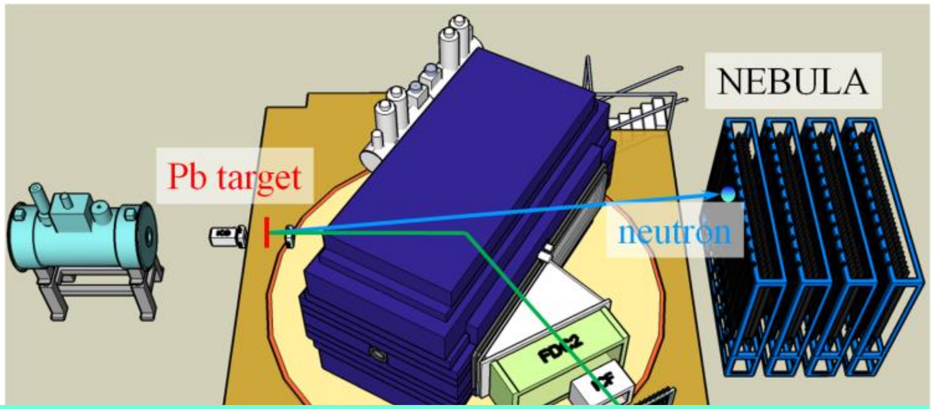
Decay energy spectrum: ^{26}O
w/o artificial offsets/treatments



Utilized to other RIBF beam line

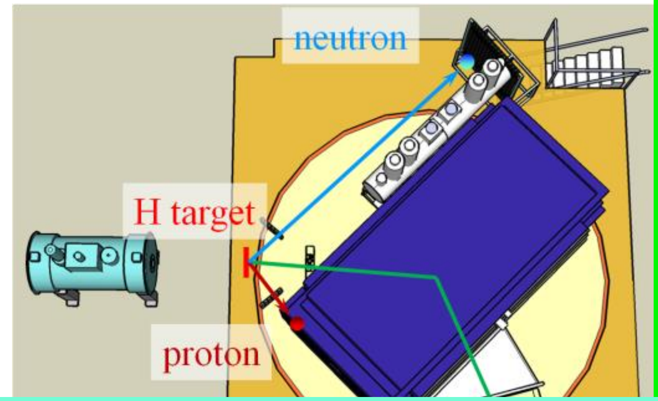
Approved programs and SAMURAI setup modes

x*n*+HI (neutron-rich side)
(©, *n*), unbound nuclei…



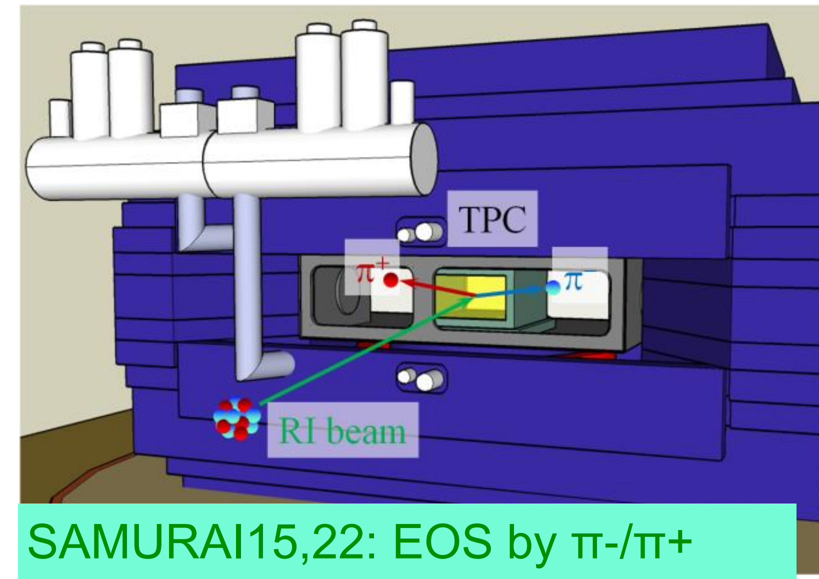
Commissioning RUN:
Day-one/two
SAMURAI21(S grade): ^{28}O
SAMURAI20: ^{26}O life
SAMURAI09: Pigmy Dipole

***p*,*n*(target frame)+HI**
(*p*,*p'*), (*p*,2*p*), (*p*,*pn*), …



SAMURAI17,11: (p,n) inverse
SAMURAI14: Fission
SAMURAI12: Cluster on Be
SAMURAI13: Polarization
SAMURAI18(w/ MINOS):
2n correlation

EOS measurement

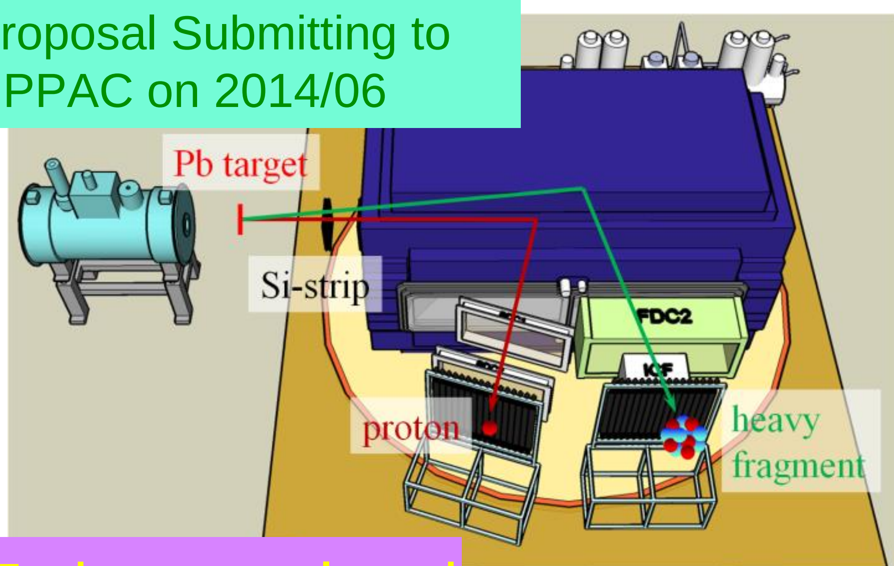


SAMURAI15,22: EOS by π-/π+
measurement on HIC

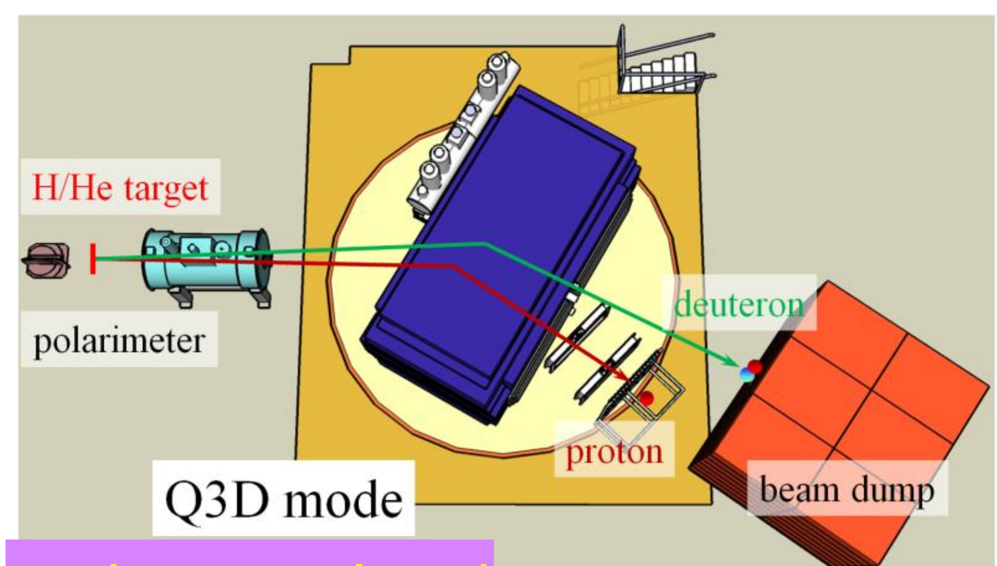
∨ On-Going
On-Preparation
～2014–2015

(©, *p*) reaction,…

Proposal Submitting to
NPPAC on 2014/06



To be completed



To be completed

To be advanced
A>100 region

Budgetary
Strategy Stage

Approved experimental program and Related devices

1) "Ready" programs

- SAMURAI17 M. Sasano/R.G.T. Zegers
  Study of Gamow-Teller and spin-dipole transitions from ^{132}Sn via the (*p*,*n*) reaction at 270 MeV/u
- SAMURAI11 M. Sasano
  Study of Gamow-Teller transitions from ^{48}Cr (and ^{64}Ge) via the (*p*,*n*) reaction at 190 MeV
- SAMURAI14 D. Muecher(W. Henning)
  Fission Barrier Studies of Neutron-Rich Nuclei via the (*p*,*2p*) Reaction
- SAMURAI12 D. Beaumel
  Cluster structure of Beryllium isotopes and study of multi-neutron systems
- SAMURAI13 S. Sakaguchi
  Vector analyzing power measurement for *p*-^{6}He elastic scattering at 200 MeV/A

Done on 2014/03-04

WINDS

Done partly on 2014/03-04

Only test part is ready

Si tele.

pol-p Target

Approved experiments (2013/12) to be performed in near future

2) Programs waiting for "User Devices"

- SAMURAI15/SAMURAI22 W. G. Lynch/T. Murakami/T. Isobe/B. Tsang
  Study of density dependence of the symmetry energy with the measurements of charged pion ratio in heavy RI collisions

SAMURAI TPC

Decay Tagging

- SAMURAI20 C. Caesar(T. Aumann)
  Measurement of the neutron-decay lifetime of the ^{26}O ground state at the SAMURAI setup at RIBF
- SAMURAI21 Y. Kondo
  Spectroscopy of unbound oxygen isotopes II : $^{28}\mathrm{O} \rightarrow 4n$ Detection
- SAMURAI09R1 T. Kobayashi/Y. Togano
  Electric dipole response of neutron-rich Ca isotopes
- SAMURAI18R1 A. Corsi/Y. Kubota
  Two-Neutron Momentum Correlation in Borromean Nuclei

neu-LAND / MINOS

γ-CATANA

MINOS/ recoil p,n detector

3) Programs waiting for "SAMURAI Development"

- SAMURAI14 D. Muecher(W. Henning)
  Fission Barrier Studies of Neutron-Rich Nuclei via the (*p,2p*) Reaction

A~200 Detection @FP

MINOS : Operated at RIBF on 2014 Spring

Submitted program on coming NP-PAC(2014/06)

4) Programs to be approved

SAMURAI TPC

- SAMURAI23 T. Isobe/T. Murakami/W. G. Lynch/B. Tsang
  Study of density dependence of the symmetry energy with the measurements of proton to neutron ratio in heavy RI collisions

SAMURAI 90Deg.

γ-CATANA

- SAMURAI24 V. Panin(RNC)
  Investigation of proton-unbound states in neutron-deficient isotopes ^{66}Se and ^{58}Zn
- SAMURAI26 N. Iwasa(Tohoku)
  Study of resonance states in ^{34}Ca using neutron removal reactions of ^{35,36}Ca
- SAMURAI25 Z. Elekes(ATOMKI)
  Study of nuclear reactions relevant for type I X-ray bursts

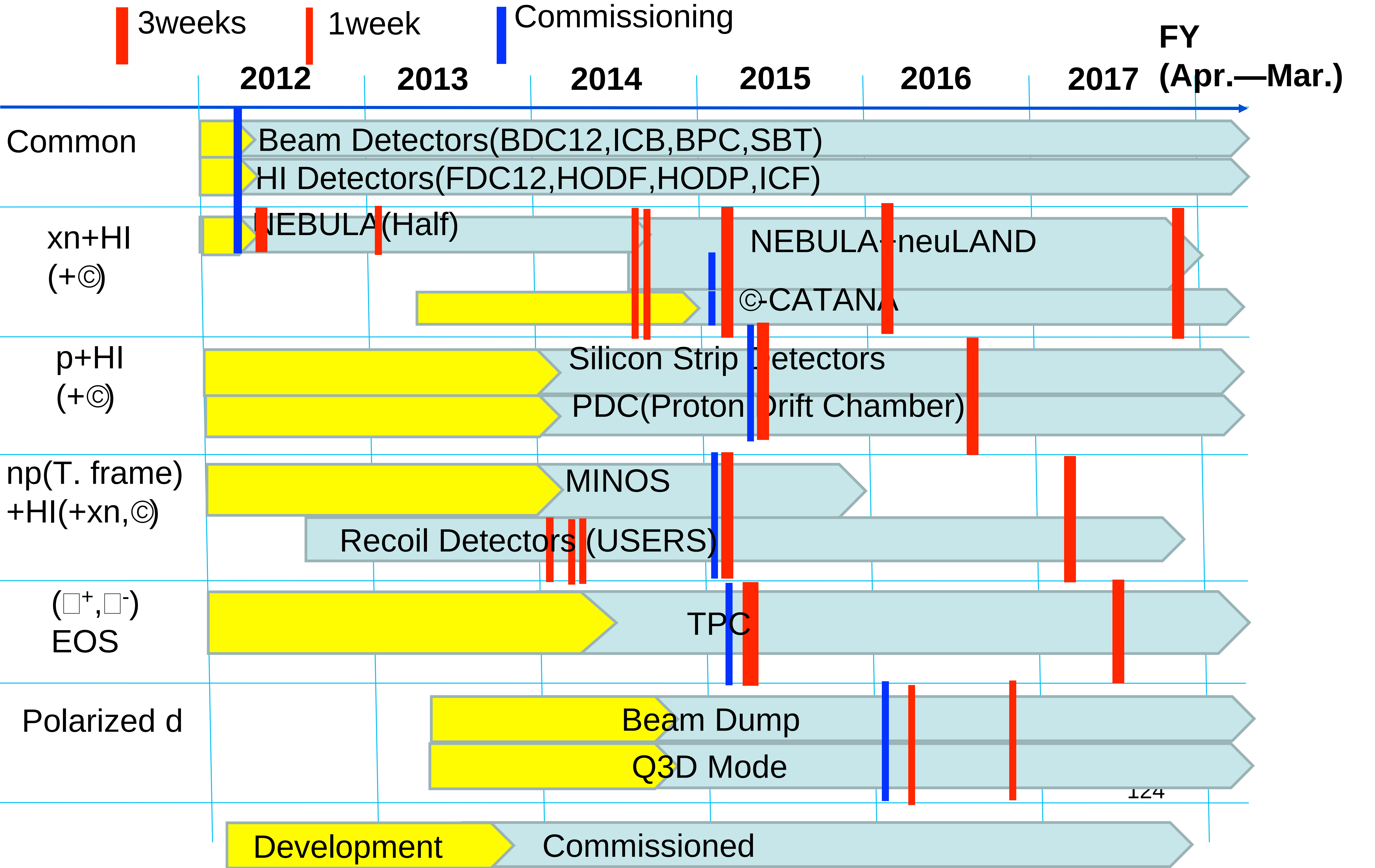
- SAMURAI27 N. Kobayashi (UT)
  Spectroscopy of Odd-A Nuclei in the Island of Inversion ; ^{31}Ne, ^{37}Mg

- SAMURAI19R1 S. Paschalls (TU Darmstadt)
  Investigation of the 4n system at SAMURAI
  by measuring p,pα quasi-free scattering at large momentum transfer in complete kinematics

Beam-Time Schedule

~ Discussed in Collaboration meeting, 2013/09
+ revised on 2014/02

Demands: 5-12 Weeks/year
TPC,*p*-detector,MINOS,γ-CATANA
to be commissioned in 2014-15

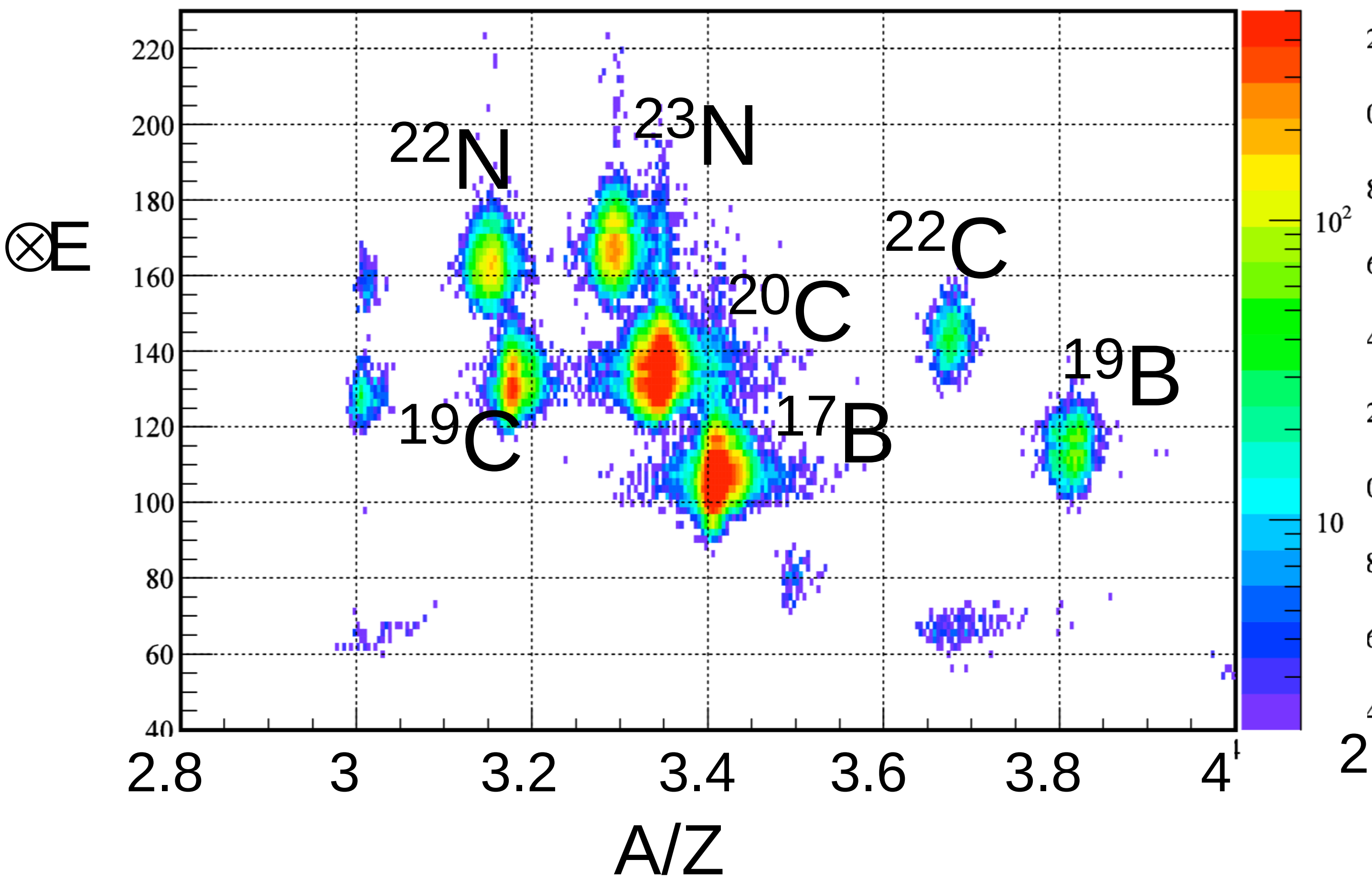


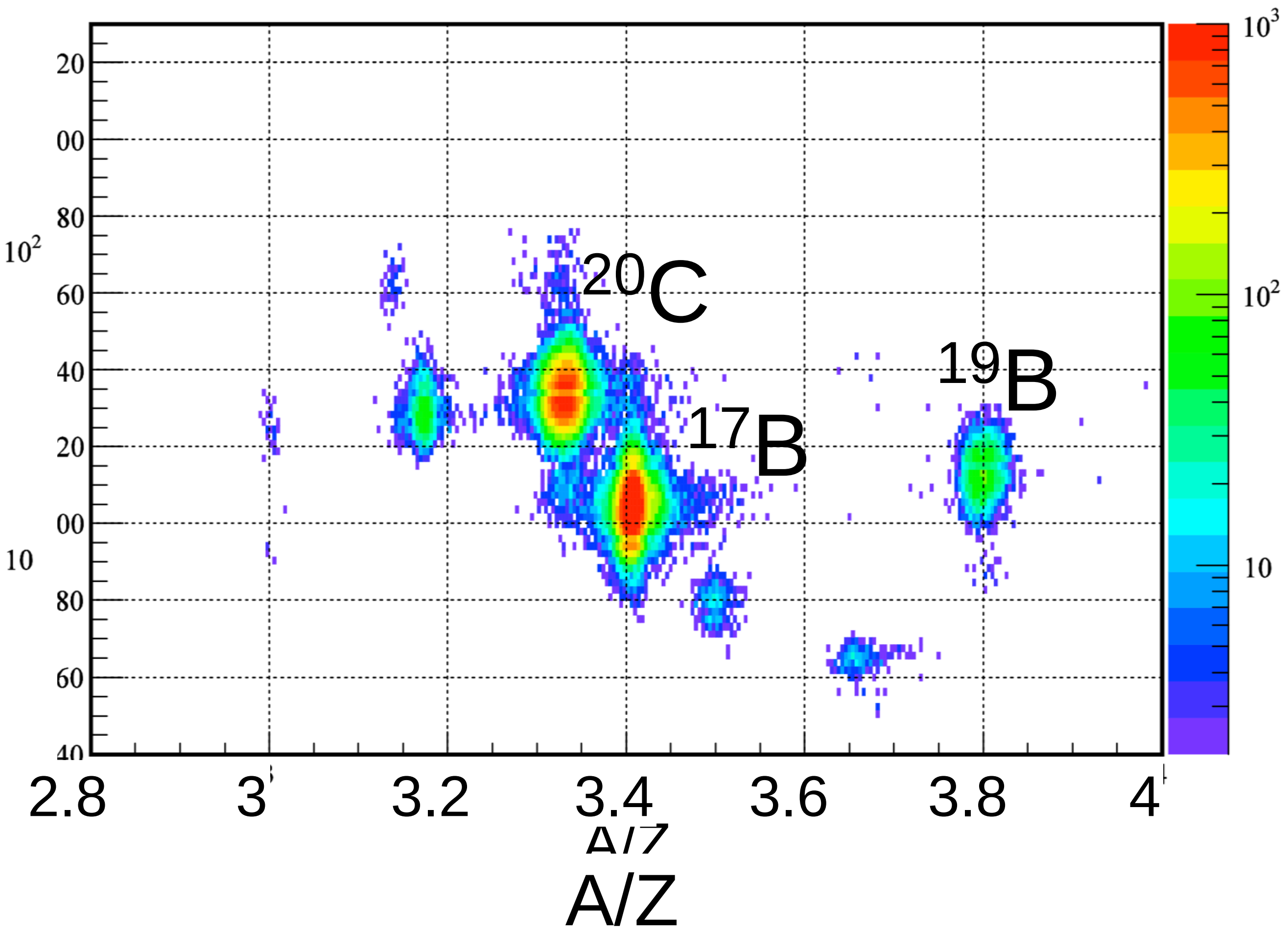
RI Beam Spectra @ SAMURAI May/2012

^{48}Ca 150~200pnA (Max 250pnA)

Tuned for **^{22}C**
(^{22}C+Pb/C→^{20}C+n+n)
^{22}C ~15 /s
^{23}N ~100 /s

Tuned for **^{19}B**
(^{19}B+Pb/C→^{17}B+n+n)
^{19}B ~100 /s
^{17}B ~1000 /s





High intense RIBF Beam

^{22}C: **~15/s** (*c.f. 10/hour K.Tanaka,PRL2010, RIPS@RIKEN)*

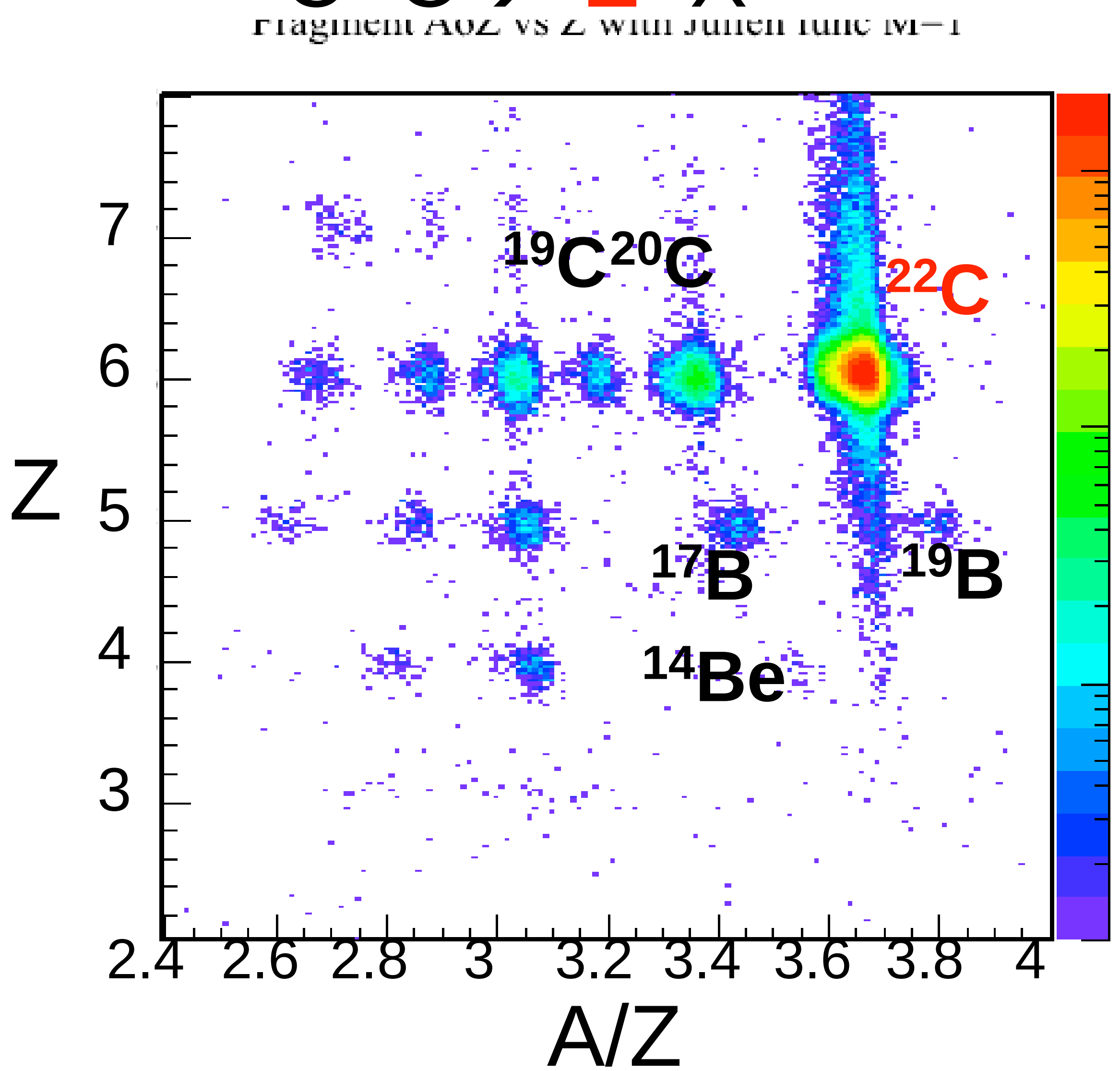
Gain of ~5000!

Results on Inclusive Data

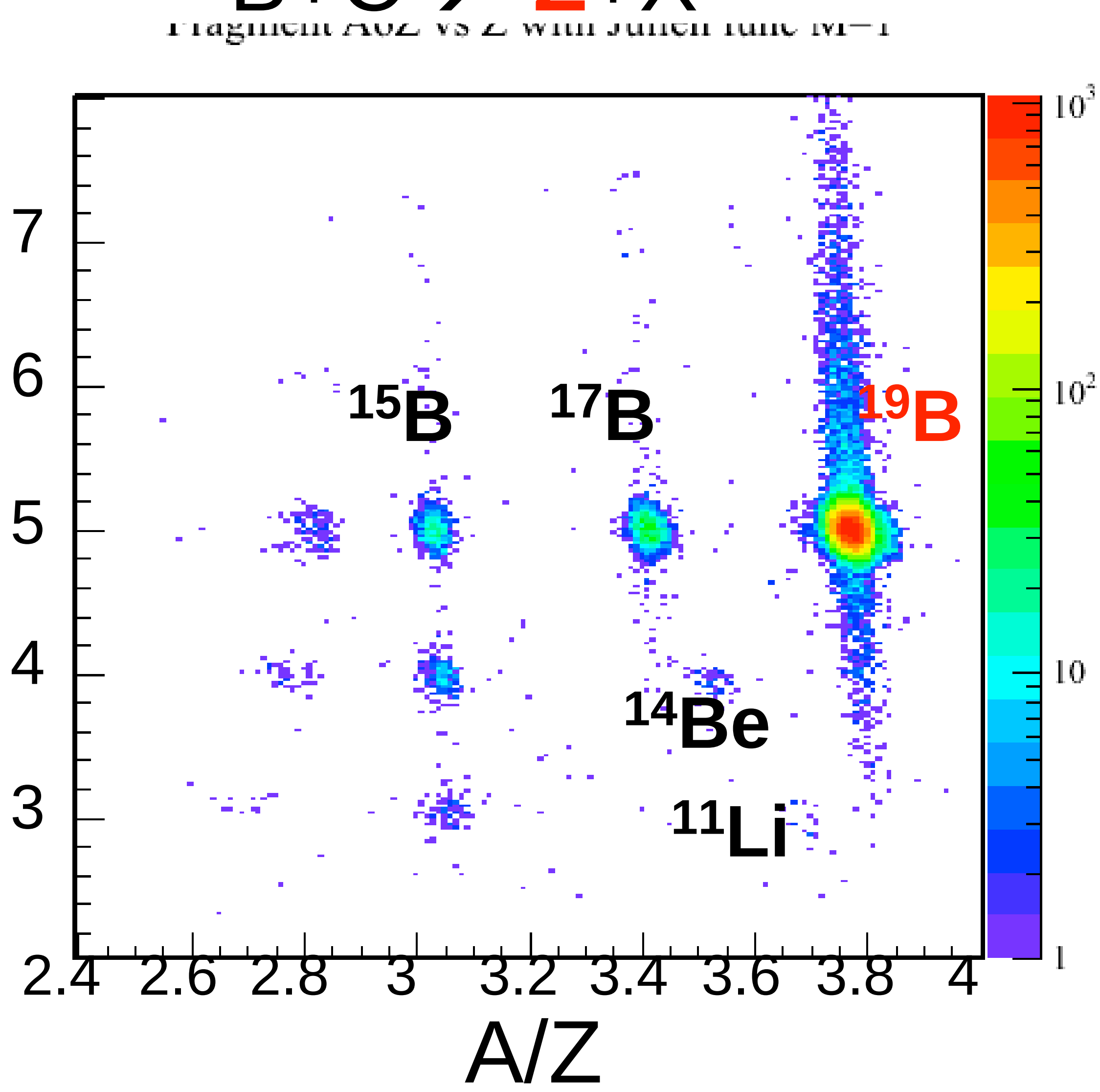
PID of Downstream Detectors at SAMURAI

By S.Ogoshi
Beam Trigger

$^{22}C+C \rightarrow {}^{A}Z+X$

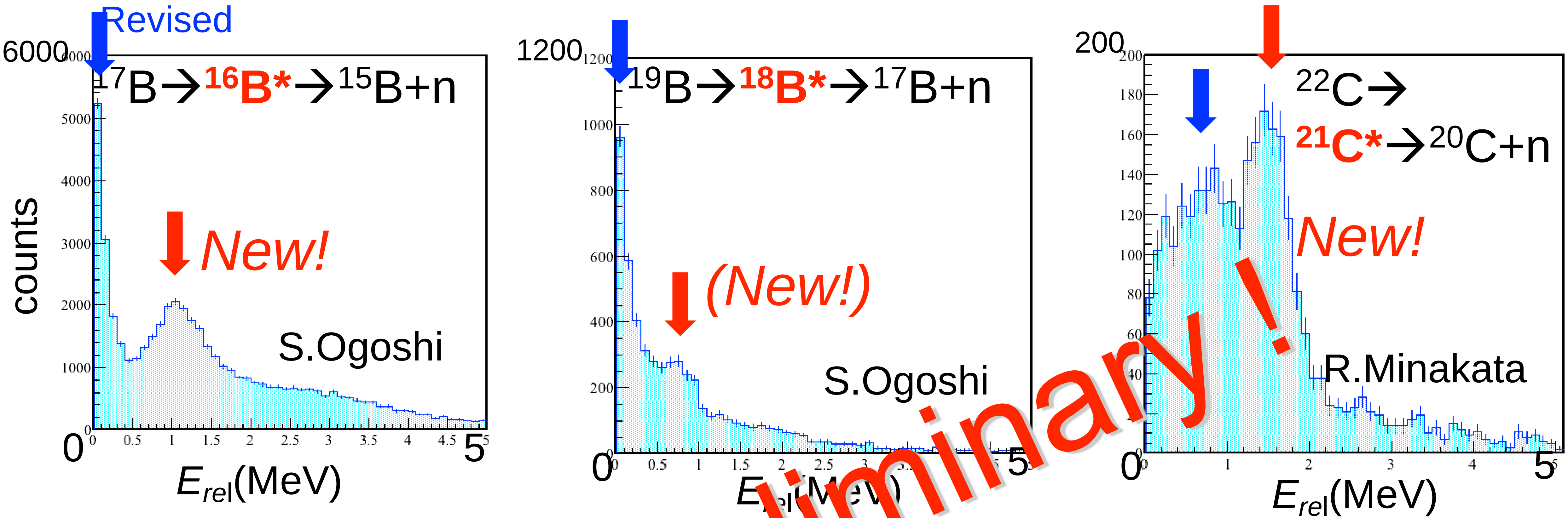


$^{19}B+C \rightarrow {}^{A}Z+X$



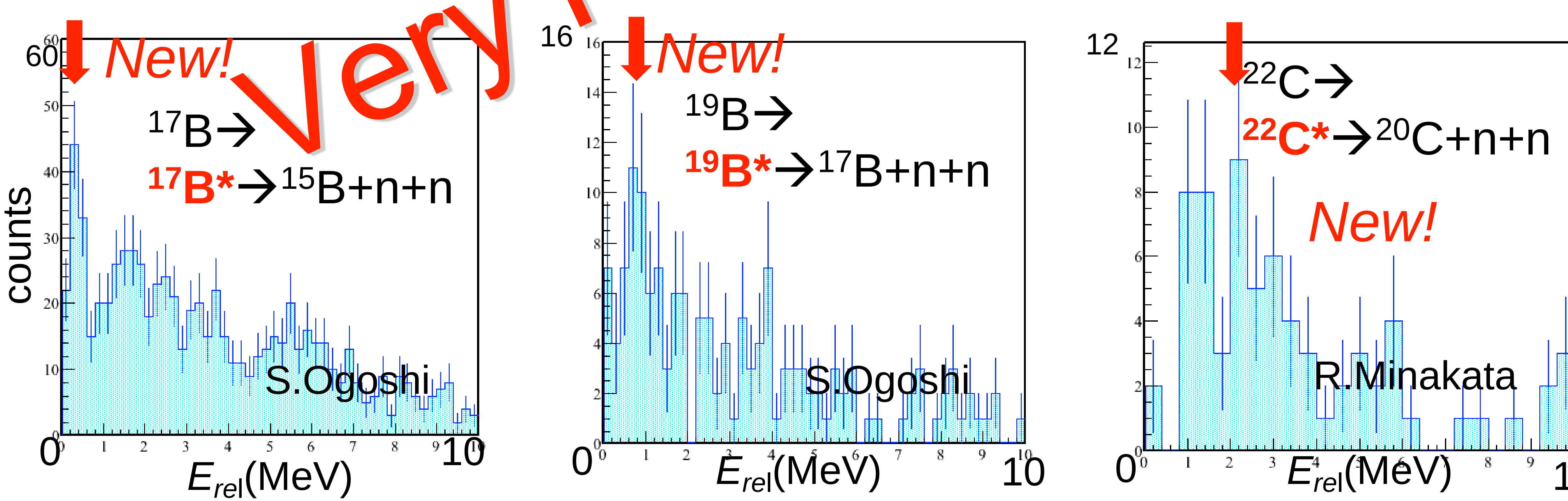
Clear Separation of Mass and Charge
Reaction Cross Sections → Matter Radii of Halo Nuclei ^{22}C and ^{19}B (Niigata/TUS)
Inclusive –xn cross sections → Reaction Theory, Shell Structure

Spectrum of (Heavy Ion) + 1 neutron for $^{A}Z + C \rightarrow {}^{A-1}Z \rightarrow {}^{A-2}Z + n$



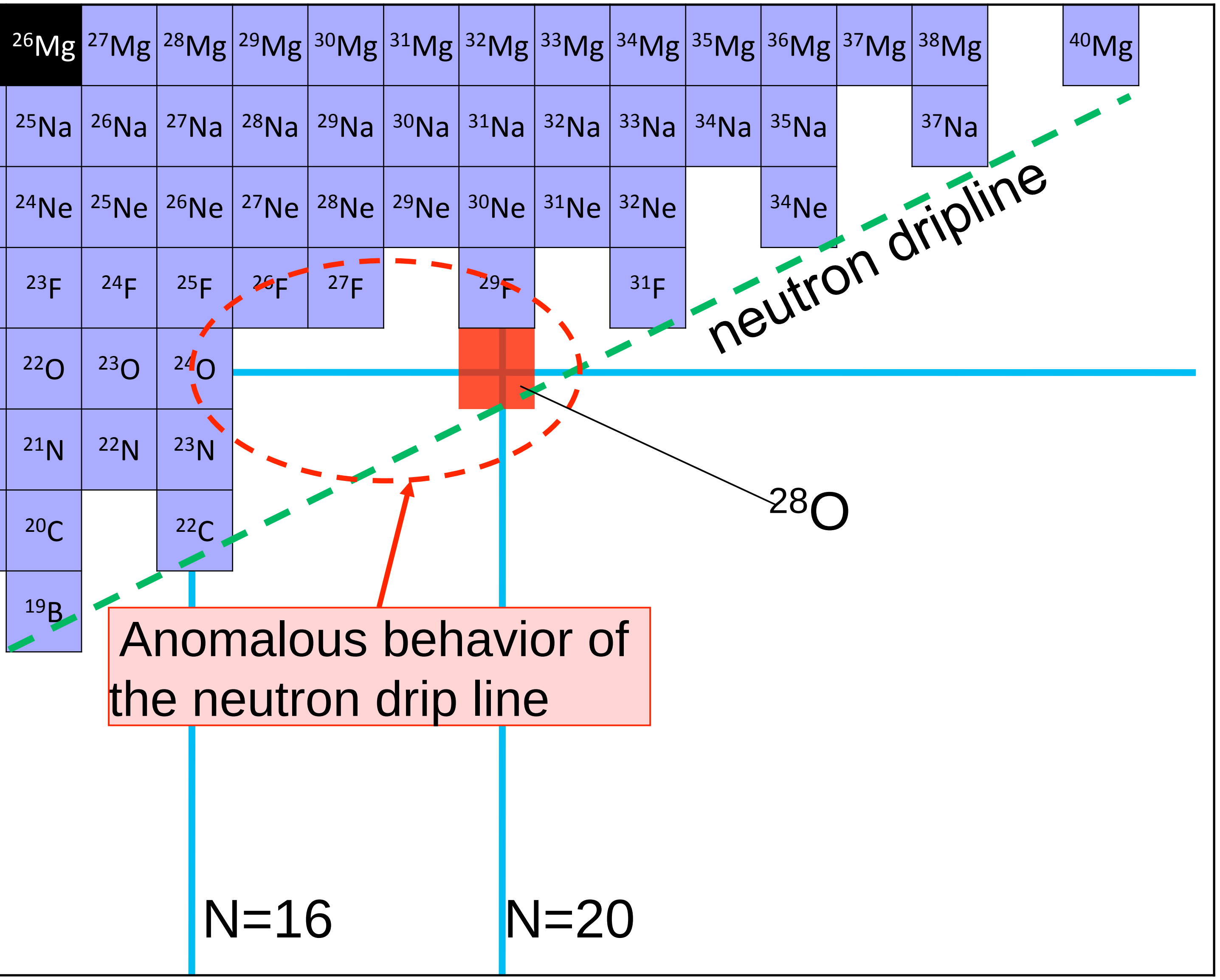
Spectrum of (Heavy Ion) + 2 neutron for $^{A}Z + C \rightarrow {}^{A}Z^* \rightarrow {}^{A-2}Z + n + n$

~40% statistics

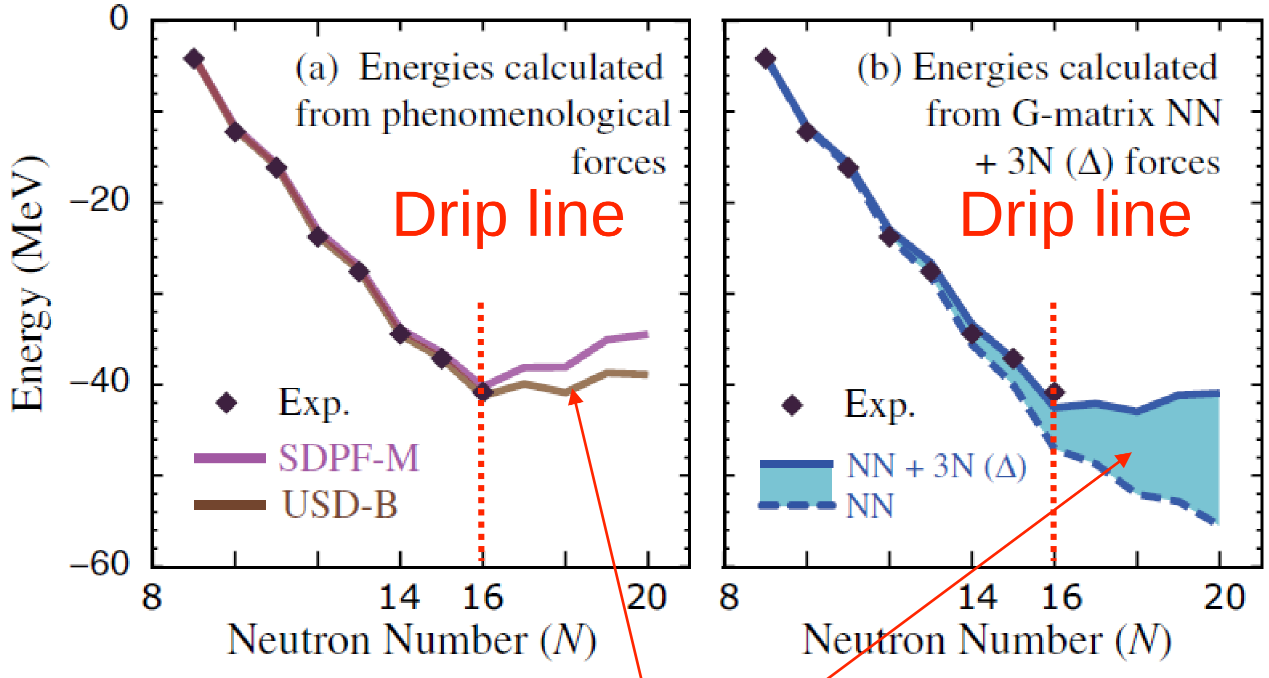


Study of unbound nuclei ^{25}O and ^{26}O

Spokesperson Yosuke Kondo



T. Otsuka et al., PRL105, 032501 (2010)



The effect is large at N>16

Experimental study of unbound oxygen isotopes toward ^{28}O

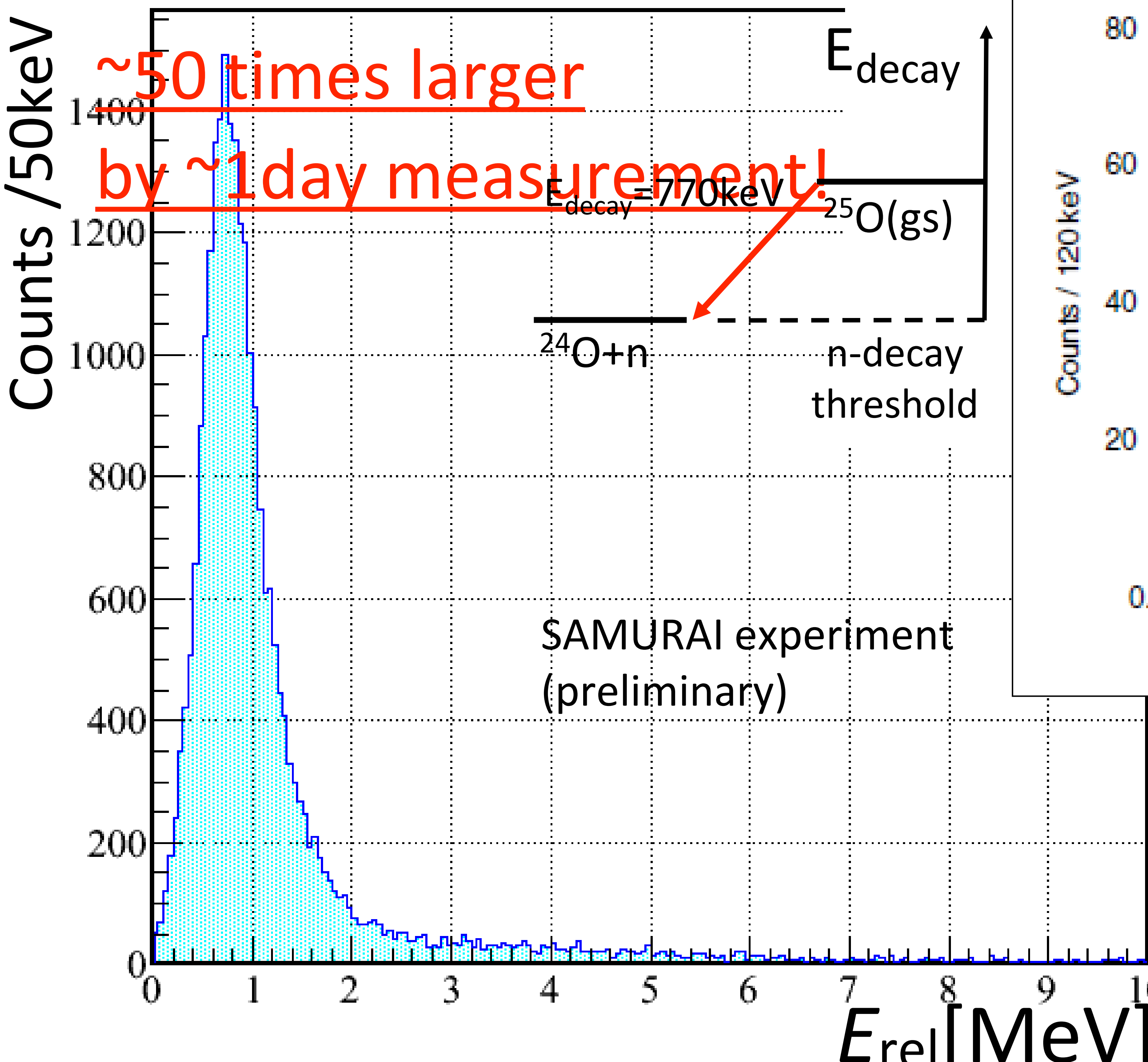
- ^{25}O and ^{26}O measurement as a 1st step
- ^{26}O 2n radioactivity ($t_{1/2}$~4.5(3) ps? Kohley PRL 2013)

Decay energy spectrum: $^{24}O+n$

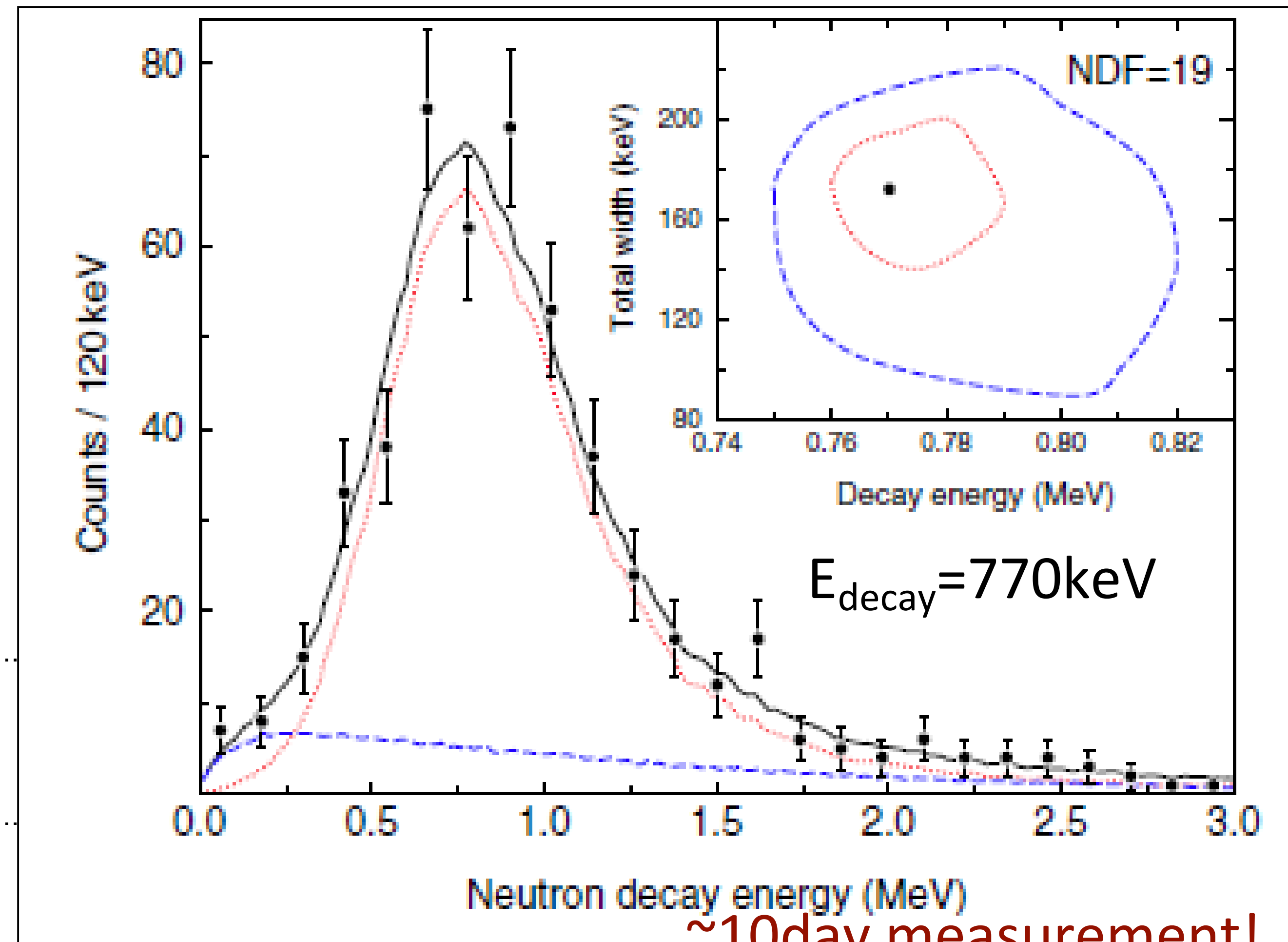
$^{26}F+C \rightarrow {}^{24}O+n$

Statistics

~50 times larger
by ~1day measurement!

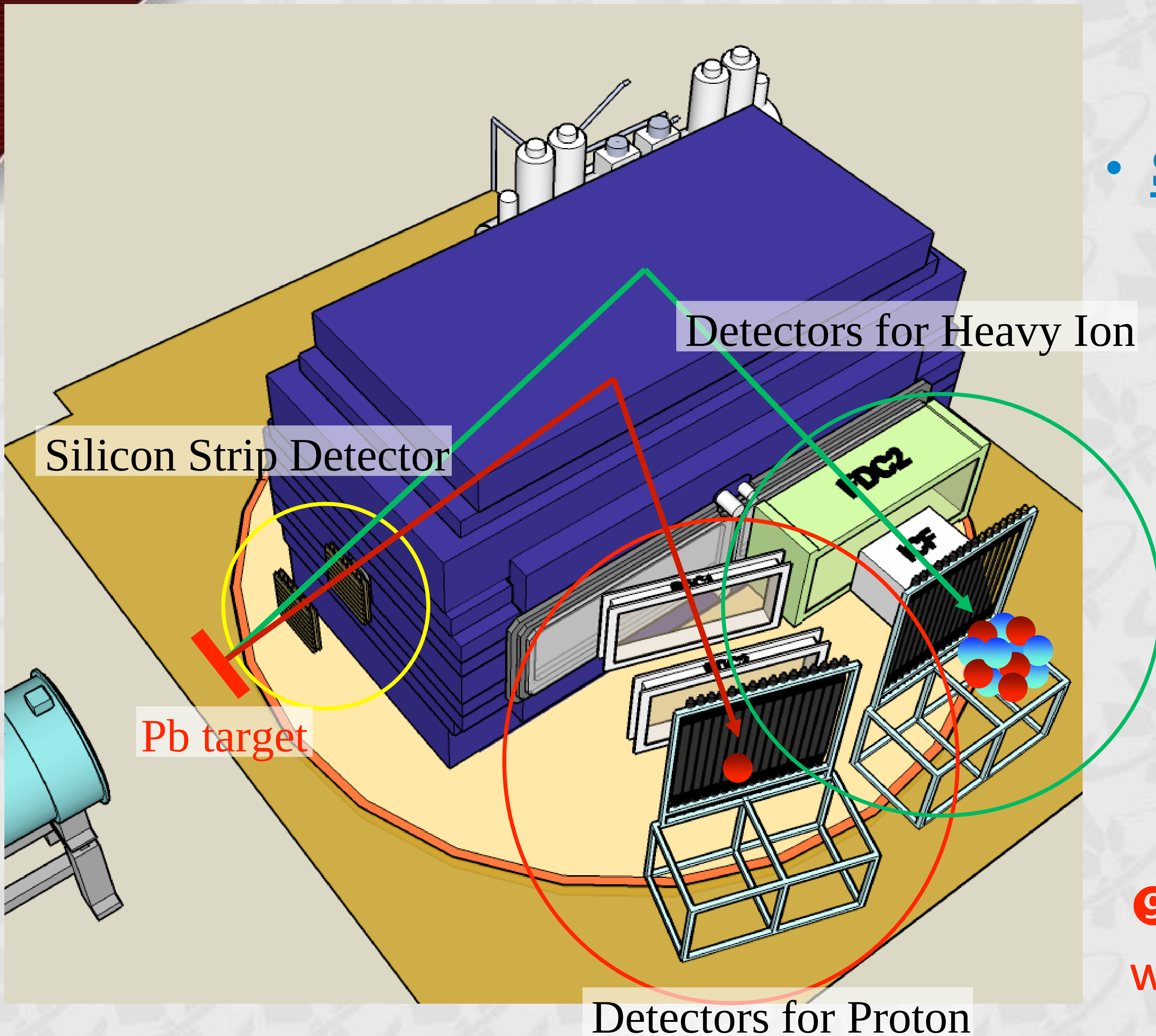


C.R.Hoffman et al.,
PRL100, 152502 (2008)



~10day measurement!

Detector System – HI-proton coincidence



- **Detectors for Proton**
  - Proton Drift Chamber
  - Plastic Hodoscope

Detectors constructed in FY2011.

- **Silicon Strip Detector**
  - Broad dynamic range

    Both proton & heavy ion (Z < 50) hit the detector
  - Capability of high density signal processing

    Signals > 1000ch in total

    Modify integrated ASD circuit HINP16C in collaboration with Texas A&M and Washington Univ.
    HINP16C --- 16ch processing in 1 chip
    two output for energy and timing

❾To be realized in collaboration with US group (TWL collaboration)

SAMURAI TPC status

Assembly completed May 2013

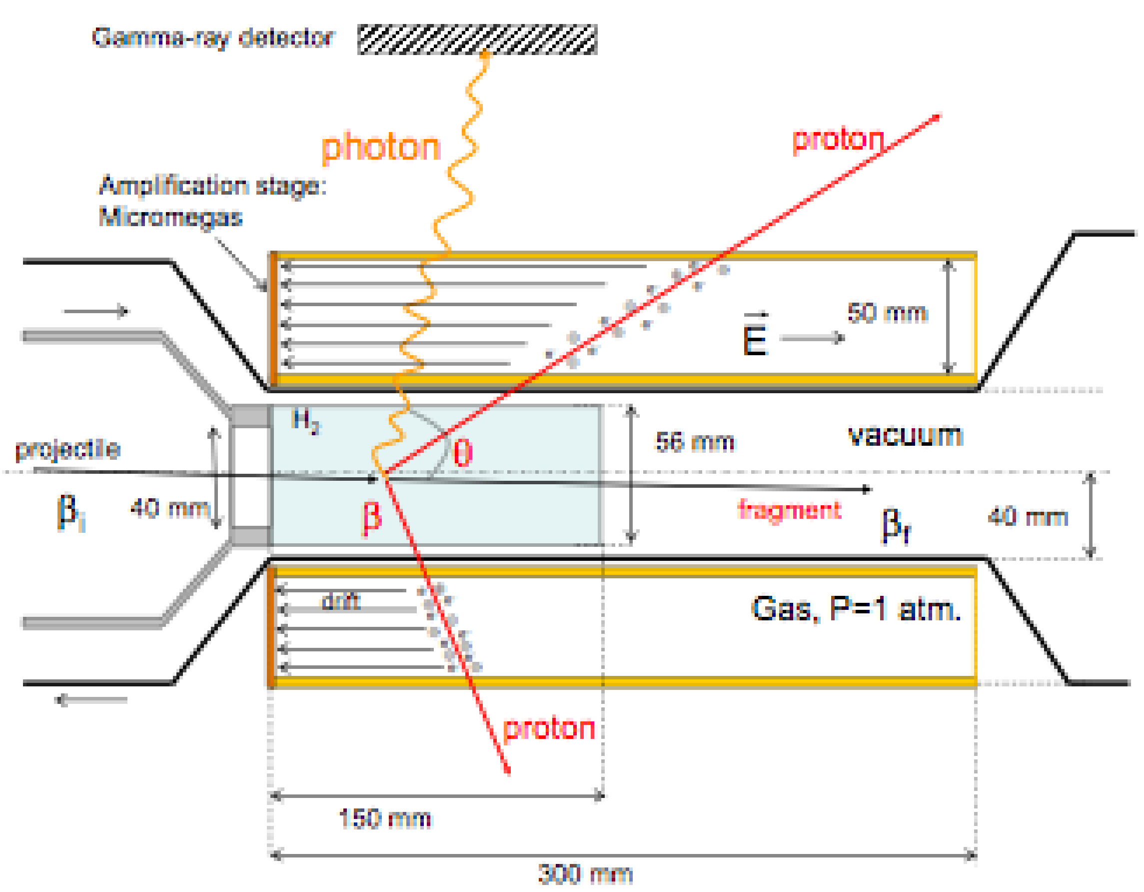
Pad plane readout tested with pulsers.
Testing with cosmic rays and sources are on going.
Experiments will use GET (Generic Electronics for TPC's) readout electronics.
Testing with gating grid driver is on going.
TPC will be shipped to RIKEN at February 2014.

2013/9/12

Neutron Star Matter "Koubo Kenkyu"

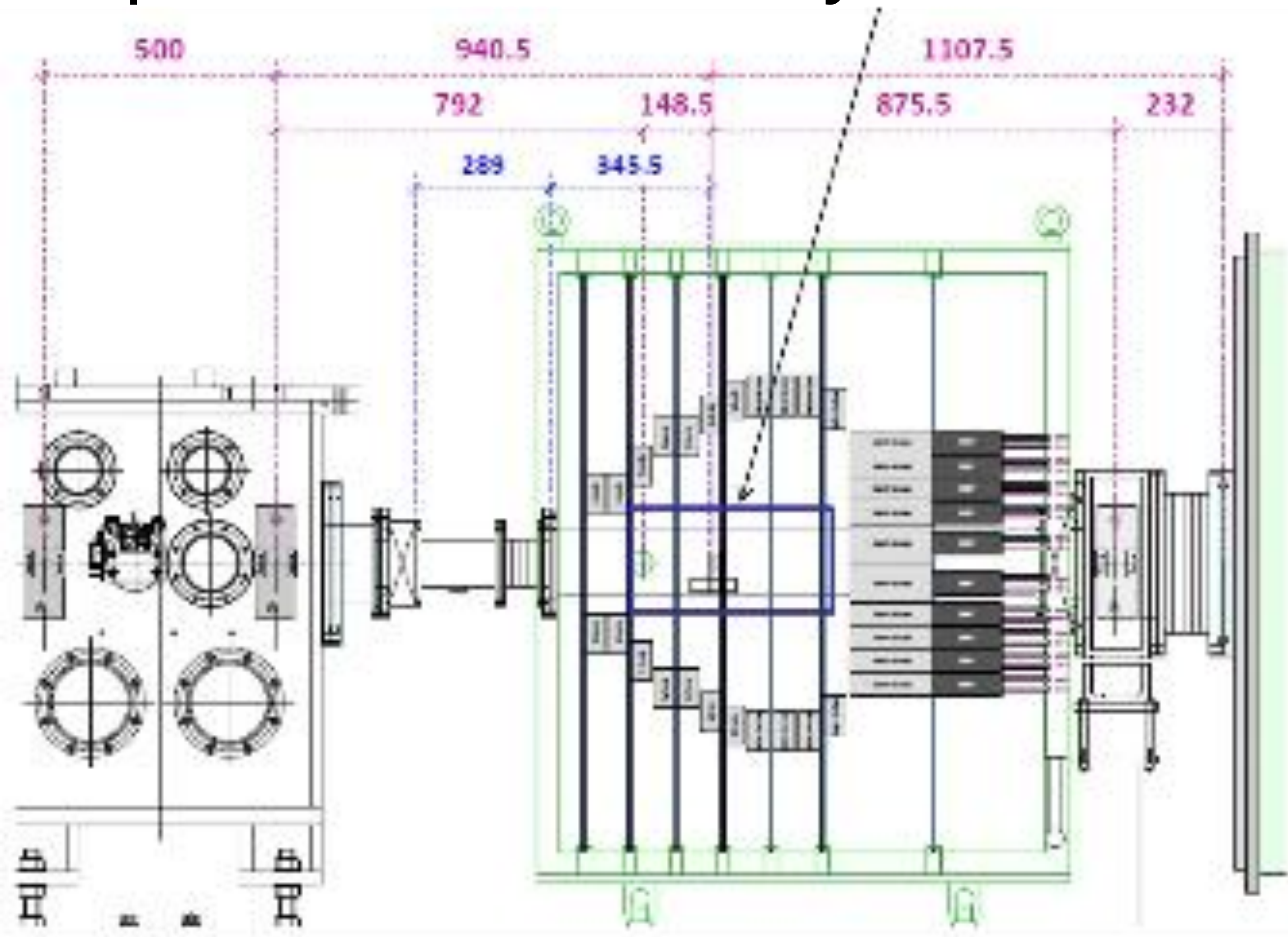
MINOS : Thick H_2 target coupled with γ spectrometer DALI2

MINOS : Thick H_2 Target cylindrically surrounded by TPC recoil tracker



Restoration of reaction Z position from vertex on the tracker
→ Doppler correction

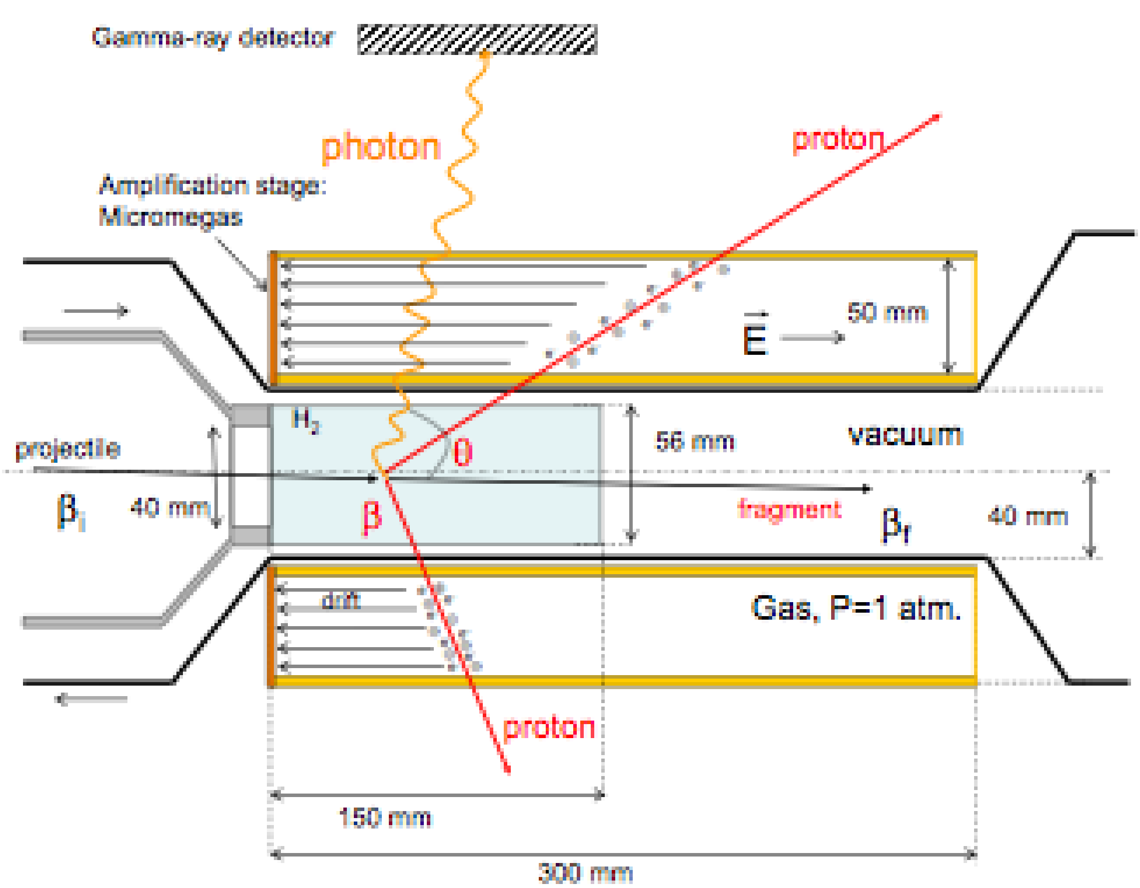
In beam γ spectroscopy induced by the (*p*,2*p*) reaction on far *n*-rich nuclei
coupled with DALI2 array



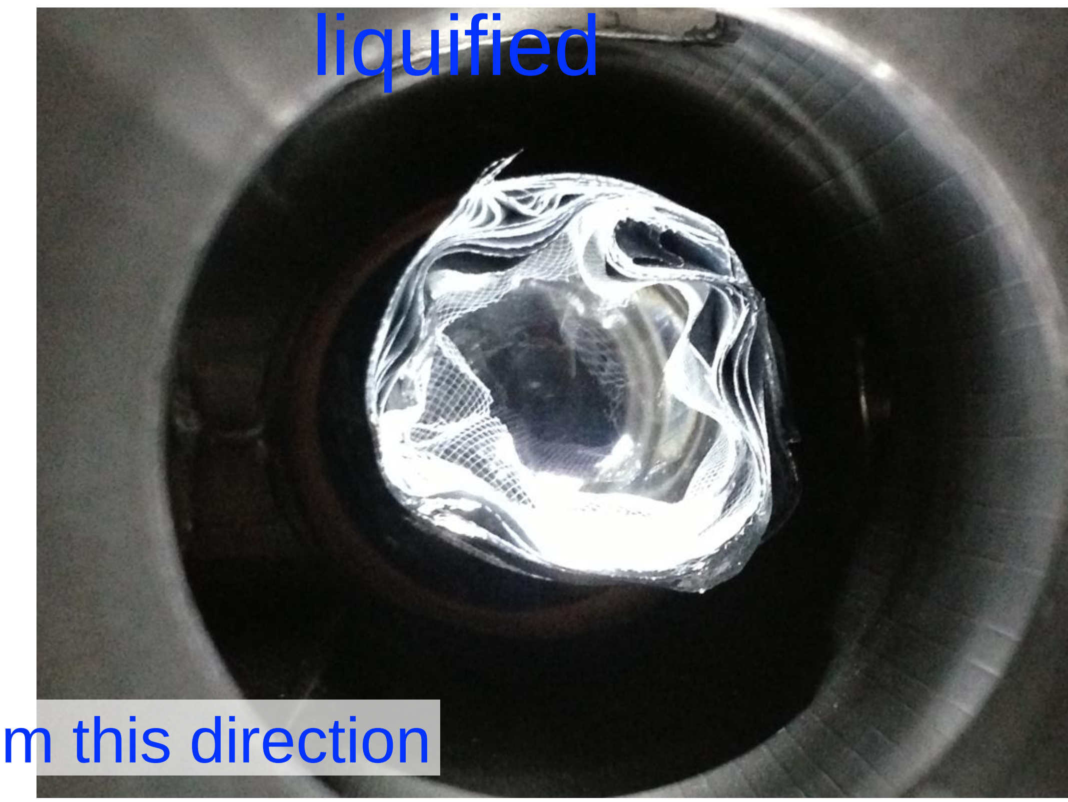
MINOS : Thick H_2 target coupled with γ spectrometer DALI2

MINOS : Thick H_2 Target cylindrically surrounded by TPC recoil tracker

Cooling test on 2013/06 by engineers from Saclay: Successfully liquified



Viewed from this direction



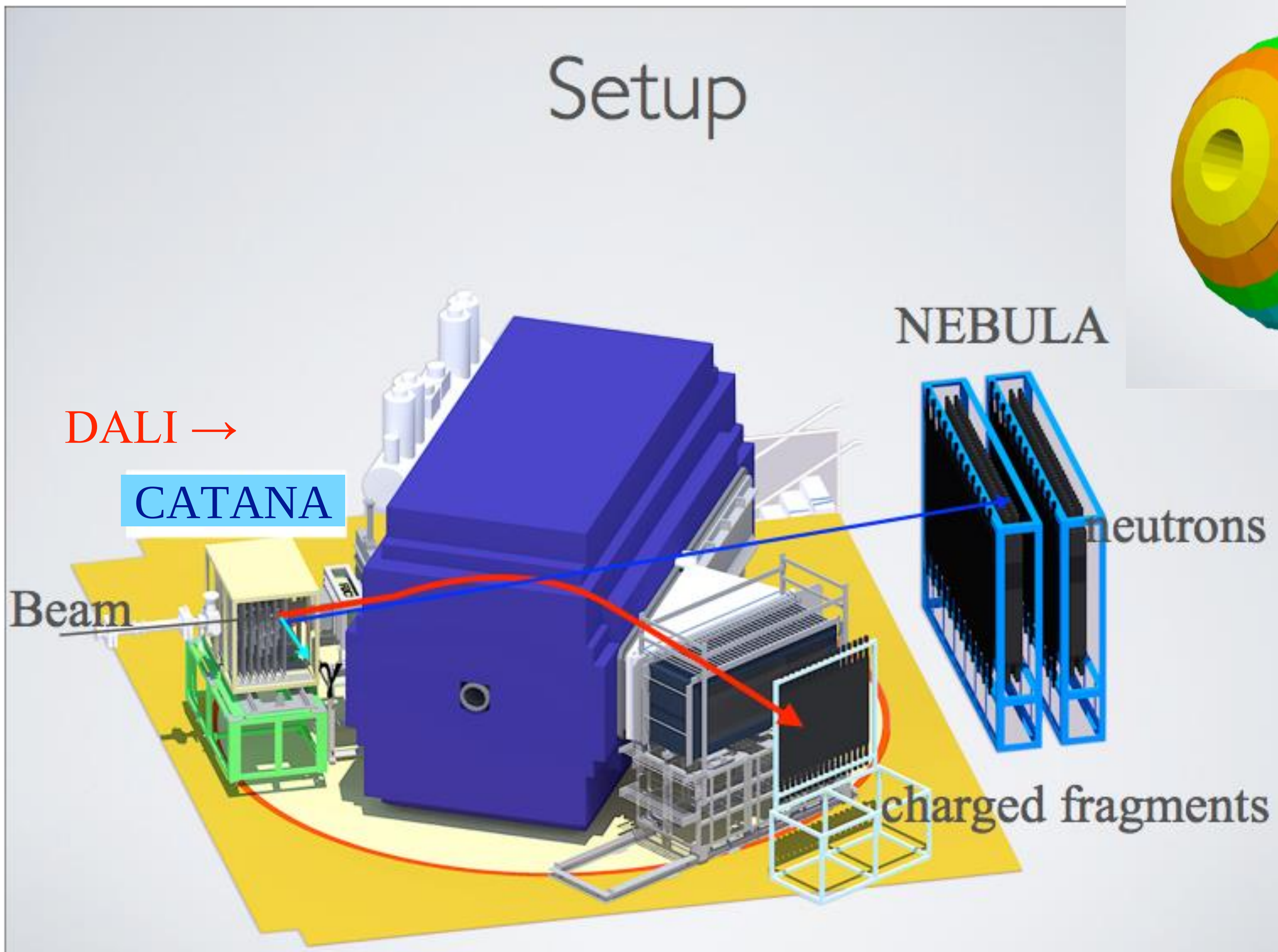
TPC tracker will be commissioned on Oct. 2013 at HIMAC facility

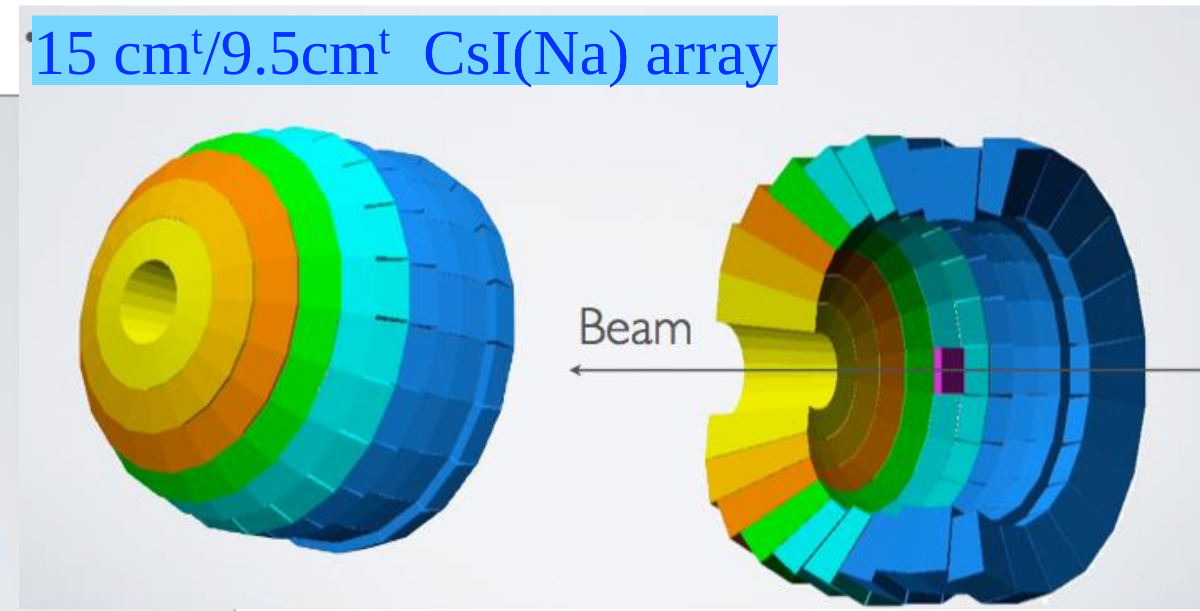
In beam γ spectroscopy: ^{53,55,56}Ca approved , ^{53}K, ^{50,52}Ar will be re-proposed.

CATANA

CAlorimetric deTector for rAdiation from exotic Nuclear beAms

- Study for E1 responses on medium heavy (n-rich) nuclei
  → high multiplicity γ detection from residual nuclei





ε_γ(1MeV) : 25%(DALI)
→ 65%(CATANA)

Ready on 2015

Difficulties (for me)

me := in-house staff in RIKEN
in this slide

- User's instruments
  - Well constructed

- SAMURAI standard detector/setup
  - n-HI setup : completed
    - Confirmed and Evaluated by Comm. RUN/ Day-1,2 experiments
  - Other versatile setups : continue to do work for achieve "Final" setup

- Separately OK

- Merging : protocols are not always well assessed.
  - Please come to SAMURAI experimental area/site as much as possible

Summary

- SAMURAI experiments:
  - Amount of programs were approved and waiting for MT assignment
  - Note that SAMURAI21(^{28}O) has Grade S.

- For MT assignment for series of 2 or 3 TPC experiments

  - Scope : FY2015 Autumn (?) Spring (?)

➡ Well organized preparation for experiment
→ Priority / Order / Strategy ... are needed

→ toward?
O SAMURAI collaboration
o Possible competitors
. MT committee

SAMURAI
International Collaboration Workshop 2014

- September 8(Mon.) - 9(Tue.)
- Tohoku Univ. (Sendai)
  - http://lambda.phys.tohoku.ac.jp/~sm-icw14
  - Abstract deadline : 17-Aug.
  - IMPORTANT : Let us join to "Get-together party" on 8-Sep., evening.

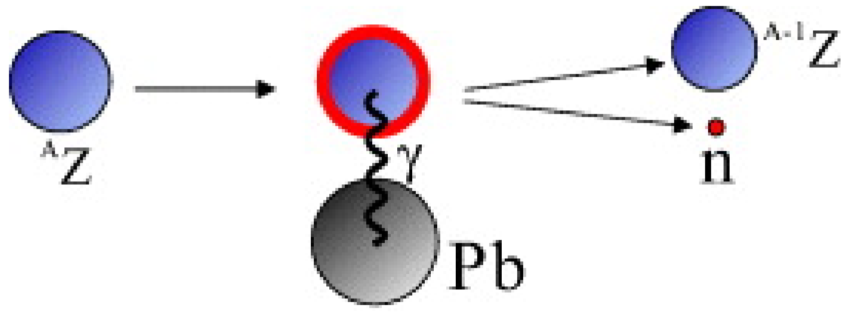
- Communication / Negotiation / Understanding with "Possible Competitors" are strongly recommended:
  - ^{28}O experiment group
  - HI-p experiment group if approved sizably in this coming PAC
  - ...

Day-One Experiments

Primary Beam: ^{48}Ca: 345 MeV/ nucleon: 150(-200) pnA

May 5 – 28, 2012

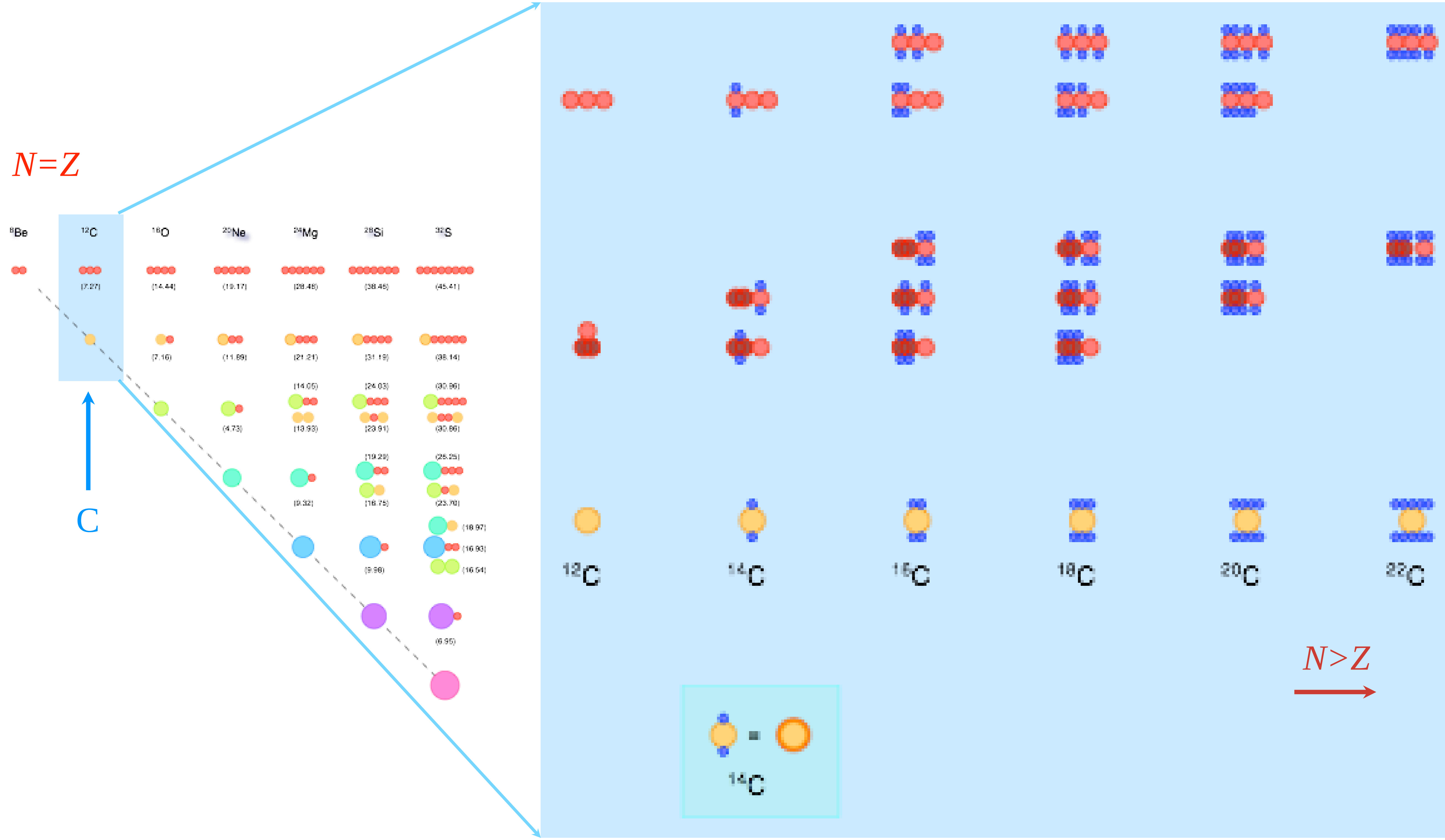
- **"Spectroscopy of unbound oxygen isotopes"**
  - Spokesperson: Yosuke Kondo (Tokyo Tech)
  - Observation of unbound oxygen isotopes
- **"Exclusive Coulomb Breakup of neutron drip-line Nuclei"**
  - Spokesperson: Takashi Nakamura (Tokyo Tech)
  - Coulomb breakup of neutron-rich boron and carbon isotopes
- **"Structure of ^{18,19}B and ^{21,22}C"**
  - Spokesperson: Nigel Orr/Julien Gibelin (LPC-Caen)
  - Observation of unbound states in neutron-rich boron and carbon isotopes



Campaign type experiments
by n-HI coincidence measurement

C diagram

•

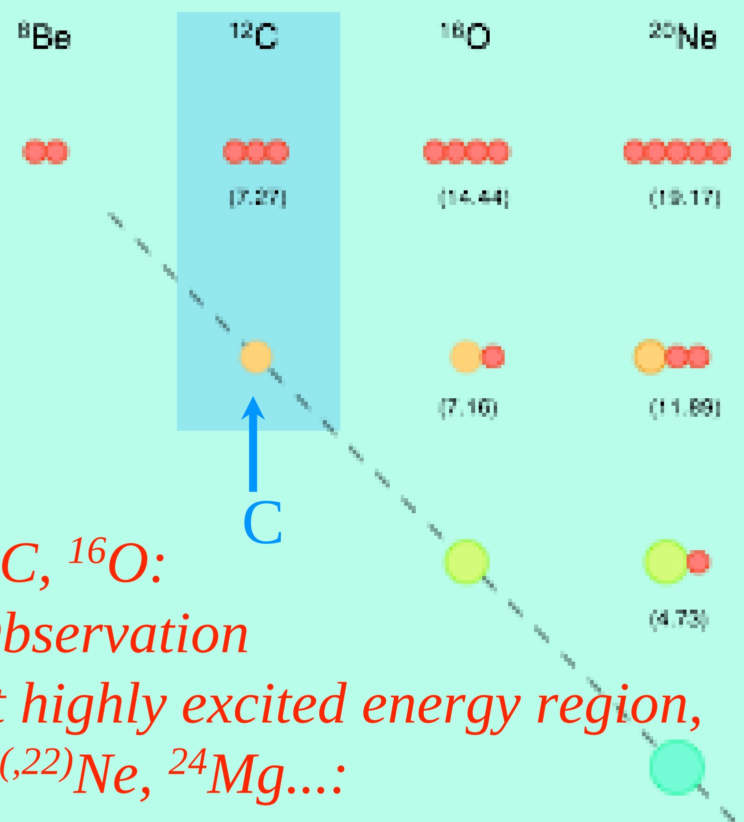

N=Z
8Be
12C
16O
20Ne
24Mg
28Si
32S
C
12C
14C
16C
18C
20C
22C
14C
N>Z

Hideaki Otsu, SAMURAI Collaboration

Exploration of cluster states on neutron rich isotopes by means of broadband magnetic spectrometer SAMURAI

Typical Cluster structure
→Appear as loosely bound system on nuclear system

4N system : on Threshold region

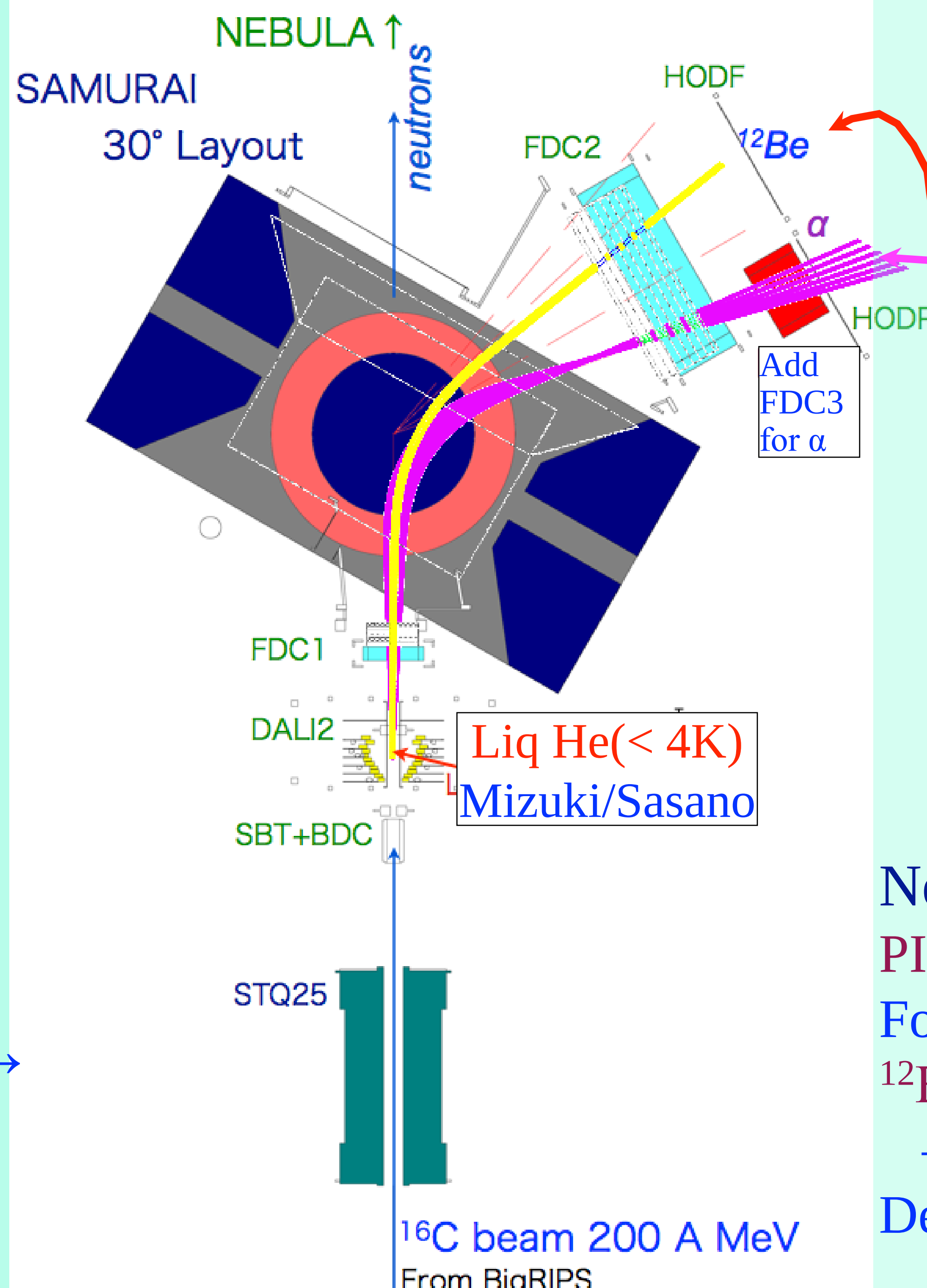


^{12}C, ^{16}O: Observation at highly excited energy region,
$^{20(,22)}$Ne, ^{24}Mg...: Spectroscopy studies

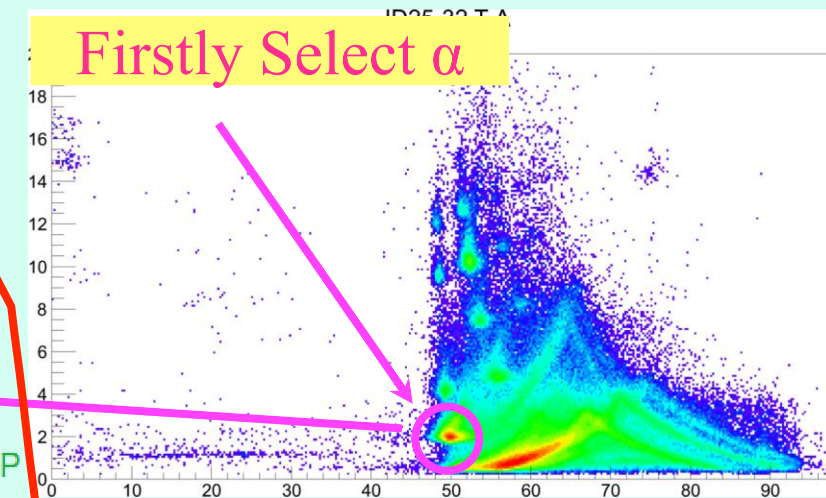
↓

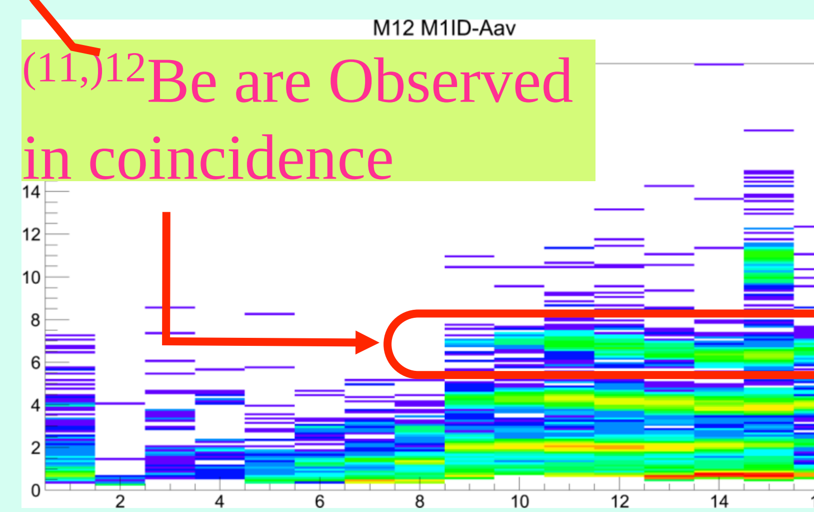
Cluster structure on *n*-rich system ?→
Beyond the Ikeda diagram
toward isospin axis :
→ ^{16}C

Large δp acceptance emables us :
→Coincidence measurement of reaction residues : ^{12}Be and α
(and also n and γ)



(Online) results:





Nextstep:
PID on Z=4
Four Momentum Analysis of ^{12}Be and α
→ Excitation energy spectra,
Decay channels

Procedure to perform Experiments at RIBF

http://www.nishina.riken.jp/RIBF/

- Approved programs
  for TPC experiments
  - SAMURAI15/22 (Approved)
  - SAMURAI23 (Submitted)

- Machine time assignment
  - by MT committee
  - How? When?
    - ○ Maximize Physics output
    - ○ Approved Grade : S >> A >>>>> A/B,B
    - ○ Optimize (Primary) beam usage
      - efficiency by campaign
    - Readiness
    - Publication from previous experiments

June/Dec.
on every FY
1 month
July/Jan.
on every FY
Approved:

Annual Operation Cycle of RIBF accelerator/SAMURAI

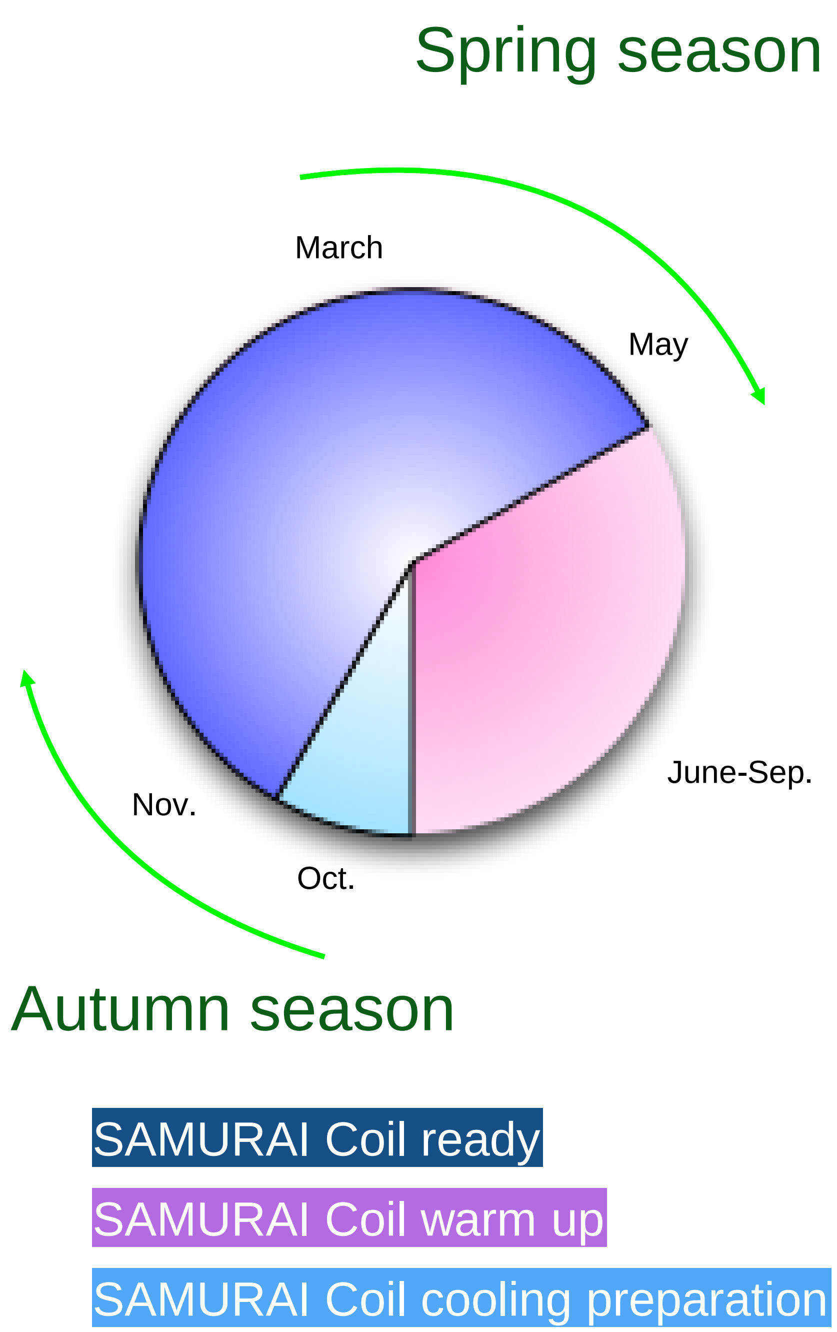
- RIBF FY2011-14 : 5 month operation
  - Spring : March-June (3-3.5 month)
  - Autumn : Oct. - Dec. (1.5-2 month)

- 2(or 3) primary beams in one season
  - U, ^{70}Zn, light ions(d,^{16}O) in this season

- SAMURAI :
  - 1 (or 2) setups at most / one season

  - 1 week exchange at target region configuration → Impossible!!!
  - SAMURAI-TPC
    → Possibly occupy one season
    ※ Depending on test operation this summer

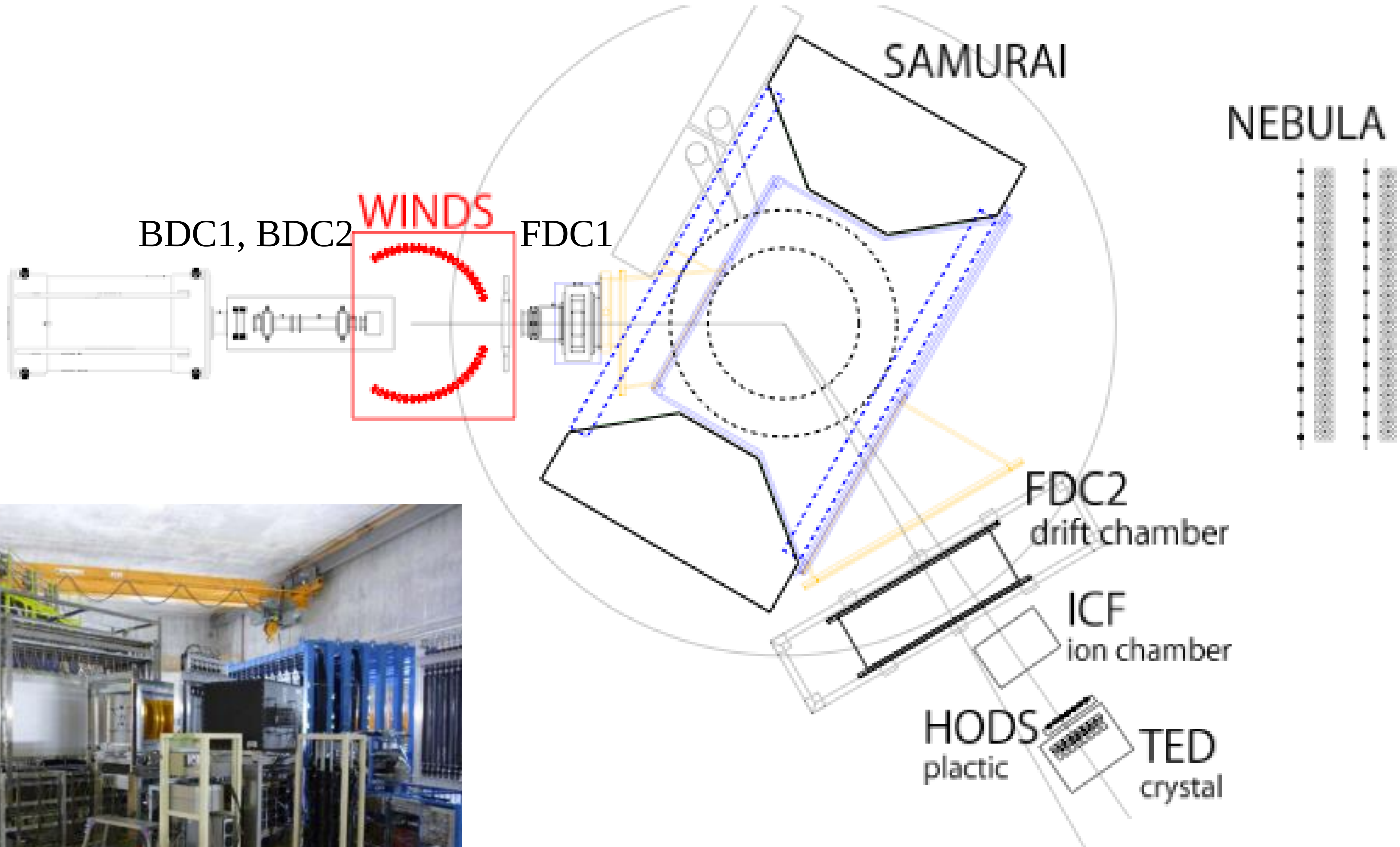
  - Collaboration based operation



※Warm up to reduce maintenance fee by half

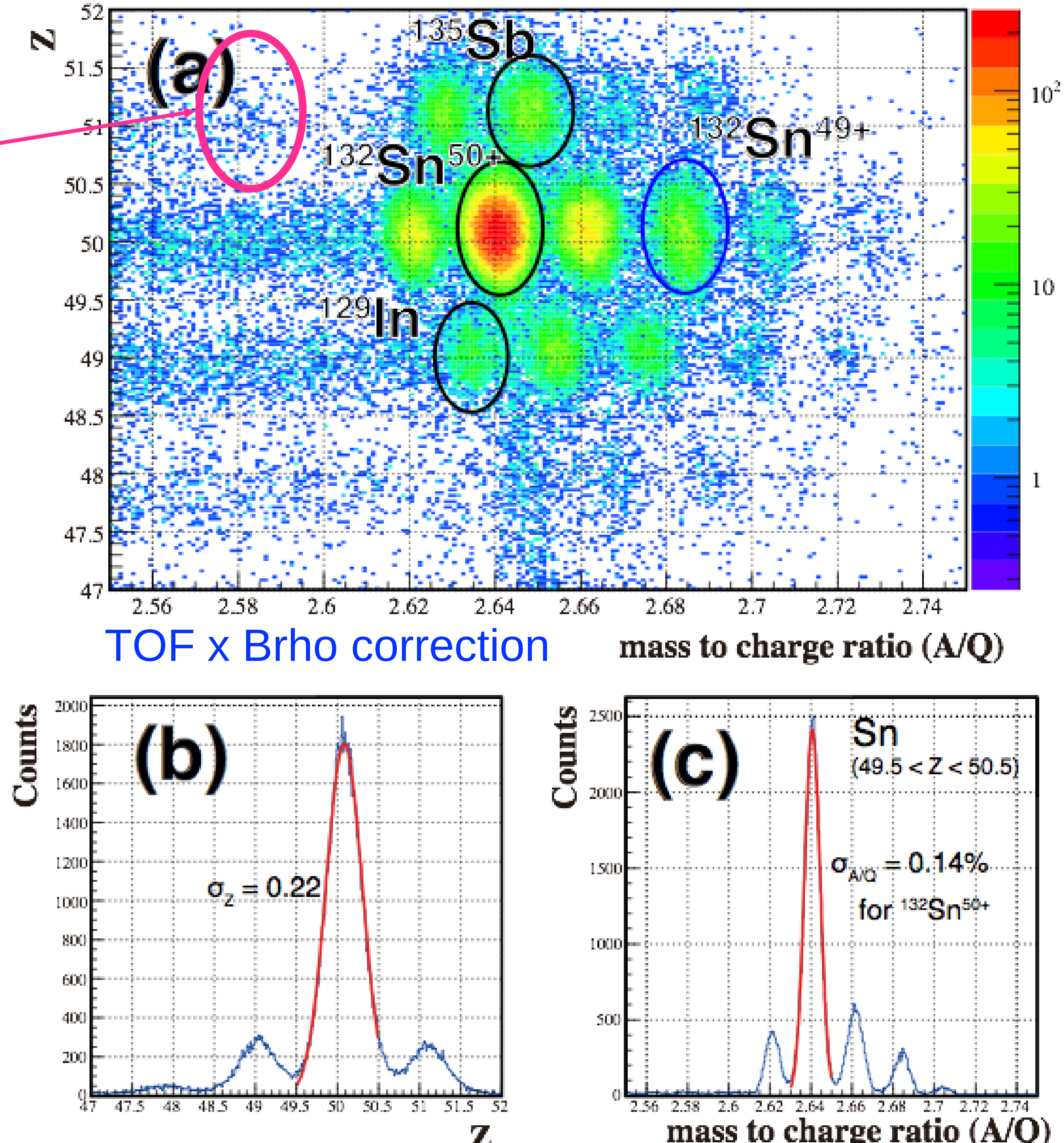
TED @SAMURAI17 exp.

- p(^{132}Sn,n) exp. April-2014



SAMURAI17
particle ID @ SAMURAI FP

$^{132}Sb^{50+}$ ROI



TOF x Brho correction

Plastic w/ position dependence correction

- TKE detector response for distinguish charge states.
- In near future.

test page

説明：Helvetica Neue ライトを使ってみる。

1) 数式のフォントの選定 -> CMU Classical Serif

sin(x)+cos(x)=

σ(x)= 0.25

dσ/dΩ=