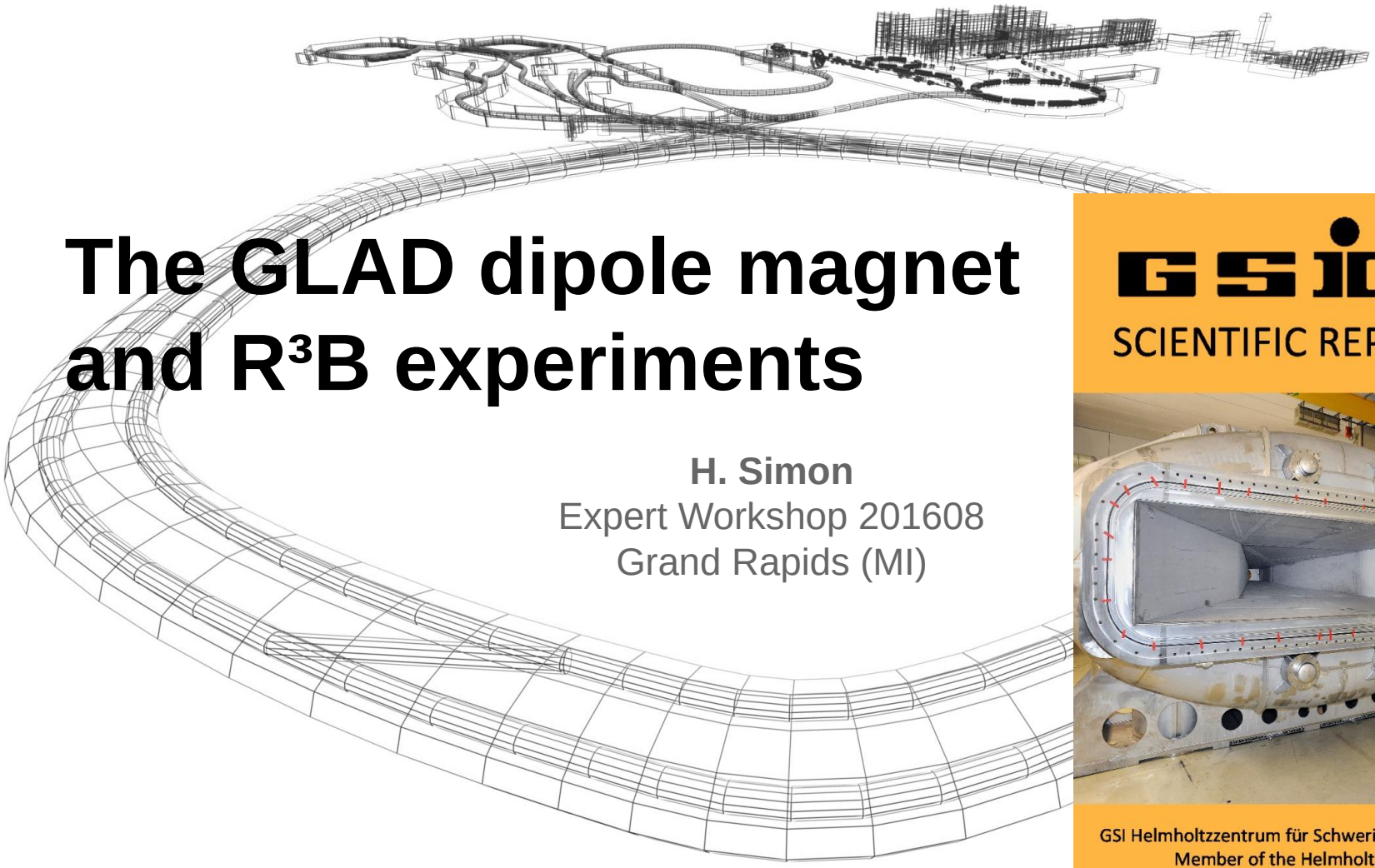


The GLAD dipole magnet and R³B experiments

H. Simon

Expert Workshop 201608
Grand Rapids (MI)

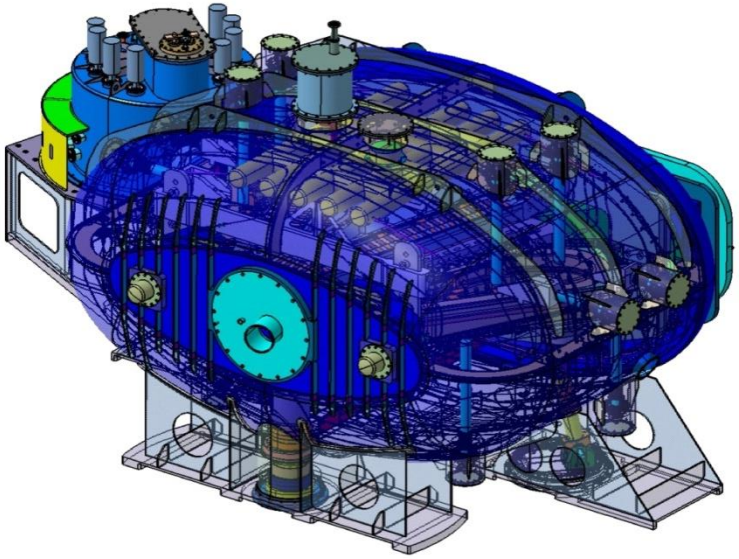
(GSI) Large-acceptance superconducting dipole magnet GLAD

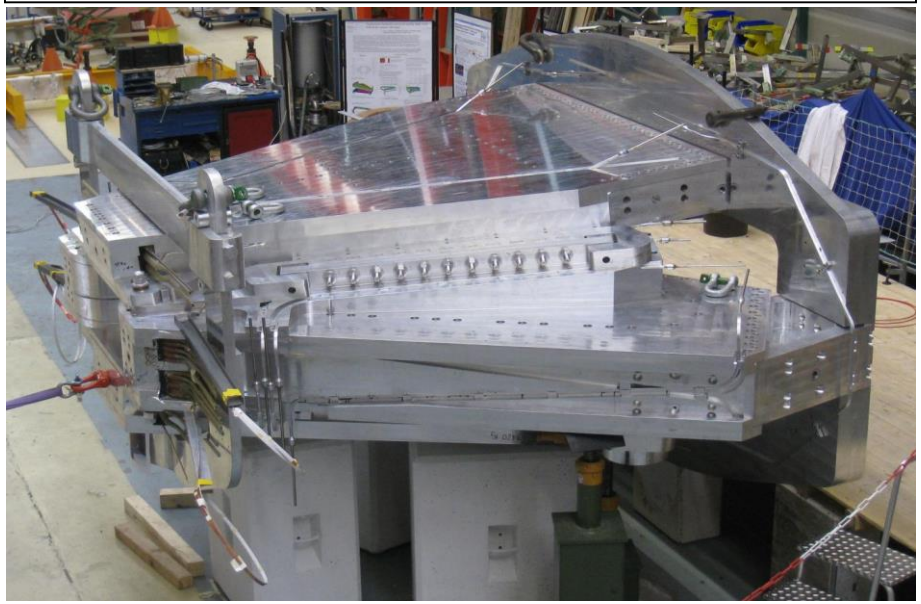
Magnet parameters:

- Large vertical gap ± 80 mrad
- High integrated field of 4.8 Tm
- Fringe field at the target position less than 20 mT
- Operational temperature 4.6 K
- The overall size of the conical cryostat: 3.5 m long, 3.8 m high and 7 m wide.

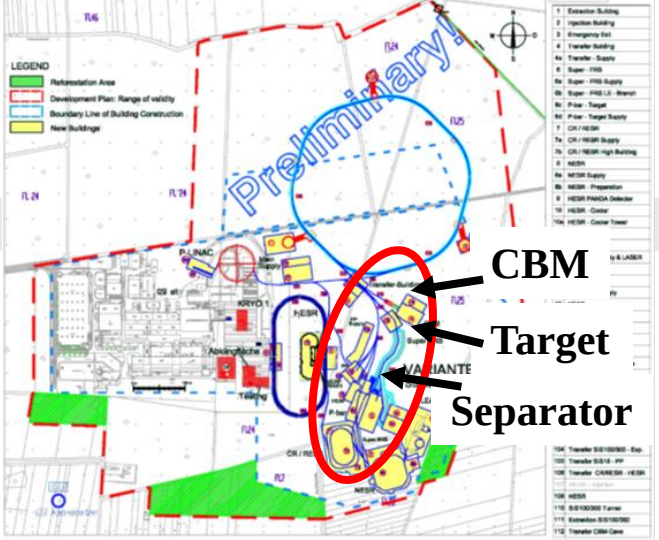
Challenging Magnet design:

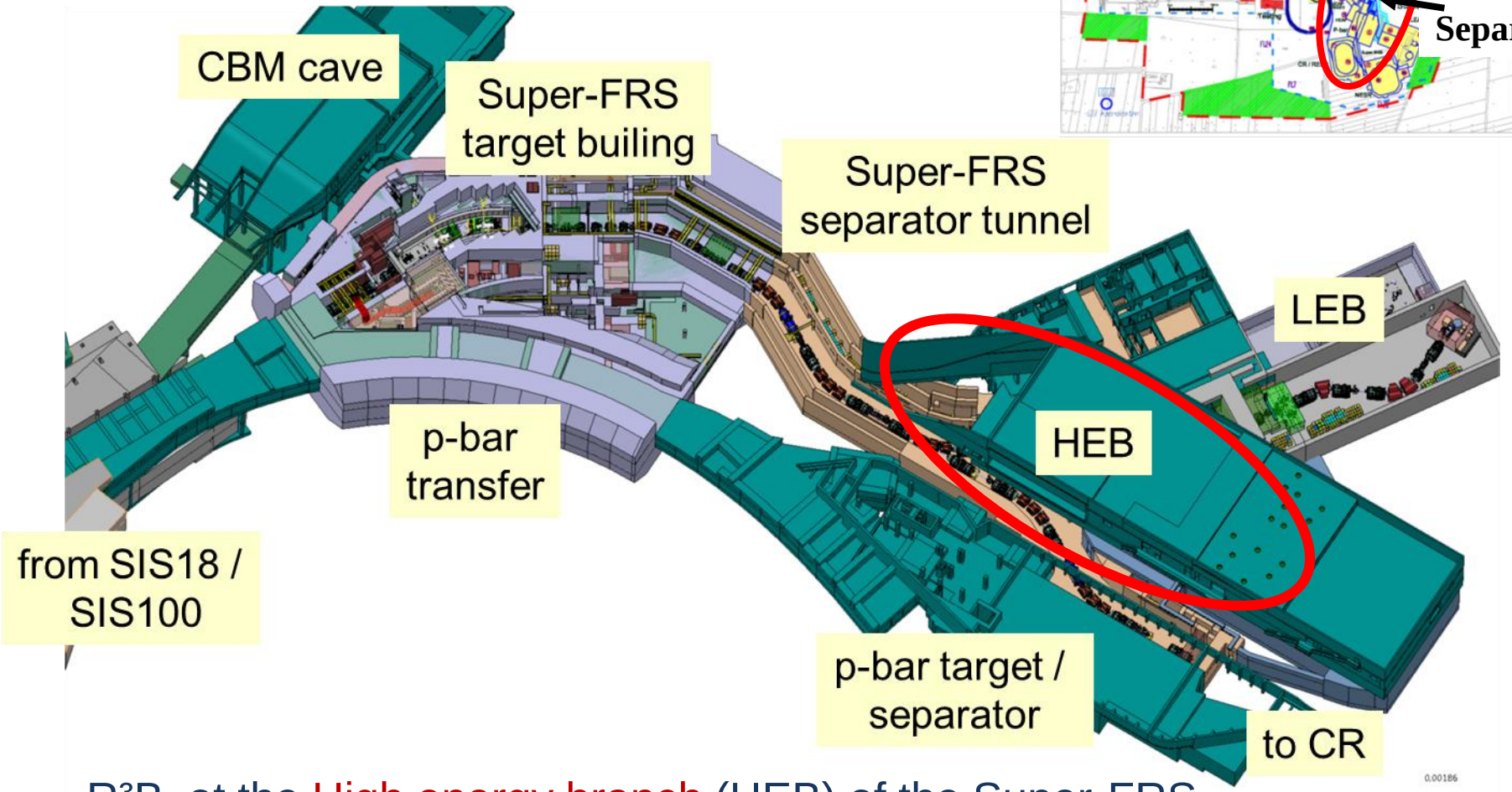
- Collaboration CEA Saclay/GSI
- Ironless design
- Correction Coils
- Lightweight design
- Indirect coil cooling
- Thermosyphon cryo distribution





NUSTAR Site @ FAIR

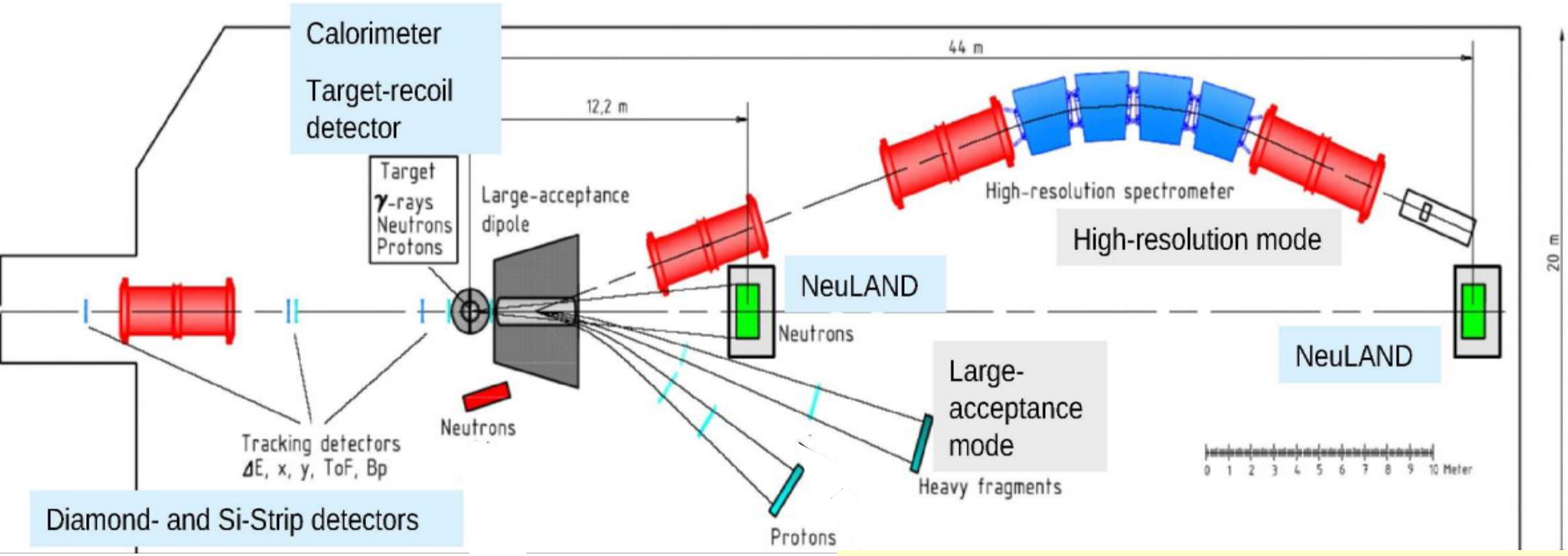




- R^3B at the High energy branch (HEB) of the Super-FRS

Reactions with Relativistic Radioactive Beams
- A versatile and flexible setup

T. Aumann

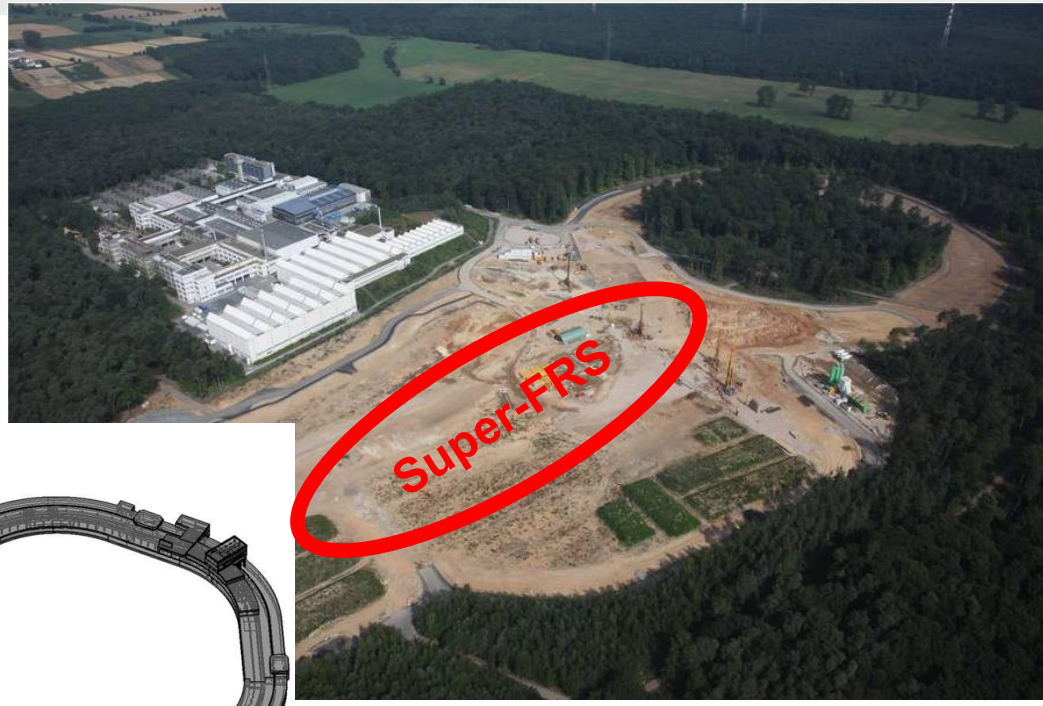


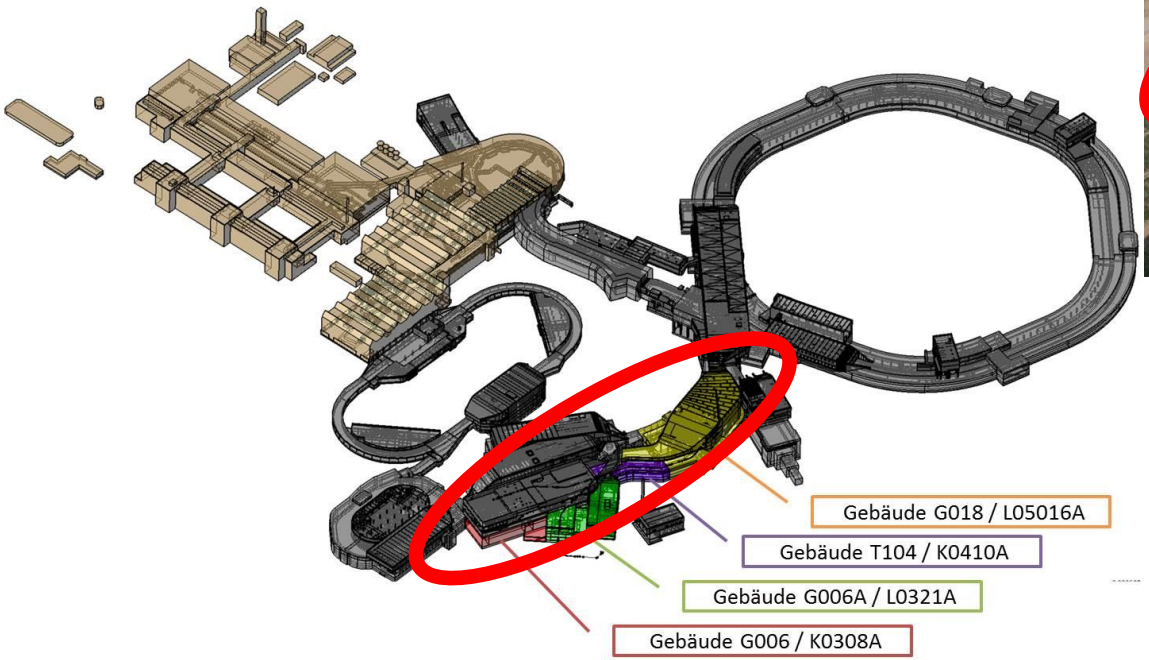
- High energy branch of the SuperFRS
  Beam energies: ~ 100 A MeV – 1 A GeV
- Overdetermined Measurement
  - Kinematically Complete
  - Target Calorimetry
  - Target Recoil Protons/Neutrons
- Incoming beam tracking
  - secondary beam emmittance

Objectives:

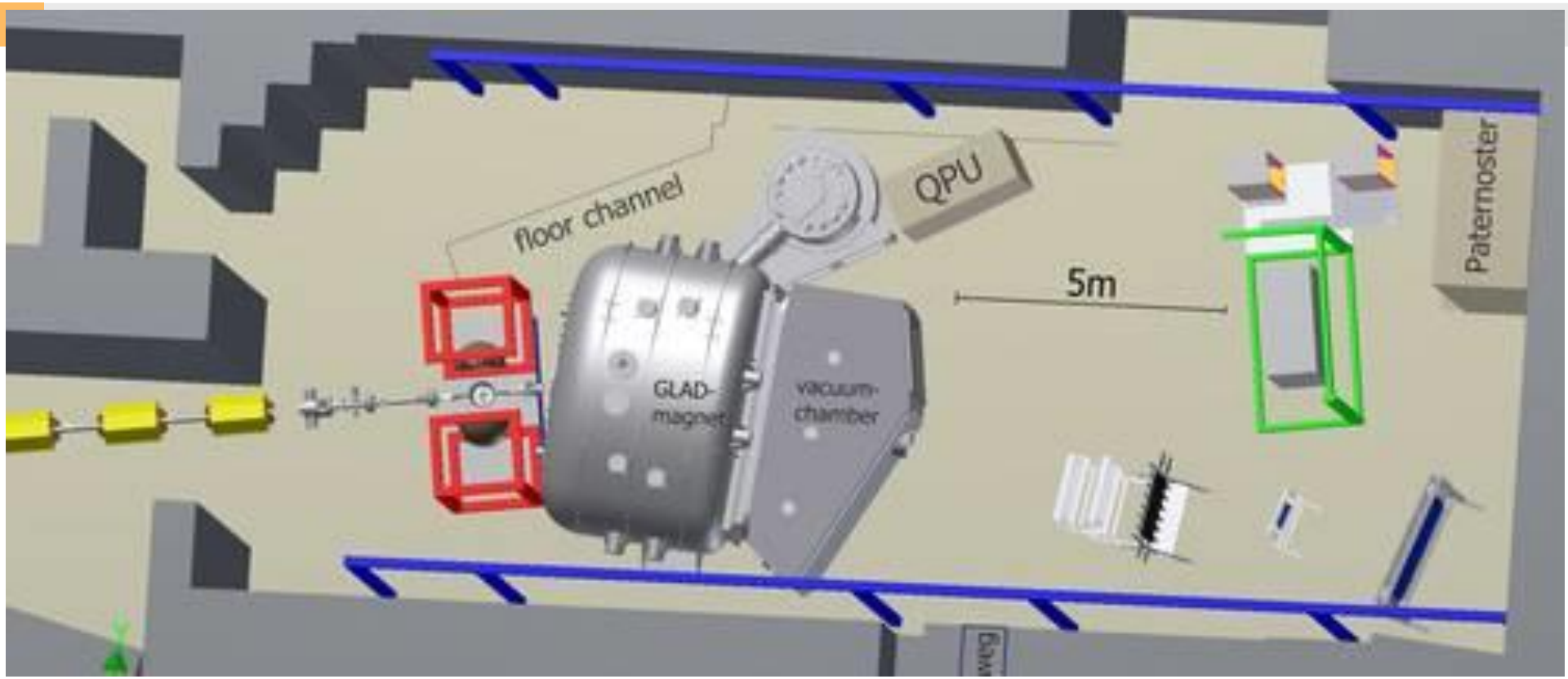
- Reaction Studies
- Nuclear Astrophysics
- Structure of (exotic) Nuclei
- Neutron-rich Matter

Towards the facility





GLAD magnet @ R³B/CaveC



Test Bench: 2016/2017 setup/commissioning, 2018+ operation

(1) Intermediate Cryogenics System

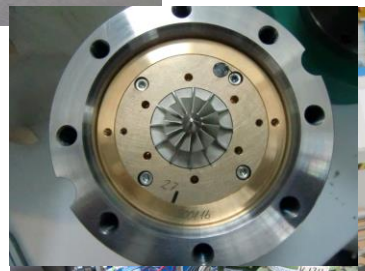
(2) Power Suppl. and QP

(3) Meaningful first detector assembly

GLAD cryosystem
Test bench & Future FAIR equipment

T. Hackler

- Refurbished TCF50 cryo plant from DESY (new compressor)
- Test stand for R³B/GLAD 2014-
- Later use for Plasma physics

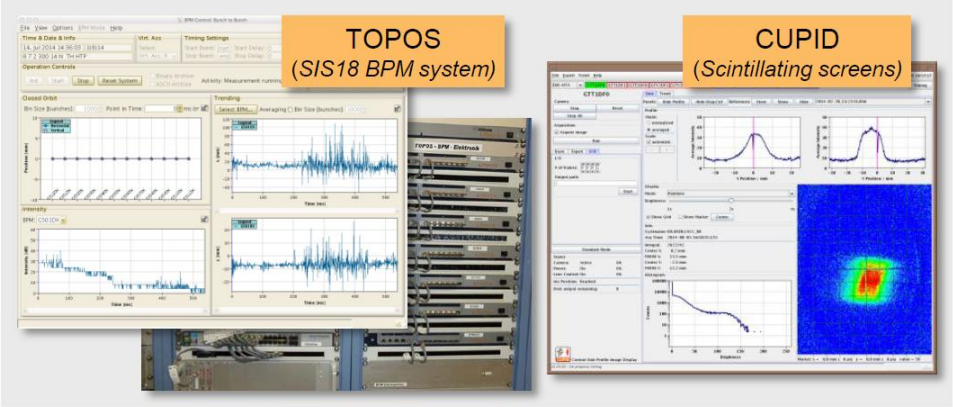


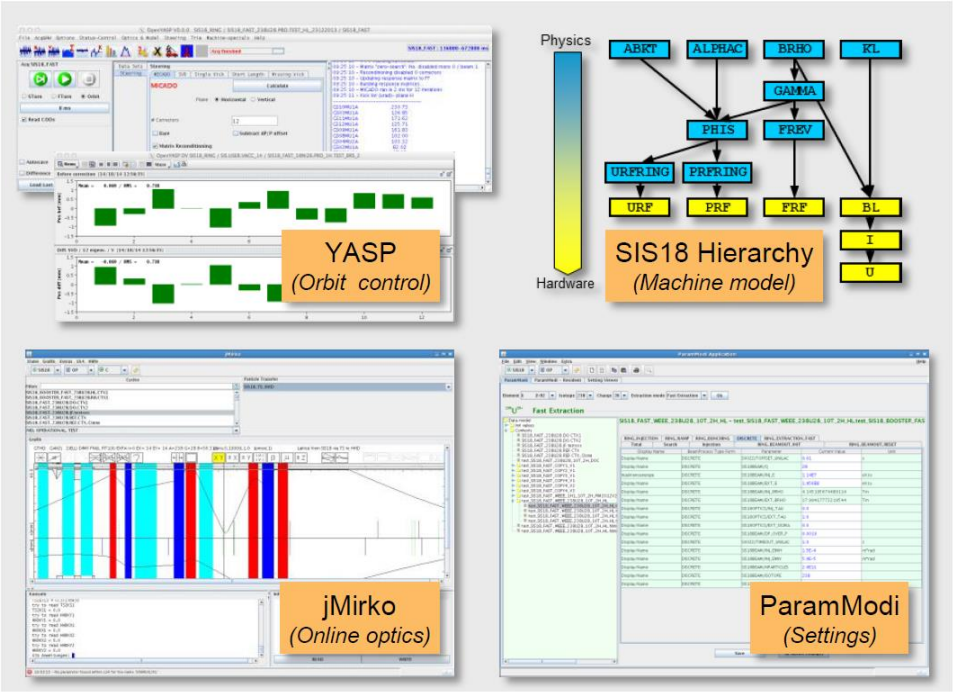
- Prototype for FAIR Cryo plants:
  - UNICOS controls
  - Instrumentation
  - PLC

Continuous controls upgrade

D. Ondreka

- Control system for FAIR
  - Completely new design
  - Collaboration with CERN
    - FESA framework for front-ends
    - LSA framework for settings management
    - Timing system (White Rabbit)
    - User Interfaces
- Prototype systems at SIS18
  - BI: BPMs, Screens
    - Routine use for orbit correction and steering
  - Settings: machine model, applications
    - Commissioning H=2 cavity
    - Resonance compensation
- Operational at CRYRING (2015)
  - Prototype of FAIR control system
  - FESA front-ends for
    - Magnet PCs, RF, HV, RFQ
    - BPMs, Trafos, Screens, Cups, Grids
  - Operating applications
  - Test bench for FAIR operation concepts

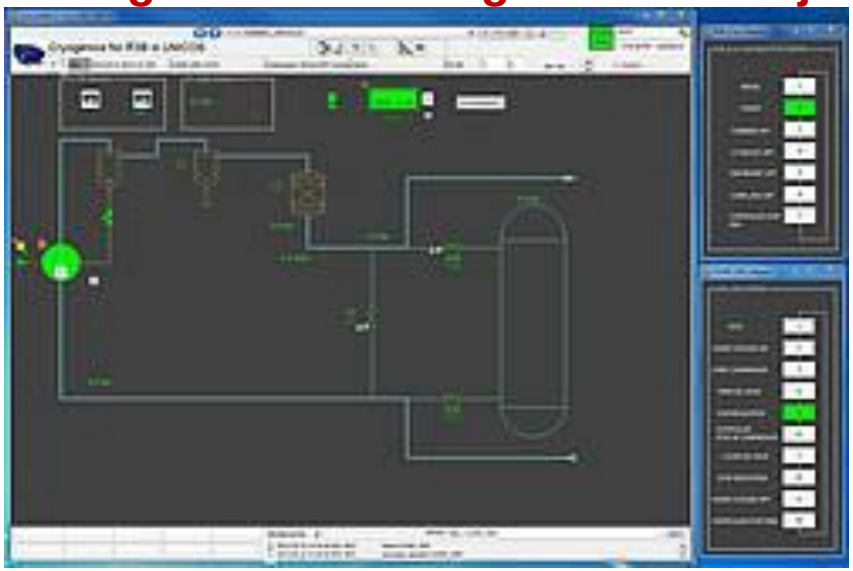




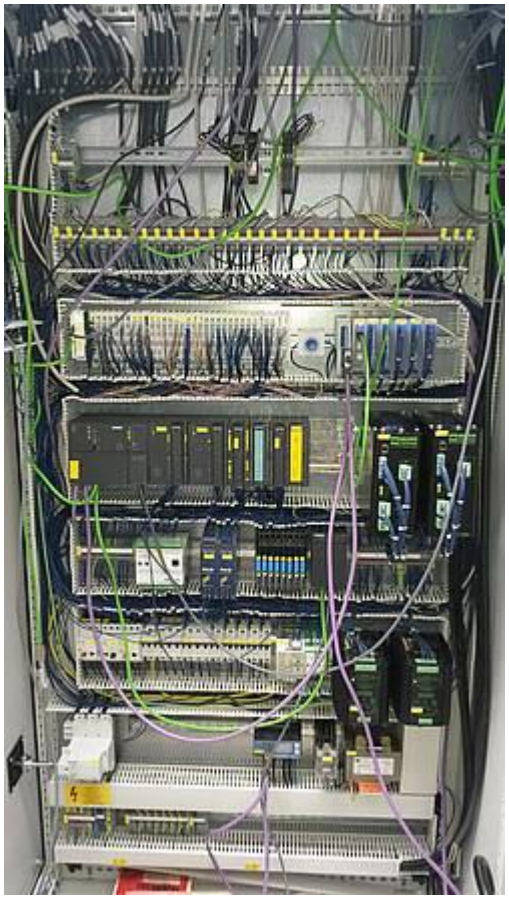
GLAD Cryo controls (UNICOS)

C. Betz/E. Momper

- UNICOS sample system for controlling the GLAD cryo system installed: April 2014
- The compressor of the R3B cryo plant with the new UNICOS control system successfully tested: June 2014
- **Liquid He produced first time (after 25y): December 2014**
- **Processes imlemented, adjustment for magnet op. started**
- **Integration with magnet controls just ongoing**



Sample GUI UNICOS controls GLAD cryosystem.



UNICOS control unit.

unicosHMI_1: R3B_SCADA_V2_DS5

S: Installation_cont_UNICOS.pnl

System Status | admin | 7:44:41 PM 10/7/2014

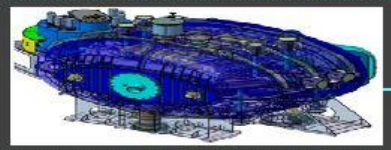
R3B CRYO V2.2 WITH UAB V1X7

LL	2014.09.26 10:16:07.131	VAC_AA_12	VAT open release pressure WR(	Alarm	TRUE	xxx	S

39/ 39 | 0 Unack.

START | B | R3B_Cryo COLD | COLD Mode | Cryostat Mode | Shield Mode | PCOs hierarchy

8.49 bara | 7.68 bara | 0.00 bara | 0.00 bara | 0.00 bara | 0.0 °K | 0.00 V | 0.00 bara | -40.32



COMP_ORS_Stepper

COMP_ORS STEPPER

STOP	1
WATER COOLING ON	2
START COMPRESSOR	3
OPEN OIL VALVE	4
RUN REGULATION	5
WAITING T1T2 STOP	6
CONTROLLED STOP OF COMPRESSOR	7
CLOSE OIL VALVE	8
STOP REGULATION	9
WATER COOLING OFF	10
CONTROLLED STOP ENDS	11

R3B_Cryo_Stepper

R3B_Cryo Controlled STOP STEPPER

INITIAL	1
STEADY	2
TURBINES OFF	3
JT CIRCUIT OFF	4
R3B MAGNET OFF	5
COMP_ORS OFF	6
CONTROLLED STOP END	7

Out Positioning | Regulation | SetPoint... | PID Param... | Limits... | Select

Auto Mode | Manual Mode | Forced Mode | Output... | Deselect

Remaining time

2014.10.07 19:44:17.351 INFO

2014.10.07 19:44:20.742 INFO

unicosHMI_1: R3B_SCADA_V2_DS5

S: Installation_cont_UNICOS.pnl

System Status | admin | 7:54:14 PM 10/7/2014

R3B CRYO V2.2 WITH UAB V1X7

LL	2014.09.26 10:16:07.131	VAC_AA_12	VAT open release pressure WR(	Alarm	TRUE	xxx	S

39/ 39 | 0 Unack.

START | B | R3B_Cryo COLD | COLD Mode | Cryostat Mode | Shield Mode | PCOs hierarchy

8.48 bara | 7.68 bara | 0.00 bara | 0.00 bara | 0.00 bara | 0.0 °K | 0.0 °K | 0.0 °K | 0.0 °K | 0.00 V | 0.00 bara | 0.00 bara

1 - EQ01QN106_PID PID Controller He flow to turbines

Status | Trends

EQ01QN106_PID

100.0 | 96.00 % | 0.0 | 0.00 %

MV = 0.8
SP = 0.8
OUT = 43.43 No Scaling

MV= EQ01QN106_MGF_O
OUT= EQ01QN106_Ana

Manual mode inhibited
Force mode inhibited
Autoregulation request
Armed recipe

Operation Modes
Active
Auto A
Manual M
Forced F
Local L

Working States
Regulation R
Output Positioning P
Tracking T

SetPoints Requests
Auto 0.8 %
Manual 0.0 %
Active 0.8 %

Output Position Requests
Auto 0.00 %
Manual 0.00 %
Active 43.43 %

PID Param Act <> Def
Kc 3.000
Ti 5.000
Td 0.000
Tds 0.000

SetPoints Limits
High 100.0 %
Low 0.0 %

Output Limits
High 96.00 %
Low 0.00 %

Warnings
Event masked
I/O Error
I/O Simulated

Out Positioning | Regulation | SetPoint... | PID Param... | Limits...
Auto Mode | Manual Mode | Forced Mode | Output... | Select

R3B_Cryo_Stepper

R3B_Cryo Controlled STOP STEPPER

INITIAL	1
STEADY	2
TURBINES OFF	3
JT CIRCUIT OFF	4
R3B MAGNET OFF	5
COMP_ORS OFF	6
CONTROLLED STOP END	7

COMP_ORS_Stepper

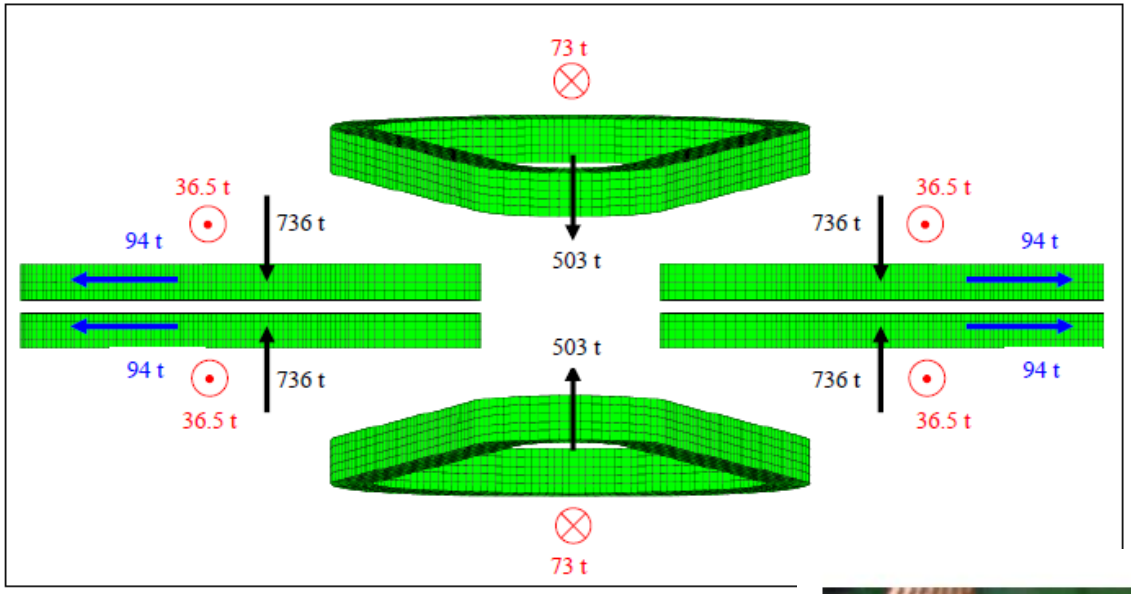
COMP_ORS STEPPER

STOP	1
WATER COOLING ON	2
START COMPRESSOR	3
OPEN OIL VALVE	4
RUN REGULATION	5
WAITING T1T2 STOP	6
CONTROLLED STOP OF COMPRESSOR	7
CLOSE OIL VALVE	8
STOP REGULATION	9
WATER COOLING OFF	10
CONTROLLED STOP ENDS	11

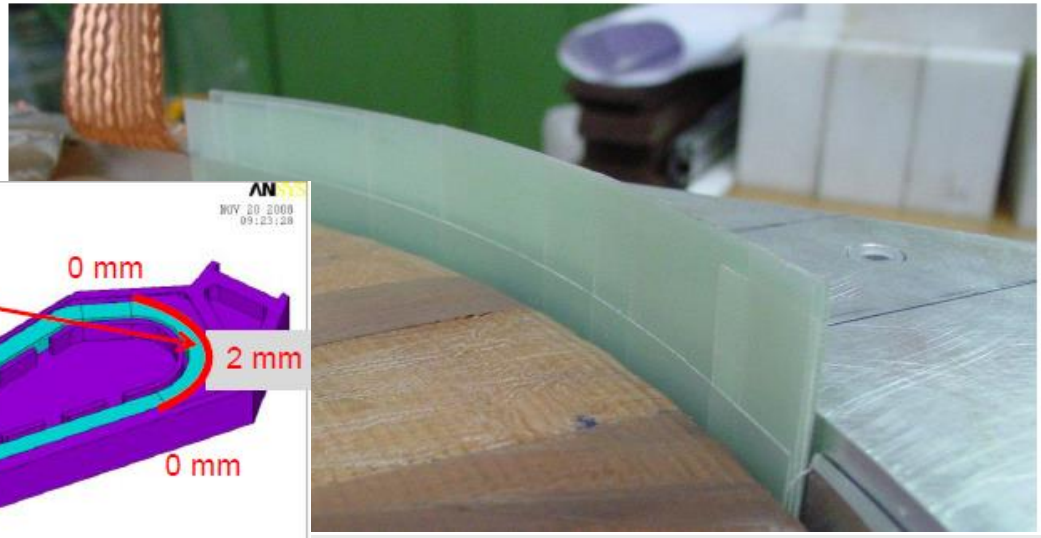
Set Value... | Deselect | Remaining time | Select

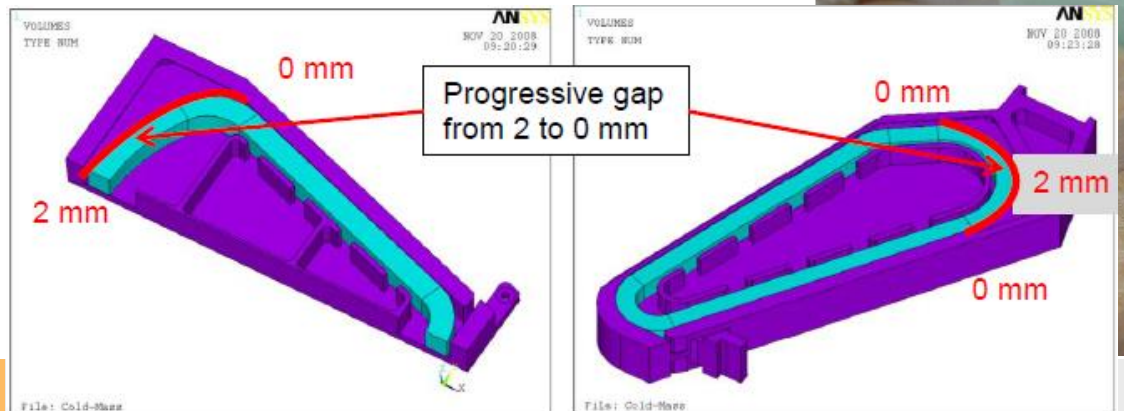
2014.10.07 19:53:51.820 INFO
2014.10.07 19:53:56.864 INFO

Rigid mechanical design (Al 5083)



- Gap filling with G10 foils





Coil parameters in brief

Peak field on the conductor	6 T
Operational temperature	4.6 K
Overall current density	73 A/mm²
Stored energy	24 MJ

	Number of turns	Number of double pancakes
Main coils	50	2x5
Lateral coils	40	4x4

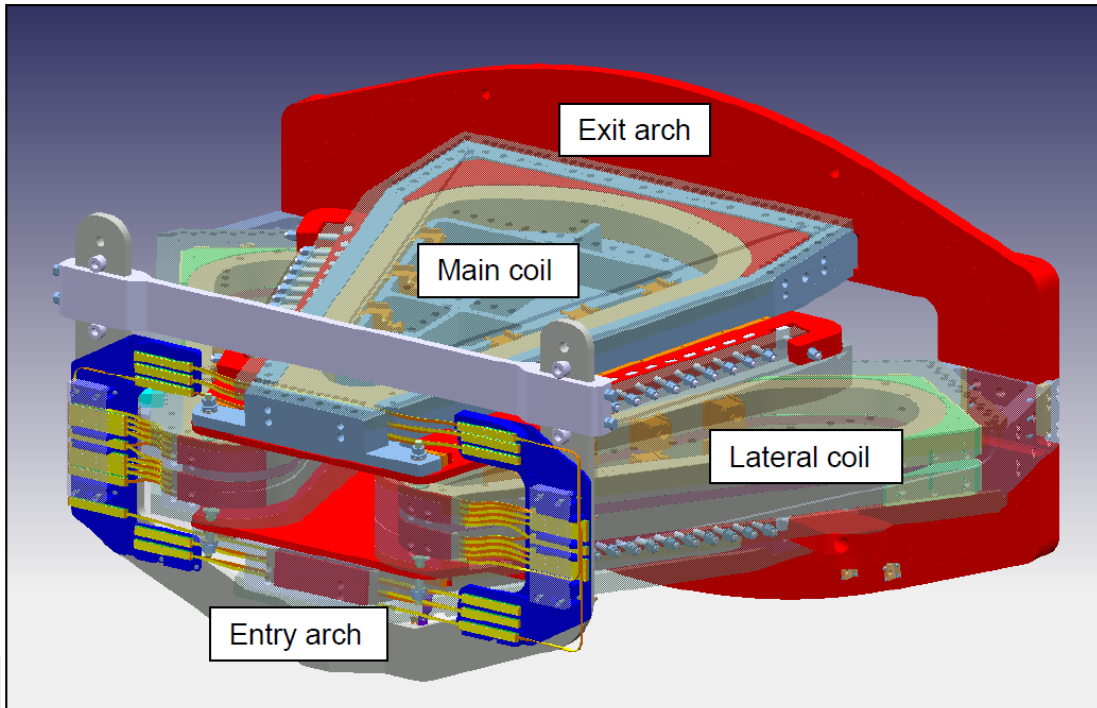
Inductance: L = 3.71 H

Dump resistance: RD = 280 mΩ
➔ τ ~ 13 s

Line resistance: RL = 0.1 mΩ to 1.6 mΩ

Nominal current: I_{nom} = 3584 A

Maximal current: I_{max} = 3764 A



GLAD power supply ACU controls

H. Welker,

GSI Helmholtzzentrum für Schwerionenforschung GmbH

FAIR

Document Title

Power Converter System for R3B-GLAD Magnet

Document Name

F-DS-PC-04e Power Converters

Date

2013-04-16

Delivery Q4/2014

SAT without magnet Q2/2016

First Ramp implementation in ACU (Frontend)

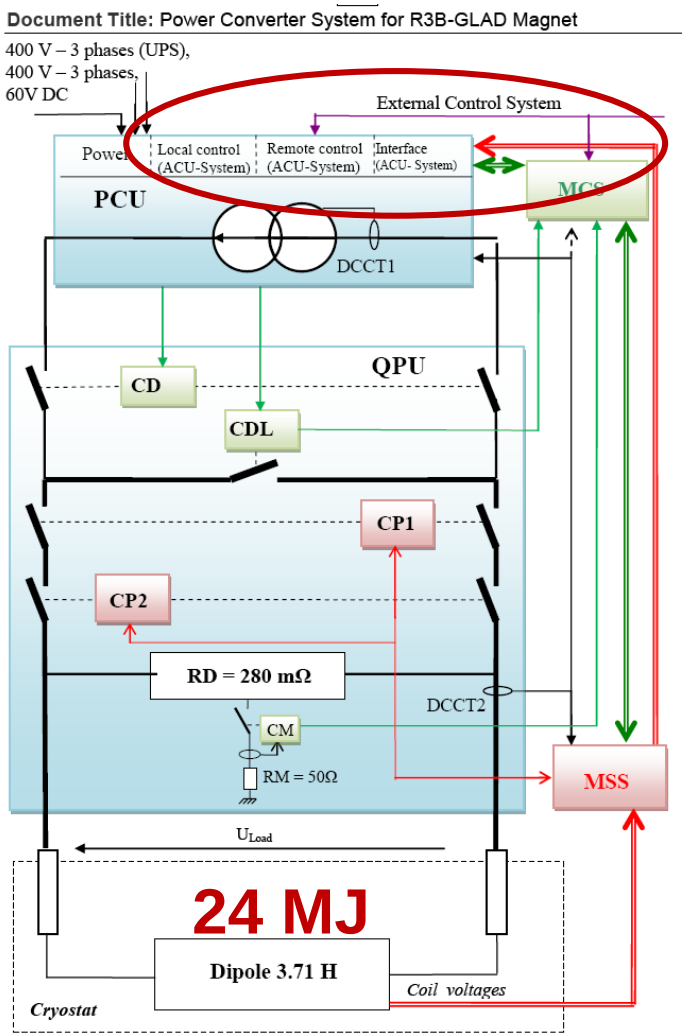
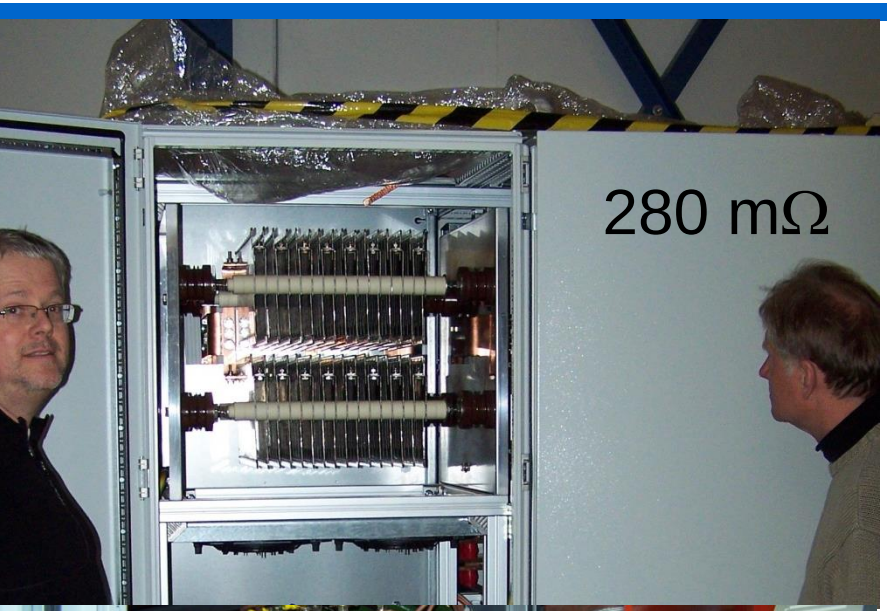
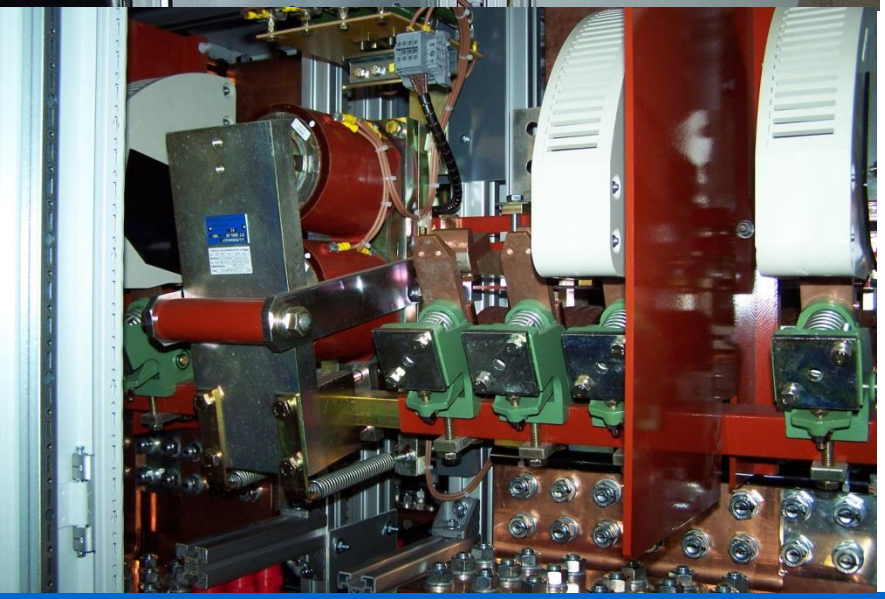
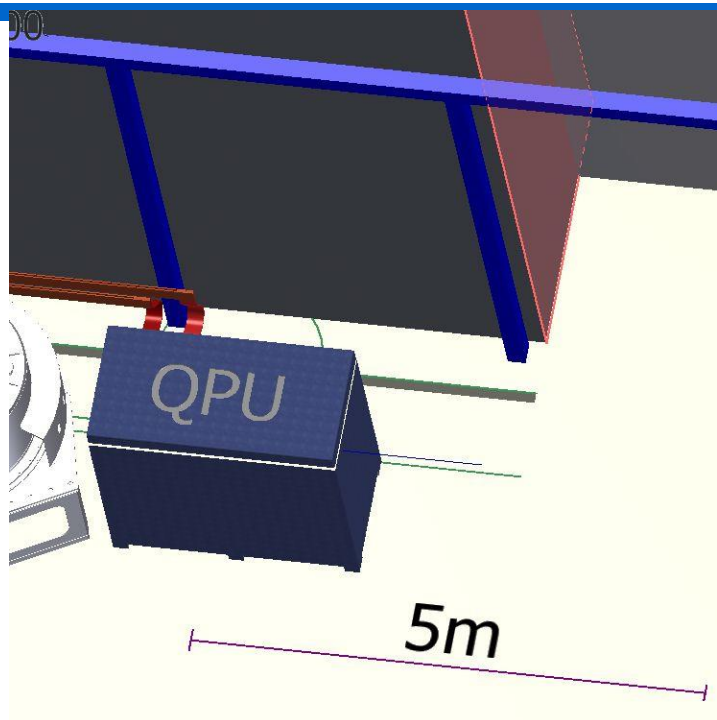


Figure 4 power converter system overview

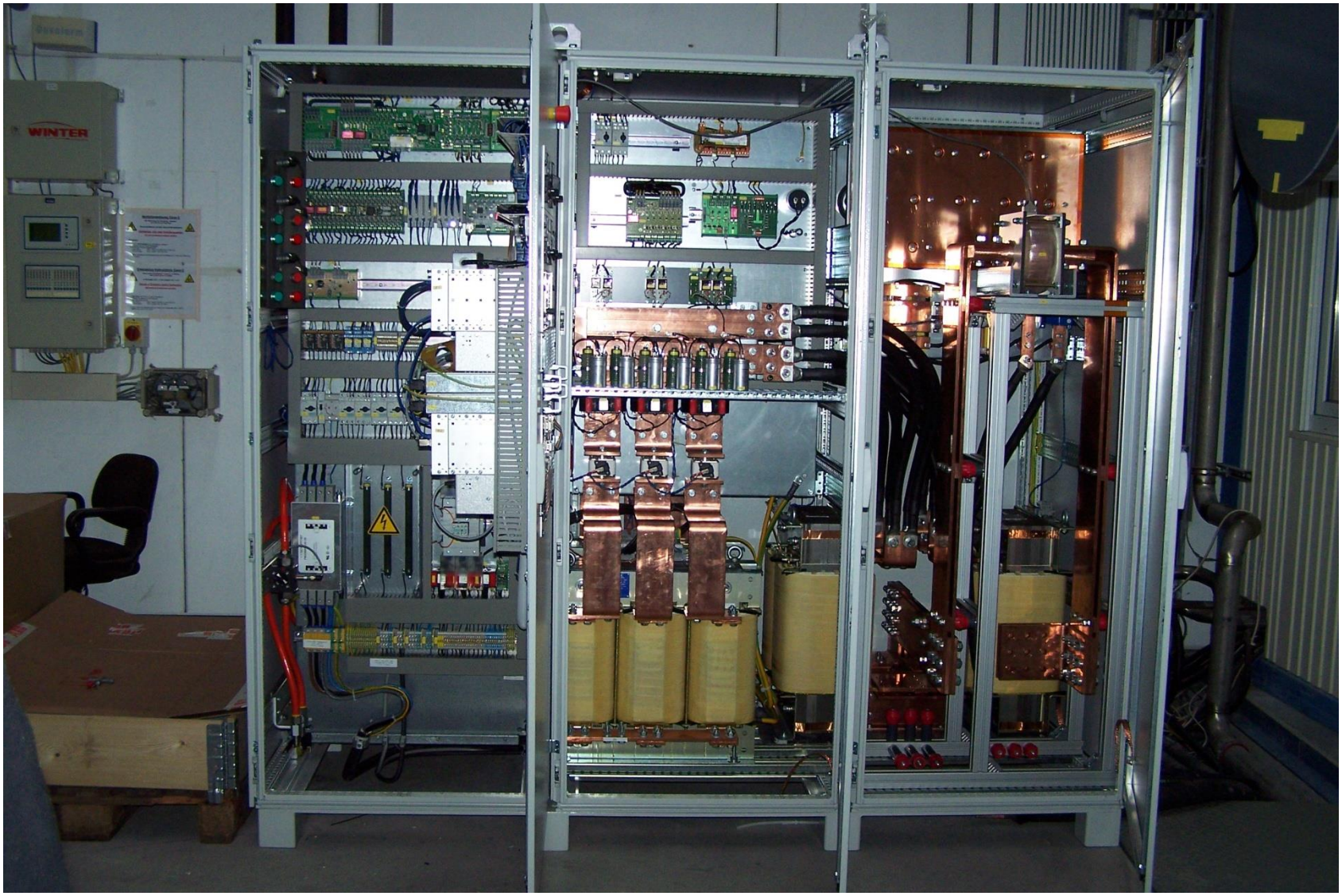
GLAD power supply – Quench Protection Unit







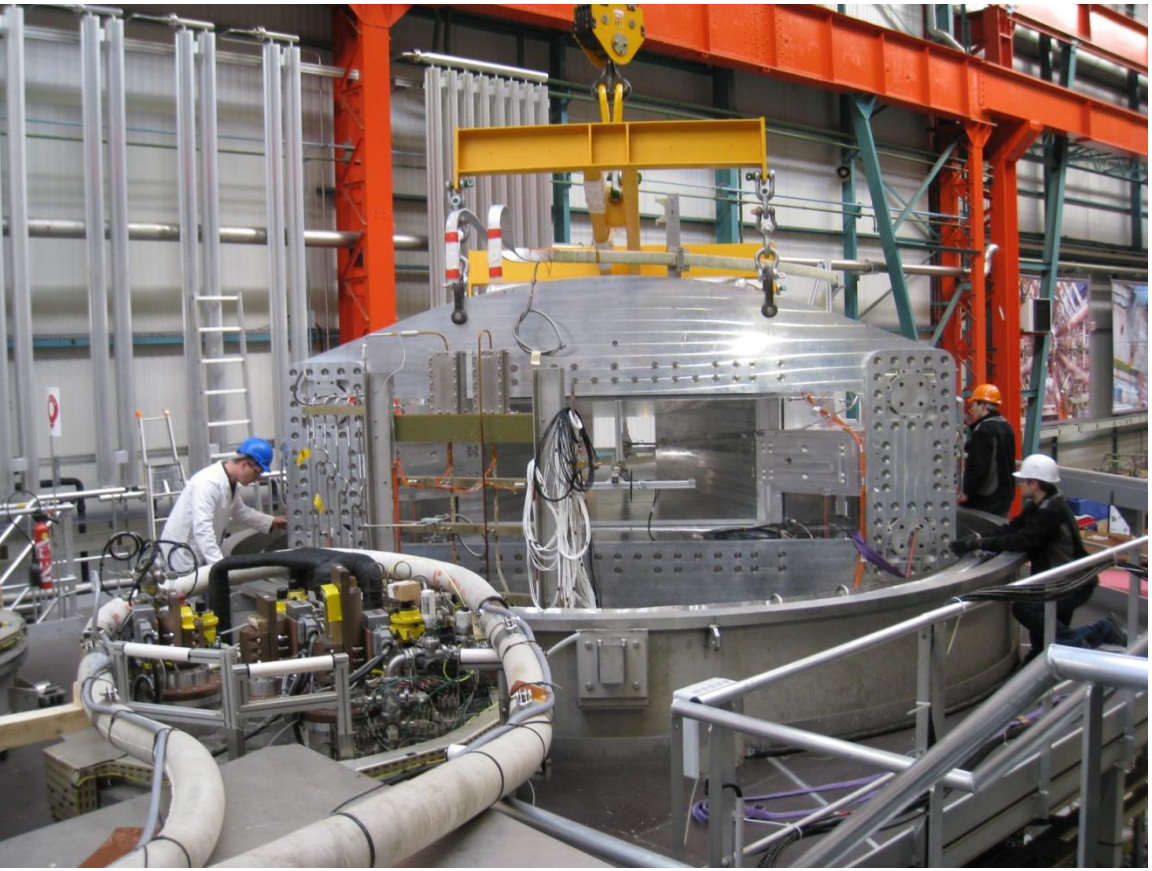
GLAD power supply – Power Cabinet



GLAD the magnet 2012 ff

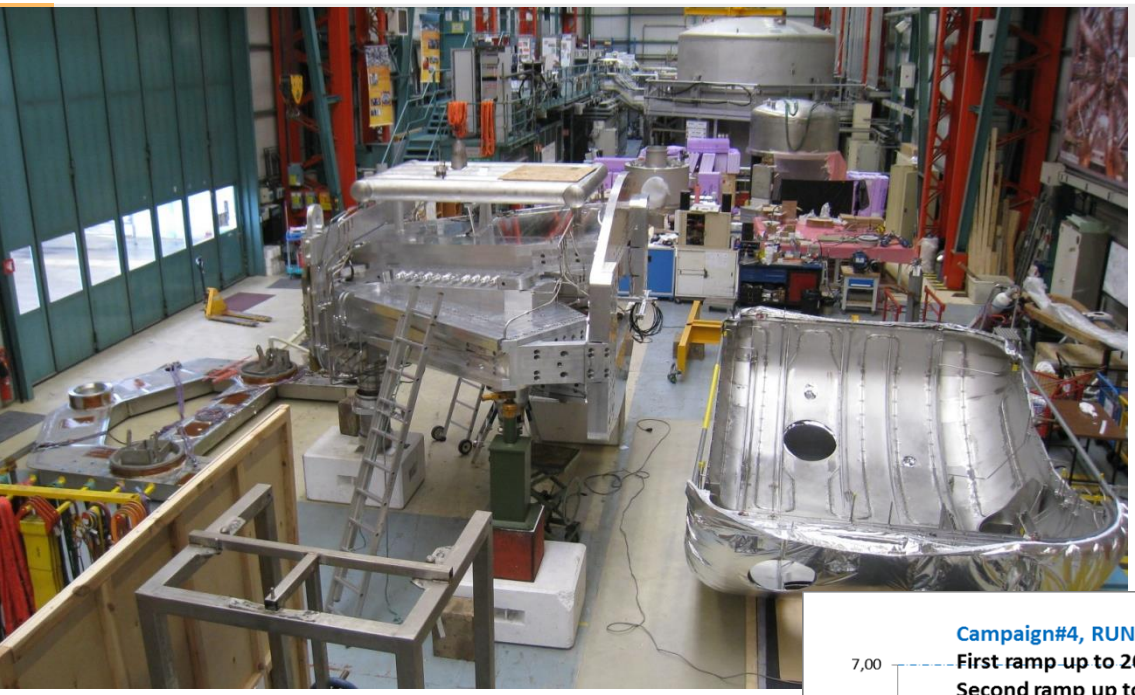
(2001-2005 CDR / 2006-2008 TR / cold mass 2010 / TDR 2011)

Cold mass tests in Wendelstein cryostat @ CEA
➔ Foot modification
➔Test-Satellite improvements



•TCF50 prepared for transport from DESY

GLAD magnet @ CEA



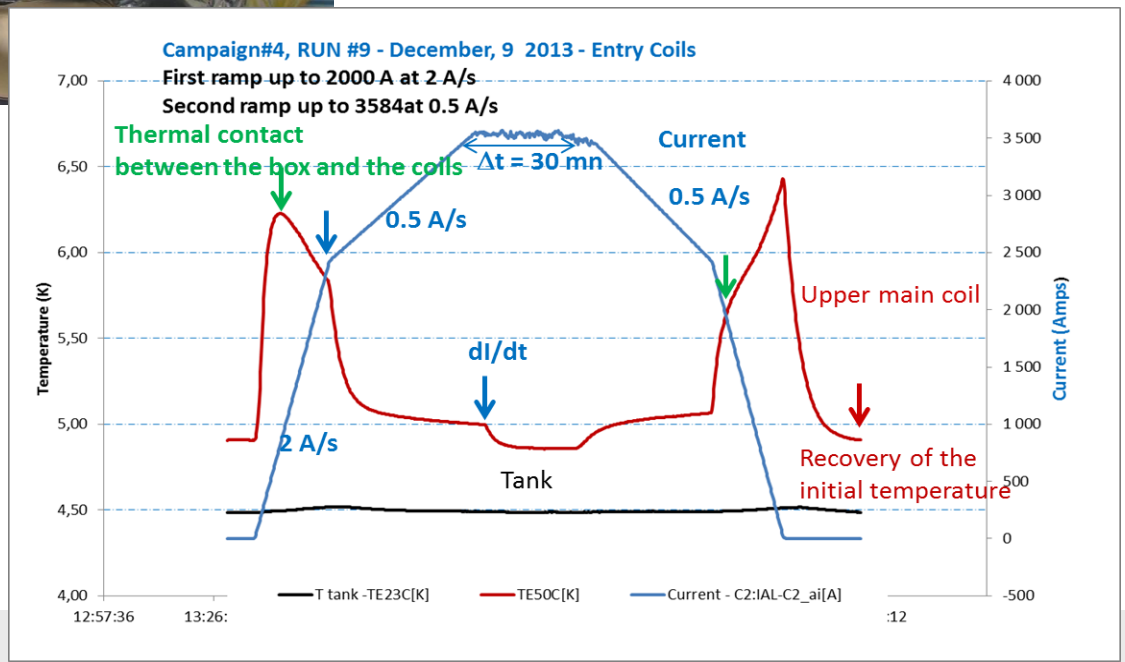
@CEA Saclay

- Magnet cold mass ready and tested, December 2013.
- Integration into cryostat

➔Vacuum leak found Q4/2014 and repaired Q2/2015) access via foot !

- Cryoplant installation **@ GSI.** Cryolines (33m) on site Cryoplant commissioning
- Vacuum chamber ready
- Power supply ready

➔ Q4/2014



The magnet ready
… for travel

- Production
(and revision) finalized.

- FAT approved 23.9.2015

August 2015

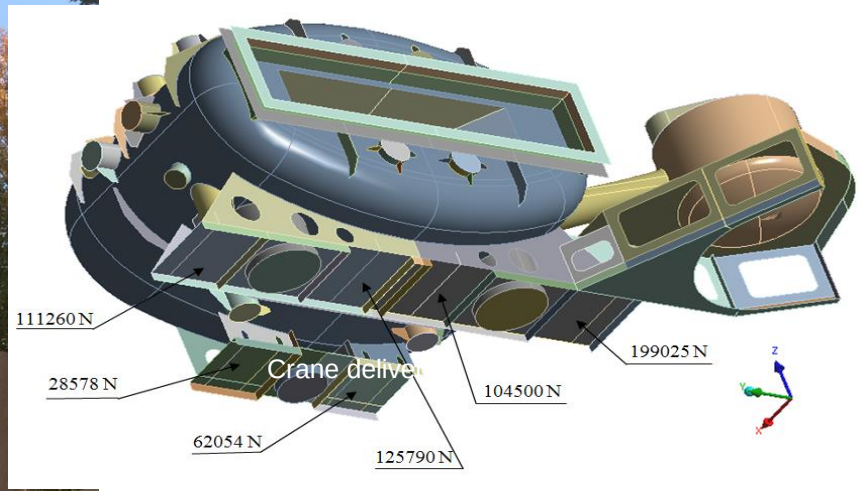
September 2015

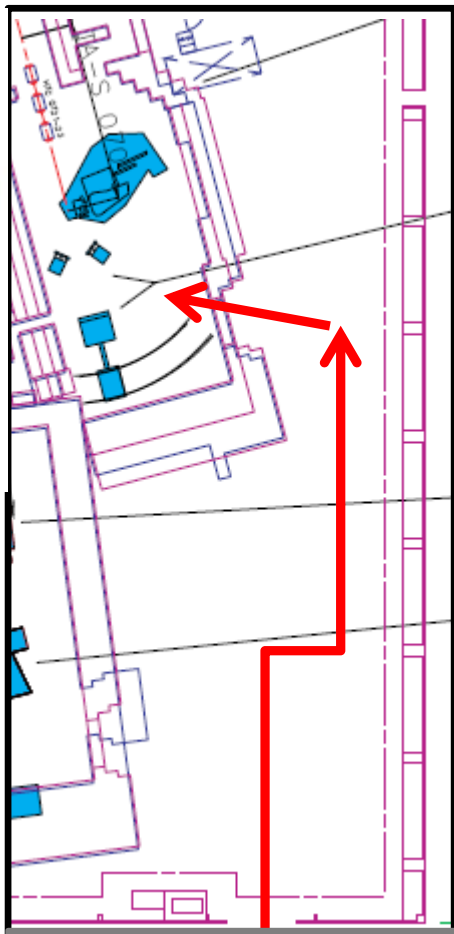
Street permits etc.

Transport to GSI
November 2015

SATa Test 01/2016

Delivery, test & repair, & air cushion transport to Cave-C (01/2016)





Crane delivery

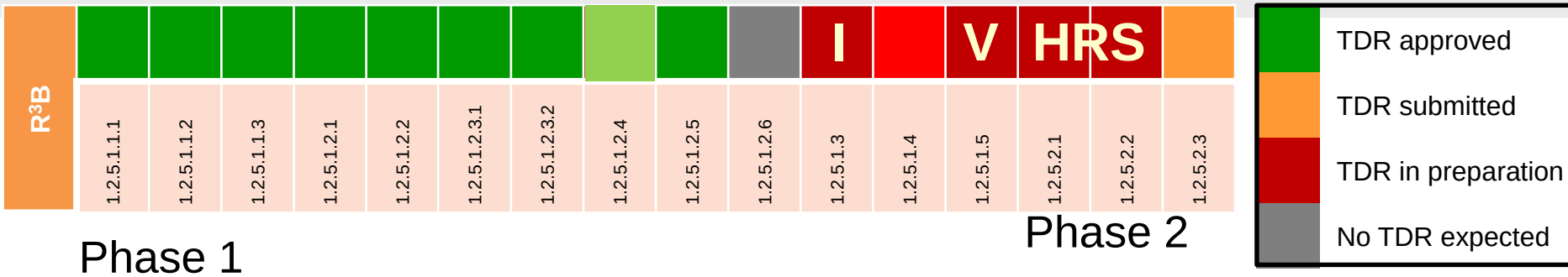
GLAD @ Cave-C 2016

- Power supply there and tested
- Crypo plant installed and tested
- Magnet has arrived and passed first series of SAT tests

➔ non conformity in the exit flange fixed @ chamber

- 04-09/2016 installation of instrumentation and MSS/MCS by CEA
- End 2016 to get magnet into operation!

R3B TDR Status

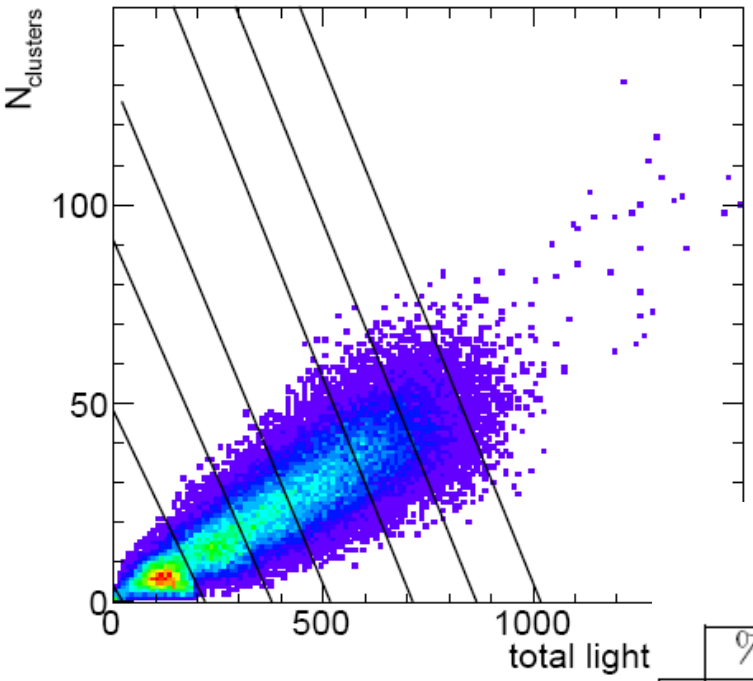


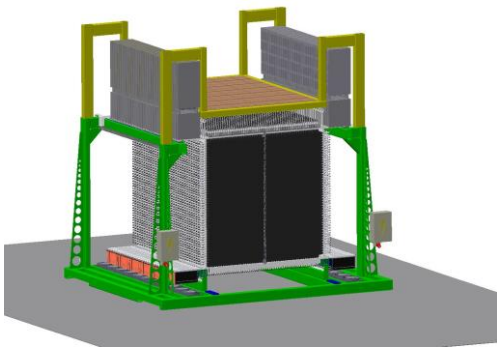
- R^3B (6) (Multiplet, NeuLAND, CALIFA-barrel, CALIFA forward endcap, GLAD, tracking detectors)
- R^3B (1) (Active target, ‘phase 2’, processing)
- 1.2.5.1.2.4 Si tracker: device soon ready, **TDR (still) to come (!)**
- 1.2.5.1.4 Common NUSTAR DAQ: final draft circulates
- 1.2.5.1.3/5 Infrastructure, Vacuum
  ➔ delayed until later move into high energy cave

Novel Neutron Detector: NeuLAND

K. Boretzky

Fully active neutron detector based on scintillators (calorimetry & tracking)





		1000 MeV generated				
	%	1n	2n	3n	4n	5n
detected	1n	**89**	12	1	0	0
	2n	7	**78**	23	3	0
	3n	0	8	**63**	26	5
	4n	0	0	12	**63**	40
	5n	0	0	0	7	**46**
	6n	0	0	0	0	8

Previously < 50%

Previously <5% !

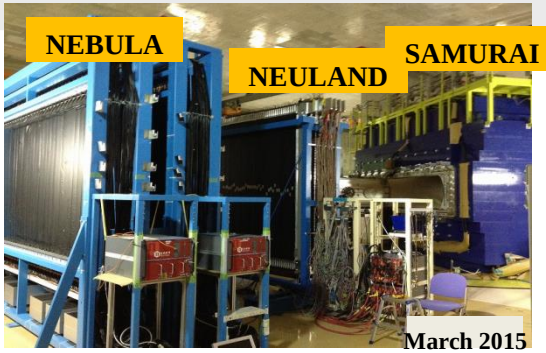
➔ 4/5n decay channels in reach

30 double planes
2 x 50 paddles each
5 x 5 x 250 cm³
RP408 / R8619ASSY

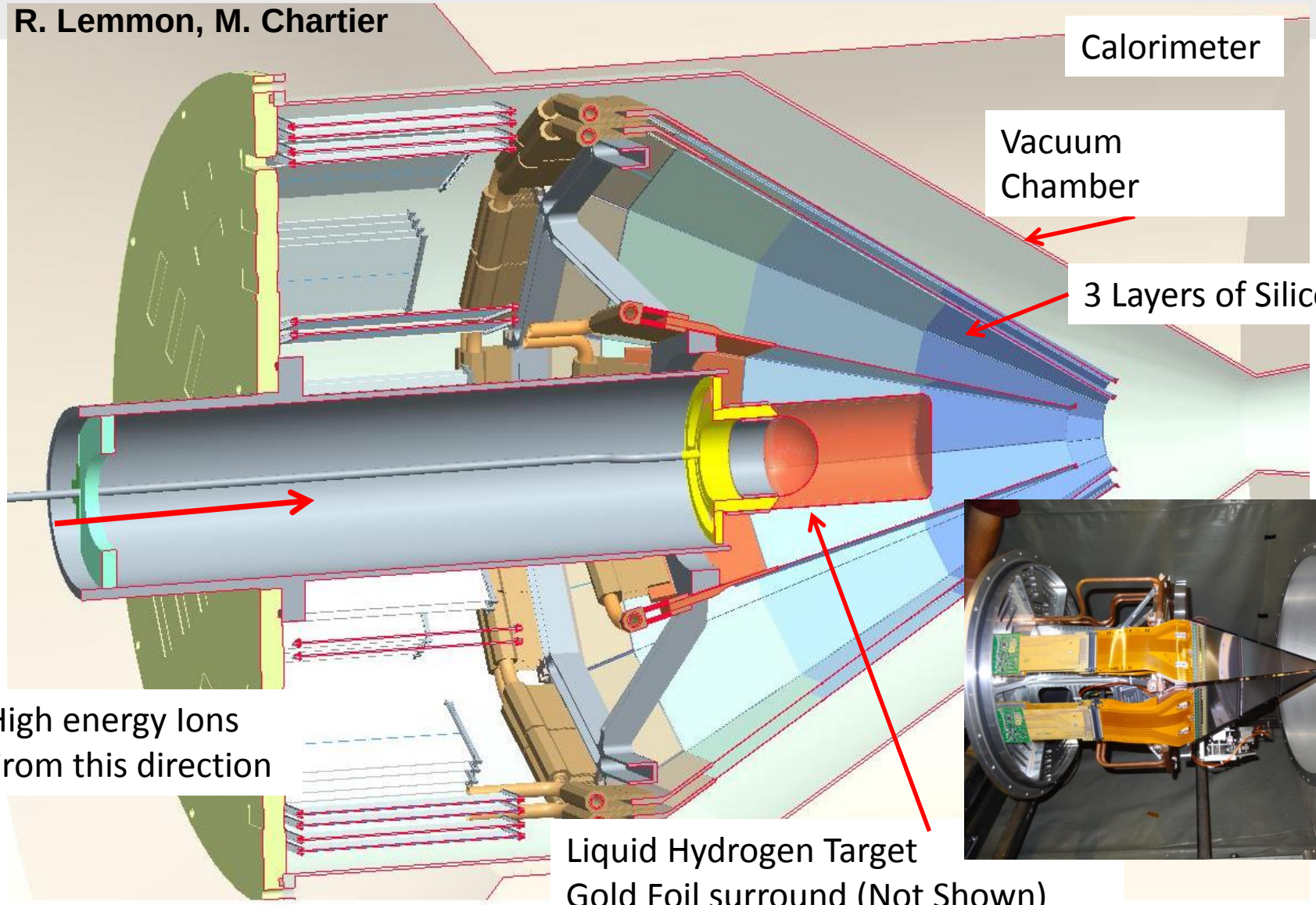
FPGA TDC readout

NeuLAND: Status

- NeuLAND demonstrator (40 cm depth with 4 double planes and 800 readout channels) at RIKEN up to end of 2017, participation in various beam times
- at GSI continuation of production (4 more double planes ready), production scheme dominated by funding profile, at least 11 d.p. in 2018
- HVDS (high voltage distribution system) as in-kind from PNPI, pre-series (200ch) in operation, 1000 ch in SAT test, full system (6000 ch) up to spring 2018
- electronics: GSI inhouse, further development of earlier Tacquila electronics. New TAMEX system in FOS prototyping.
- One of the two NeuLAND support frames produced and mounted, allows to hold up to 20 double planes.

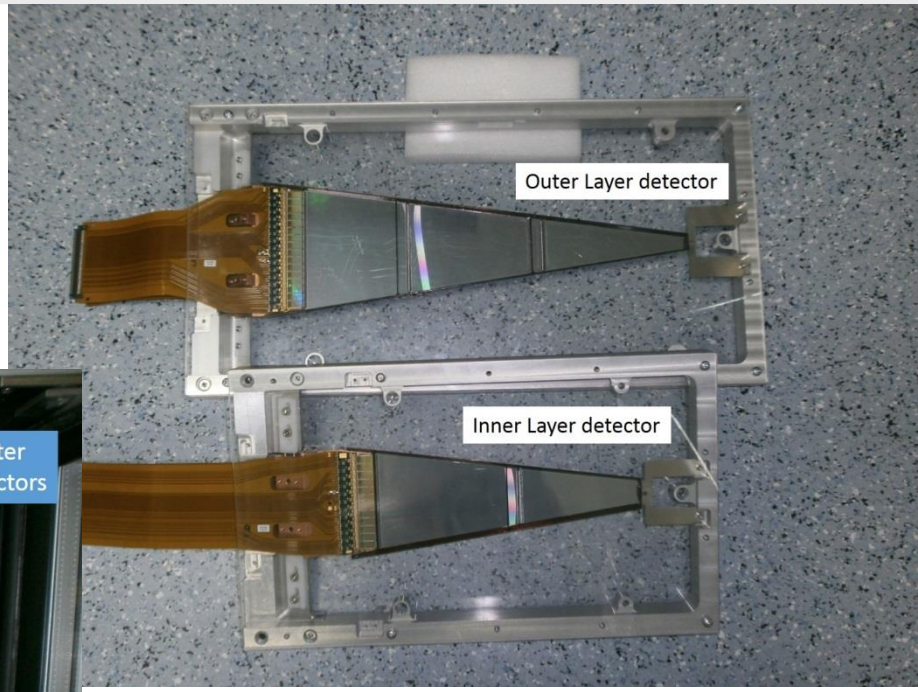


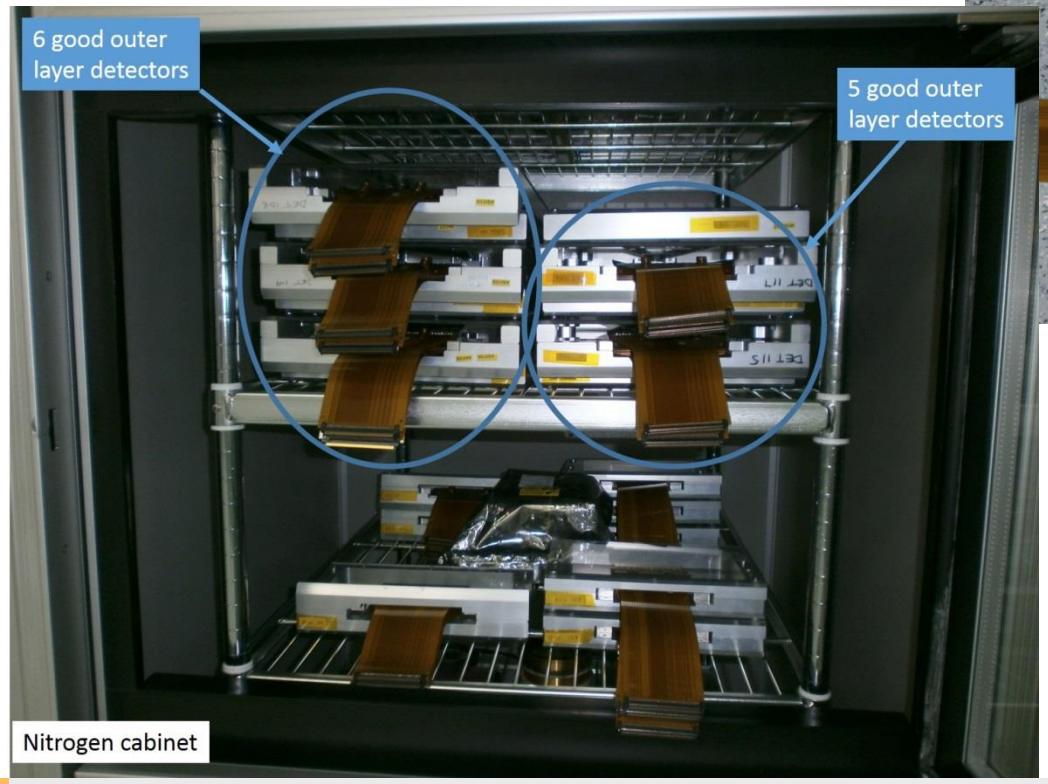
R3B Si Tracker



R3B Si Tracker - Status

"In brief, we will have by end of March the full system (in boxes)." (R. Lemmon 20160226)





Assembly 03/2016 - 04/2017

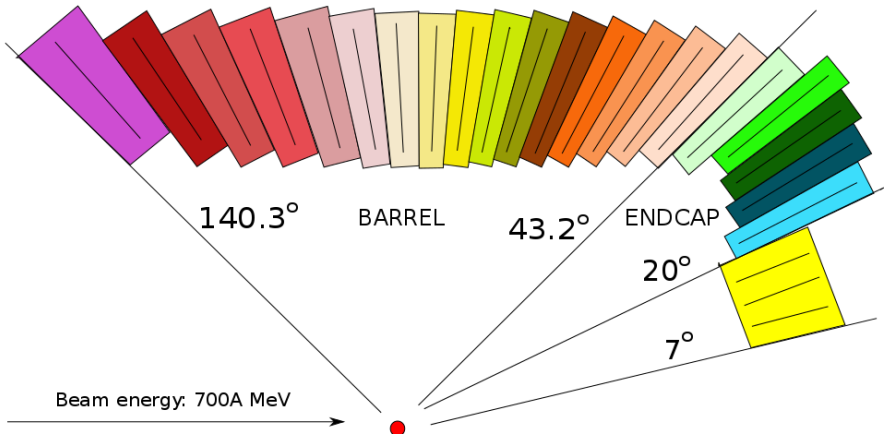
CALIFA : Calorimeter in-flight detection for γ-rays and LCP

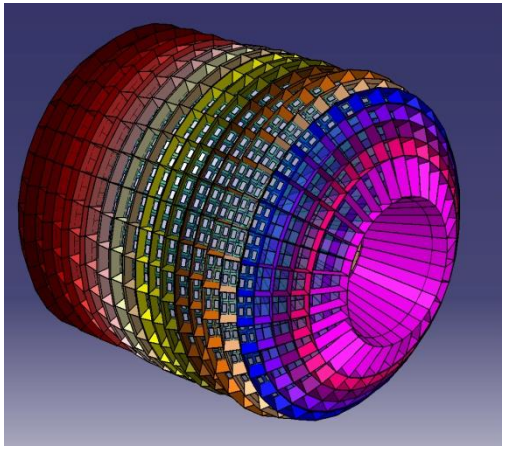
D. Cortina

Design dominated by the kinematics of particles emitted by relativistic sources

Detector split in two sections : BARREL and ENDCAP

TDR's approved 2013 and 2015





Intrinsic photopeak efficiency	40% (up to Eg=15 MeV PF)
Gamma sum energy resolution $D(E_g sum)/<(E_g sum)>$	< 10% for 5 γ rays of 3 MeV
Calorimeter for high energy LCP	Up to 320 MeV in lab system
Gamma energy resolution	~5-6% (FWHM at Eγ=1 MeV)
LCP resolution	~2%
Proton-g ray separation	For 1 to 30 MeV

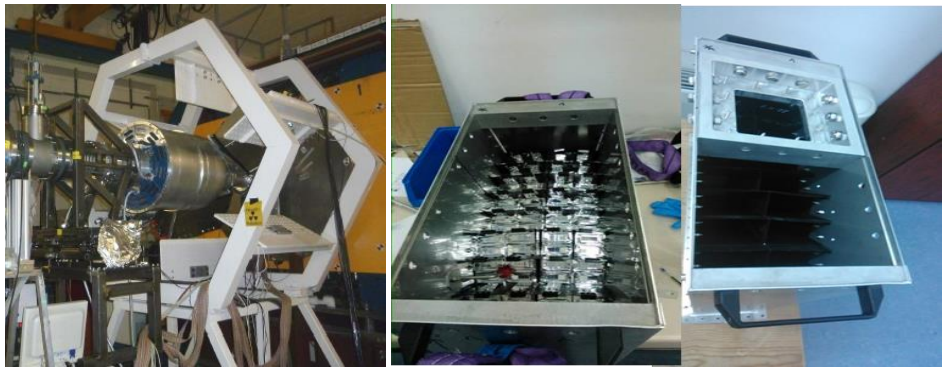
Physics imposes the scientific requirements

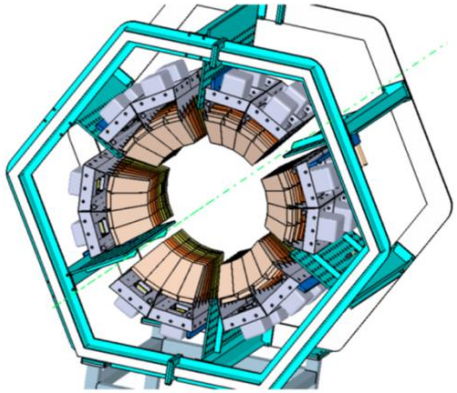
- Huge dynamic range
  100 keV γ-rays – 700 A MeV charged particles
- high efficiency, good resolution
- high granularity → Doppler correction
- particle identification

USC-IEM UVigo | GSI-TUM EMMI-TUD | Chalmers Lund | CFNUL | JINR NRC

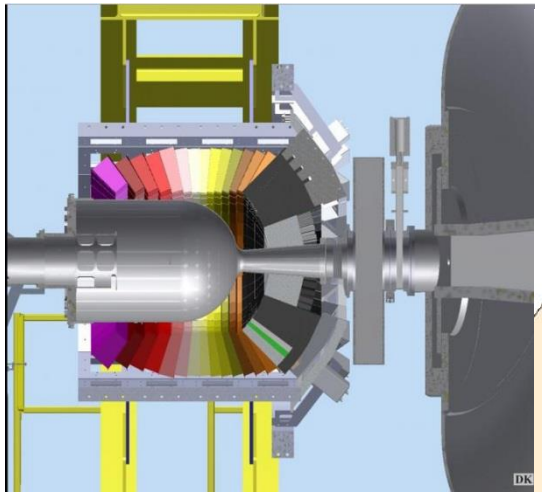
CALIFA : Status

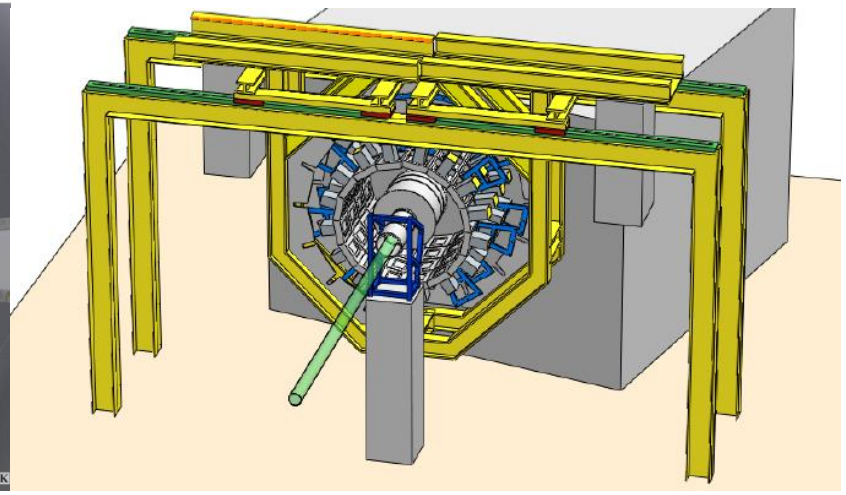
Construction of 12 petals (~ 768 Barrel detection channels) is foreseen to be completed within 2016/7





Partial detector available 2018 ➔ Cascade reconstruction





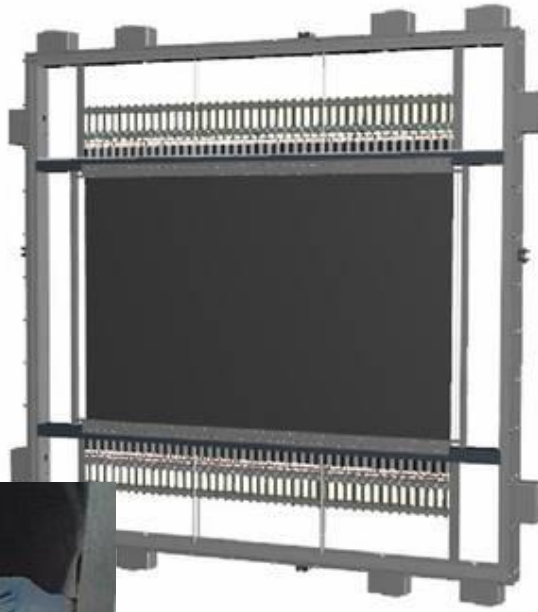
Time-of-flight wall prototyping

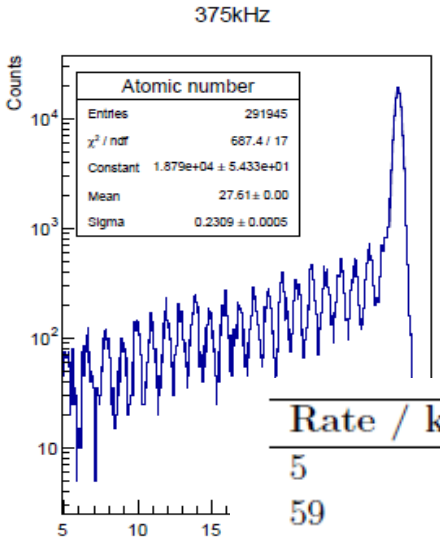
M. Heil, Tracking WG, RBEE

Performance goals:

- Time resolution σ_t/t = 2E-4
  ($\Leftrightarrow$ σ_t =20 ps for 20 m flight path at 1 *A*GeV)
- Energy resolution σ_E/E = 1%
- High-counting rate capabilities (~1 MHz)
- Large dynamic range (up to Pb-U).
- **FPGA based TDC** readout (ΔE via ToT Techniques)

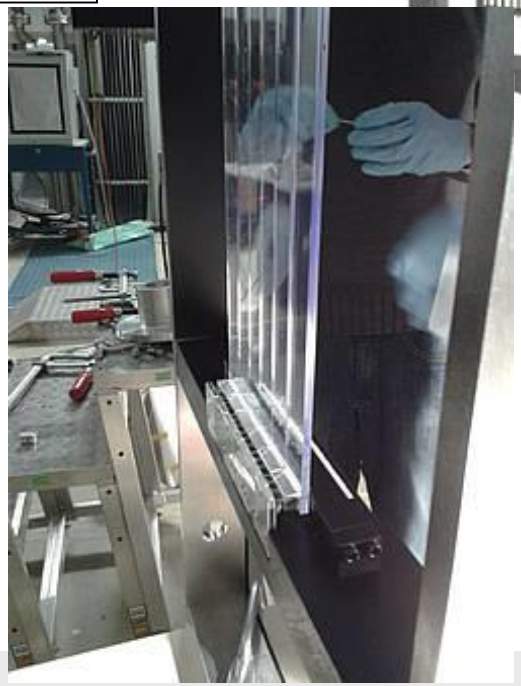
Detector layout





Excellent time and energy resolution at high rates

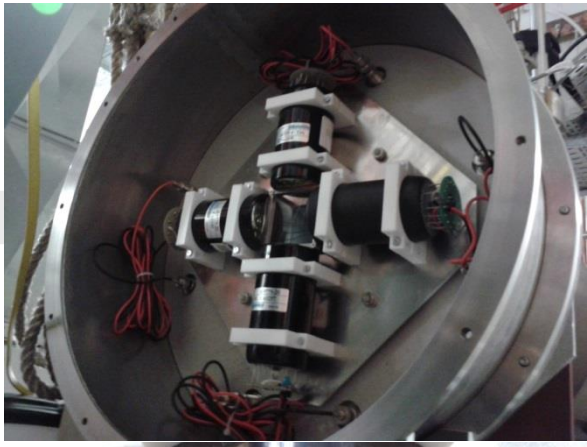
Rate / kHz	σ_t / ps	σ_t^{det} / ps
5	41	14
59	41	14
375	45	16
1000	64	23



Prototype studies
@ Cave-C
08/2014
10/2014
05-07/2016

Start detector „LOS“

M. Heil, Tracking WG, RBEE

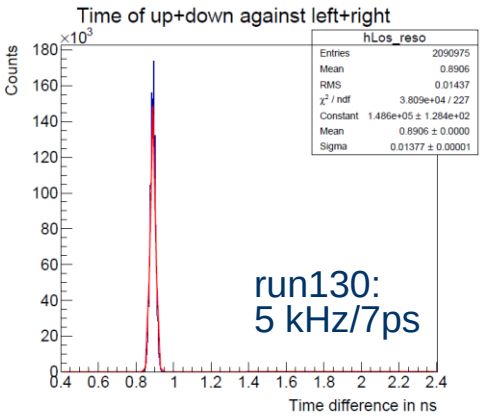


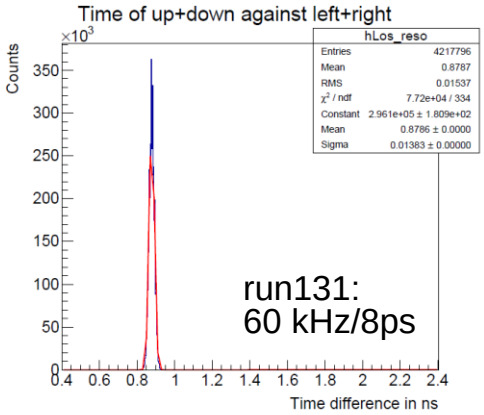
- EJ230 scintillator with thickness of 0.5 mm
- Aluminum frame for stabilization of thin scintillator foils
- active area: 5 x 5 cm^2
- 4 Hamamatsu R9779-20 PMs, TTS: 250 ps
- Mesytec MCFD16-PMT constant fraction discriminator

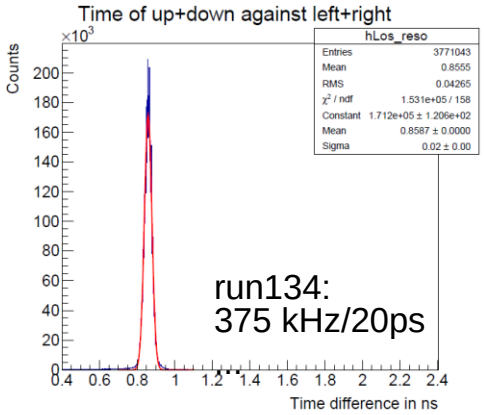
  - LOS: $t_{(up+down)}$-$t_{(left+right)}$ = 14 ps
  -

⇒ detector resolution: σ_t = 7 ps

⇒ .. stable at high rates





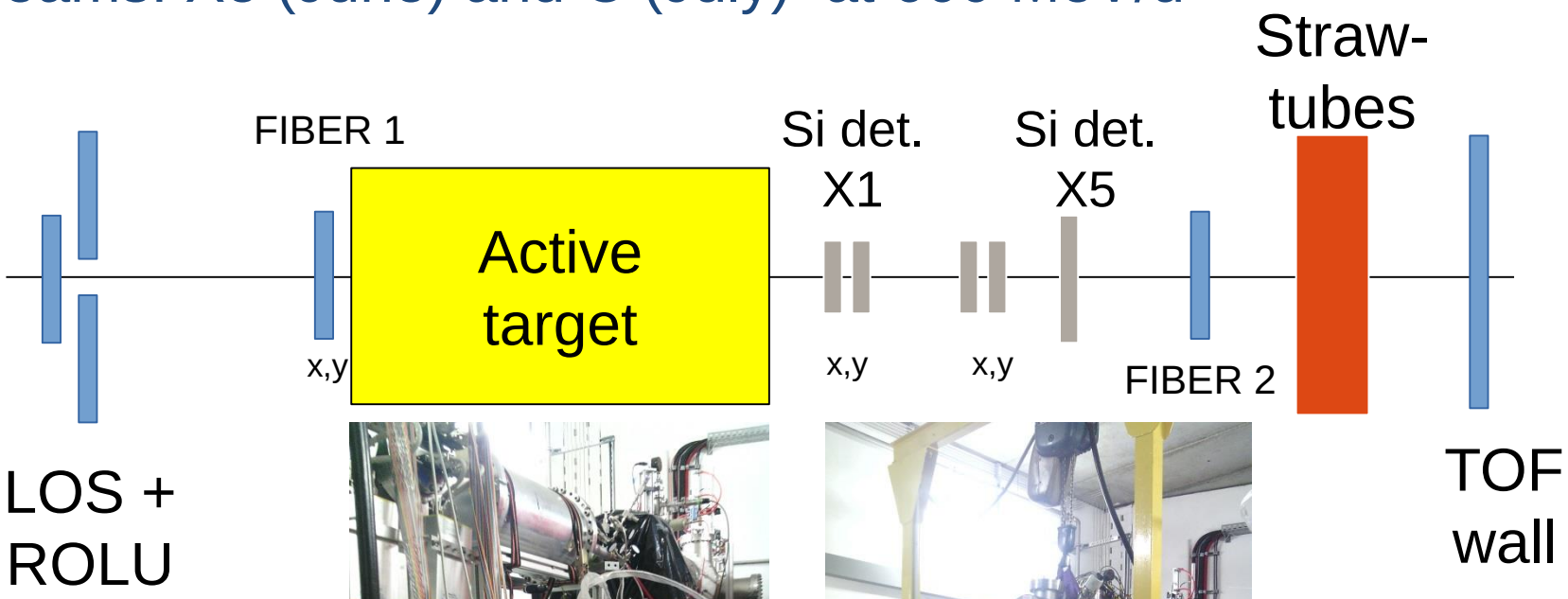


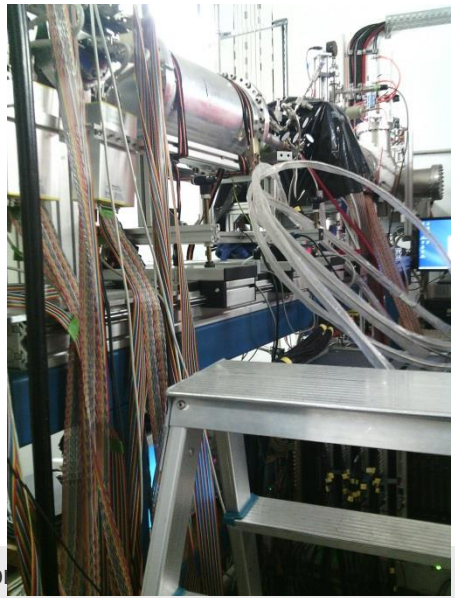
Beam tests of tracking system prototypes

PNPI Gatchina/TU-Darmstadt

Cave-C/HTD

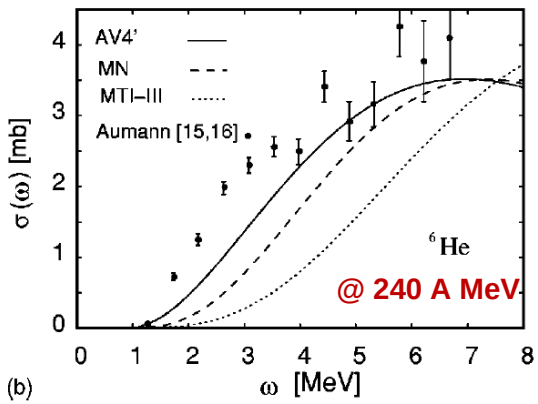
- Beams: Xe (June) and C (July) at 600 MeV/u

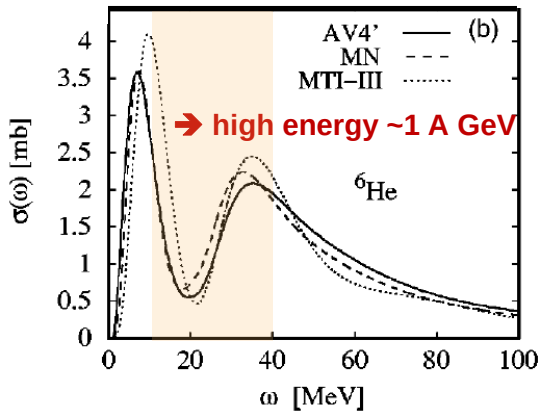




Program starting with 'moderate' beam requirements and make use of high energy beams (on Pb target)

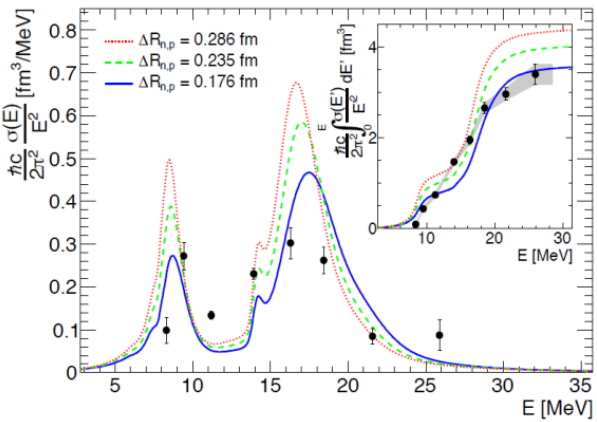
- core vs. neutron skins & halos → density / asymmetry





S. Bacca et al.
PRL **89** (2002) 052502
PRC **69** (2004) 057001

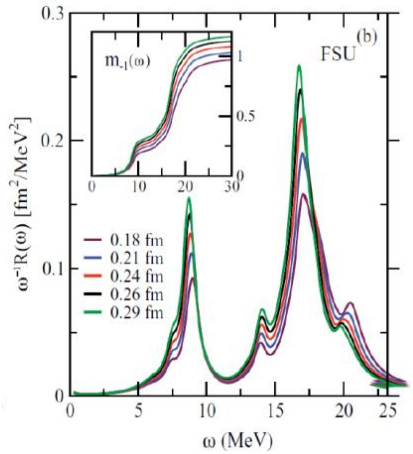
- access to EoS (e.g. neutron star) & low lying E1 strength (r-process)



$$\alpha_D = \frac{\hbar c}{2\pi^2}\int_0^\infty \frac{\sigma(E)}{E^2}dE$$

D. Rossi et al.
PRL **111** (2013) 242503

skin thickness **^{68}Ni**
0.175(21) fm



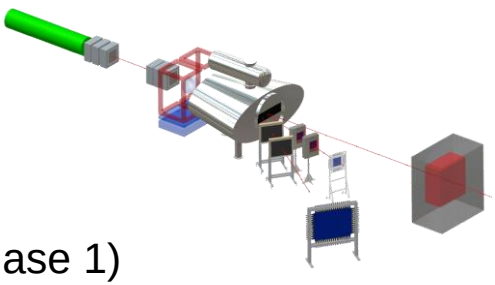
Pb chain & N=126 isotones

~1 A GeV →
bare ions
Fragment identification

J. Piekarewicz, PRC **83** (2011) 034319

Schedule and first experiments

2014	Installation of 20% detectors NeuLAND and CALIFA Commissioning run in Q3/2014 done.
2015/16	Construction and installation of detector components
2017/18	Commissioning of full R3B setup (Cave C)
2018-202x	Physics runs at GSI (Cave C) (phase 0)
202x-202x+1	Move to High-Energy Branch building
202x+1 →	Commissioning and first experiments at Super-FRS (phase 1)



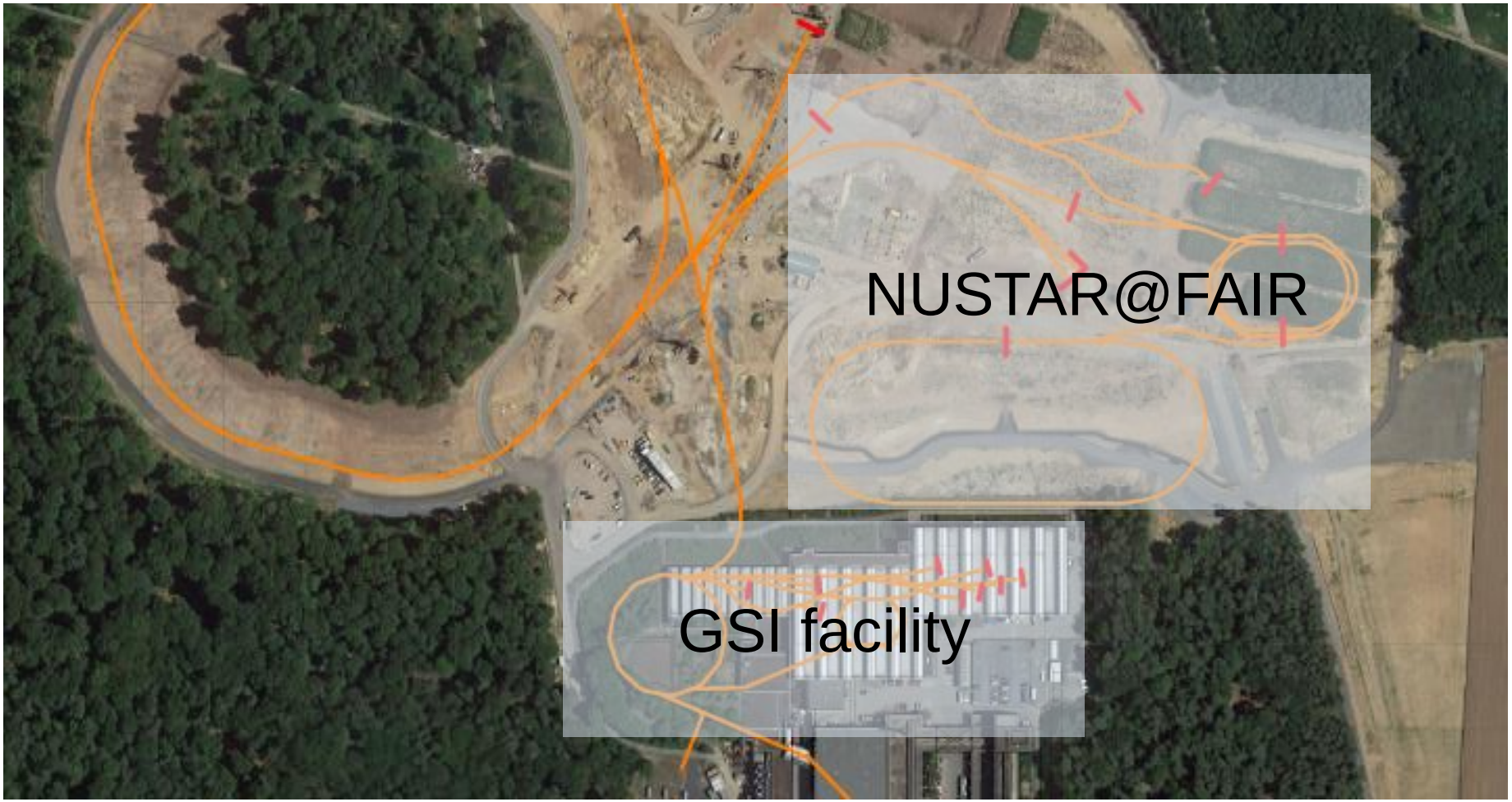
Experiments will make use of uniqueness of R^{3}B (and benchmark components):

- Reactions at high beam energies up to 1 GeV/nucleon
- Tracking and identification capability even for the heaviest ions
- Multi-neutron tracking capability, high-efficiency calorimeter

Experiments possible for the first time:

- Multi neutron decays beyond the drip-line (also heavy n-rich isotopes)
- Kinematically complete measurements of quasi-free nucleon knockout reactions
- Electric dipole and quadrupole response of Sn nuclei beyond N=82,
  and of neutron-rich Pb isotopes (polarizability, symmetry energy)
- fission barriers from (p,2p) reactions (SOFIA)

Outlook: Areal view of the combined facility



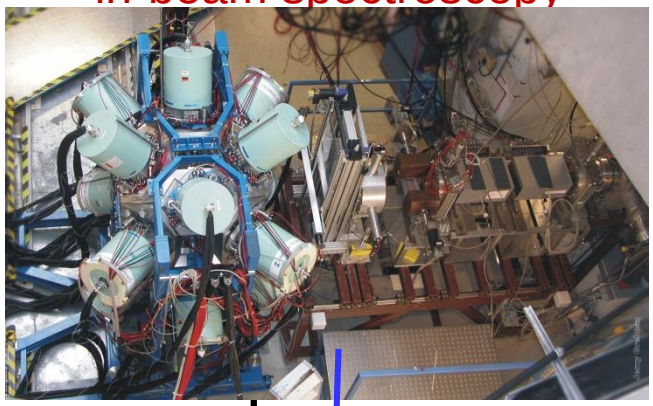
Thanks to all collaborators …

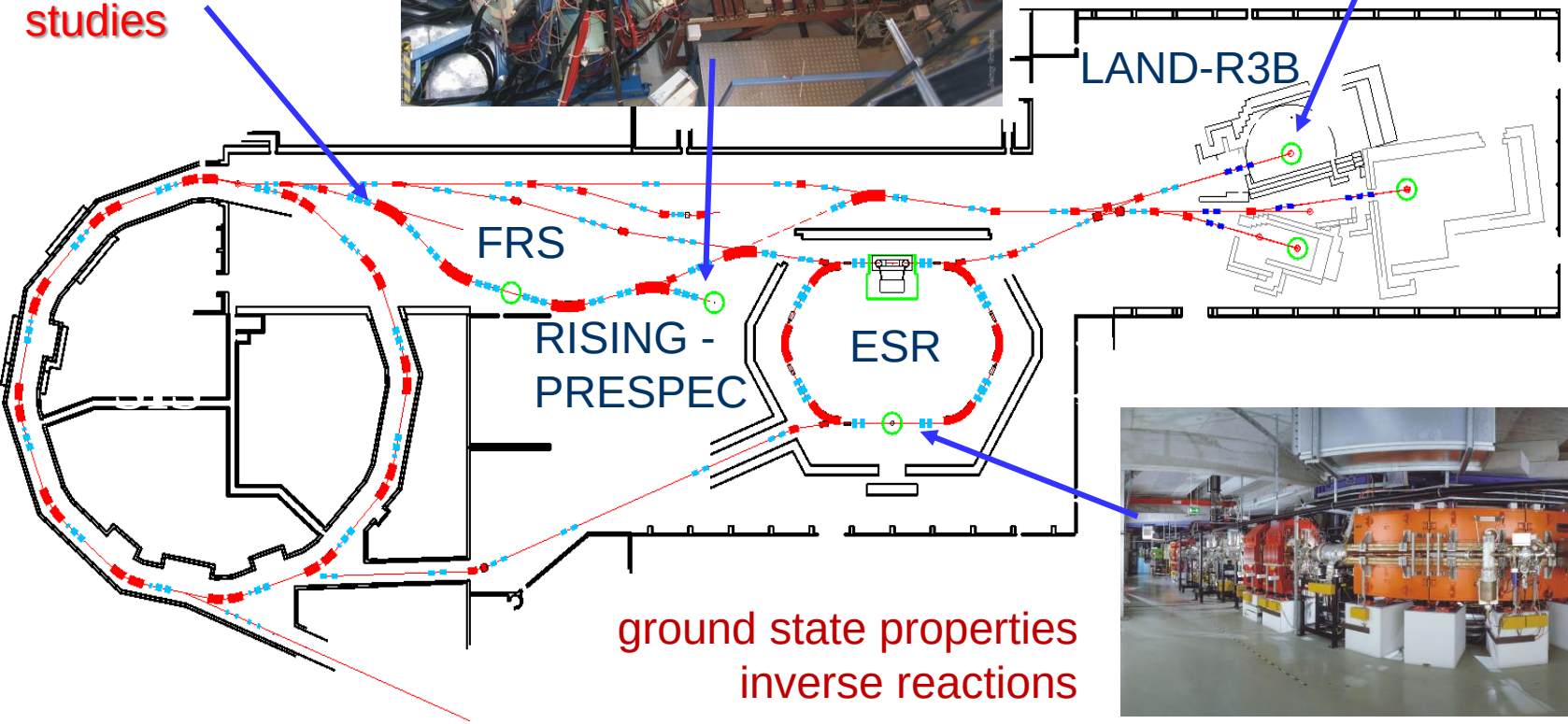
Existing research opportunities at SIS

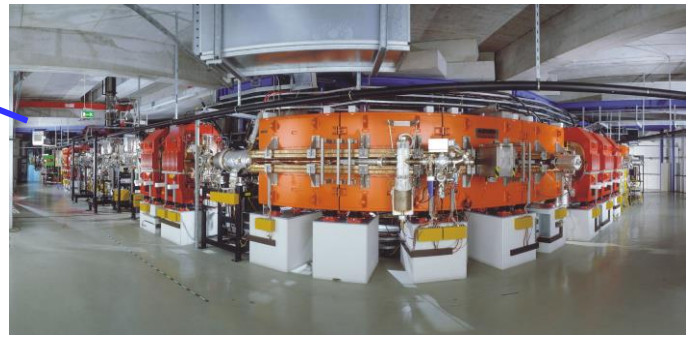
decay studies,
in-beam spectroscopy

reaction studies

production and
separation of
exotic nuclei
high resolution
spectrometer
studies







ground state properties
inverse reactions

[1] After warm up time of 30 min.

Characteristics

Maximal output current (I_{max})	**3800 A**
Magnet nominal current (I_N)	**3584 A**
Output voltage range	**+8 V / -8 V**
Short term current stability (1h)	< 50 ppm
Long term current stability (8h)	< 100 ppm 1
Output current setting range	from 0 to I_{max}
Current setting resolution	< 50 ppm
Current accuracy	< 50 ppm
Current reproducibility	< 200 ppm
Ripple and noise (10 Hz / 10 MHz range)	**< 50 mV p to p**
Ramp up, ramp down slew rate	**min 0.1 A/s to max 2 A/s. (§ 6.3)**
Ramp precision	**±0.05 A/s**
Communication interface	**Profibus DP**
Mains power	400 VAC ±10% / 50 Hz ±5 %
Line regulation (±10%)	< 50 ppm
Cooling	Water or air
Ambient temperature coefficient	< 10 ppm/°C
Insulation resistance	> 1MΩ

COMMAND interface

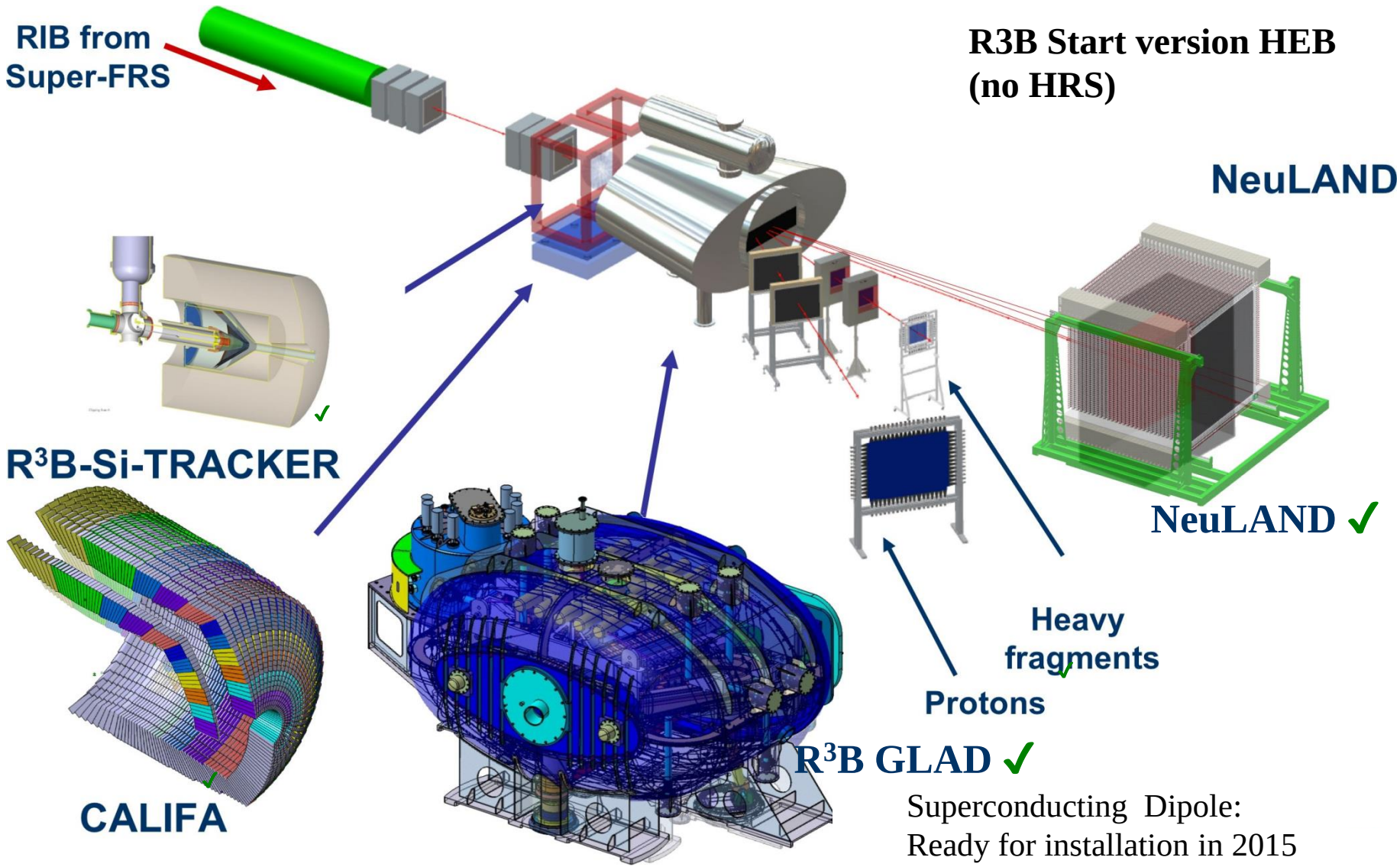
Control power ON/OFF switch
Power ON command

Local/remote button (start in remote mode)
Reset push button

Current setting (resolution < 10^{-4})

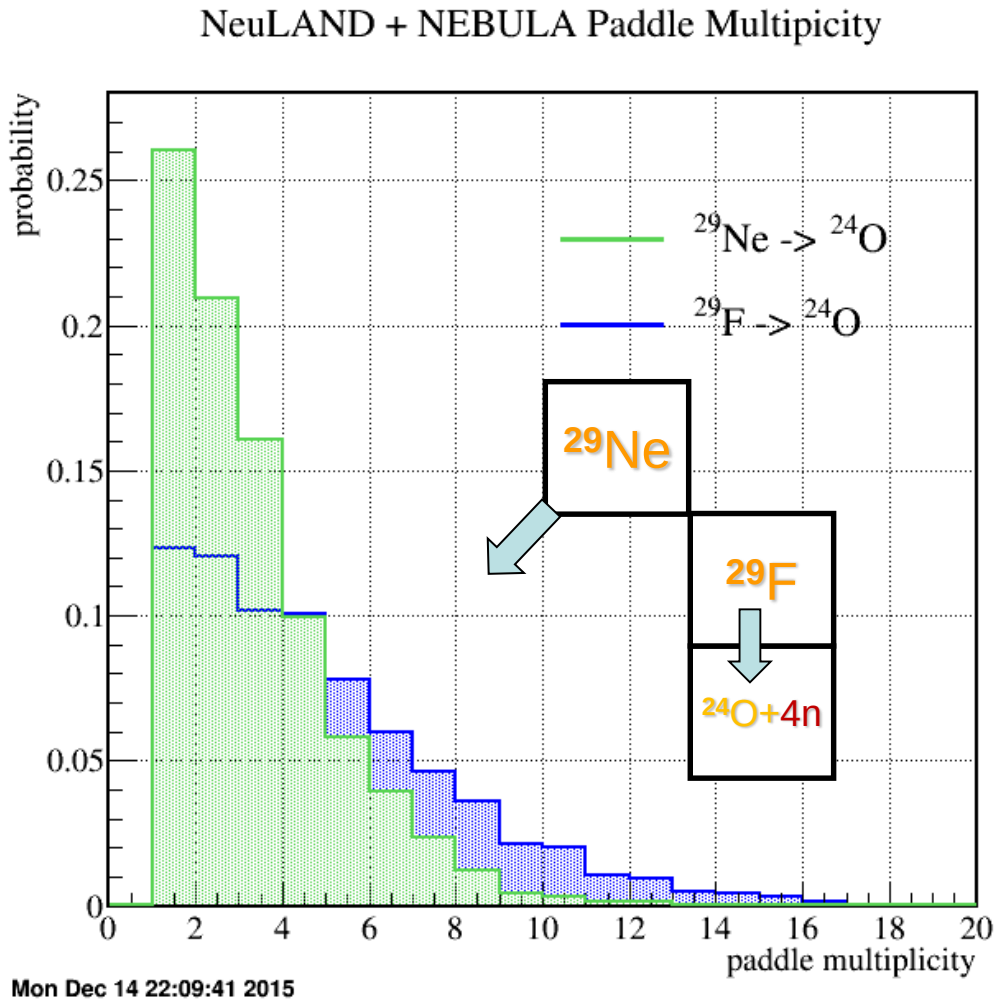
Slew rate setting: 0.1 to 2 A/s

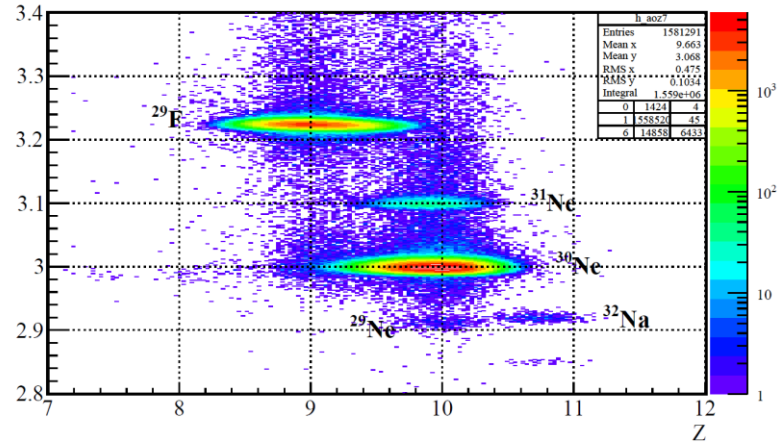
Reactions with Relativistic Radioactive Beams R³B

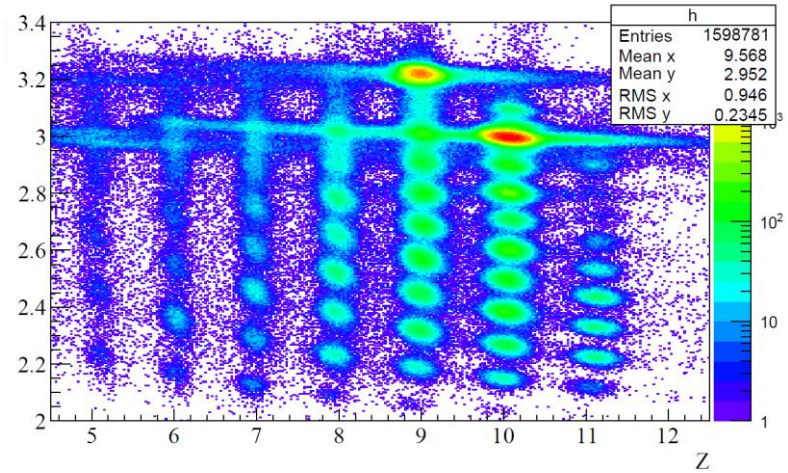


Superconducting Dipole:
Ready for installation in 2015
Construction by CEA Saclay

RIKEN: “Performance studies for the prototype”







Efficiency evaluations in progress … not only ;o)

J. Kahlbow/TUDA

NUSTAR experiments

N. Kalantar

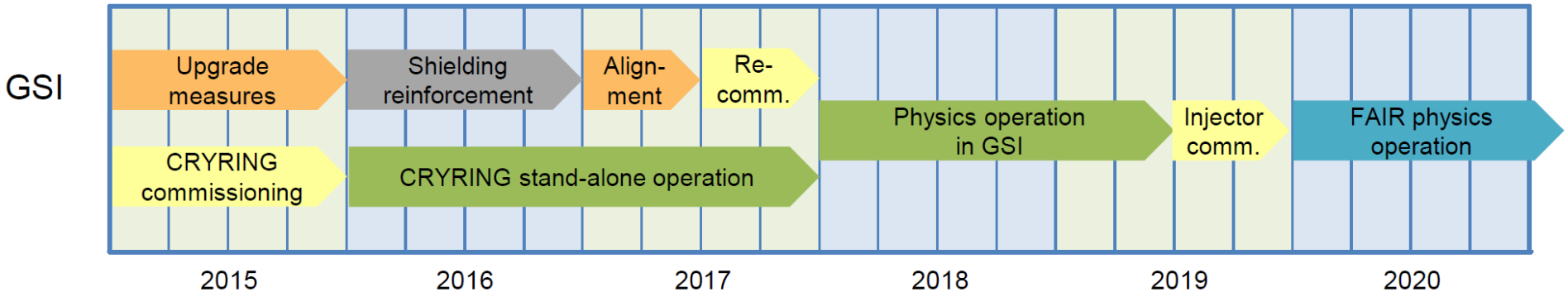
Super-FRS	RIB production and identification
DESPEC	γ-, β-, α-, p-, n-decay spectroscopy
HISPEC	in-beam γ spectroscopy at low/intermediate energy
ILIMA	masses and lifetimes of nuclei in ground and isomeric states
LASPEC	Laser spectroscopy
MATS	in-trap mass measurements and decay studies
R^3B	kinematically complete reactions at high beam energy
ELISE	elastic, inelastic, and quasi-free e⁻A scattering
EXL	light-ion scattering reactions in inverse kinematics
Super-FRS physics	high-resolution spectrometer experiment
Superheavy elements	synthesis, nuclear structure, atomic physics, chemistry experiments with elements Z ≥ 104

The Approach

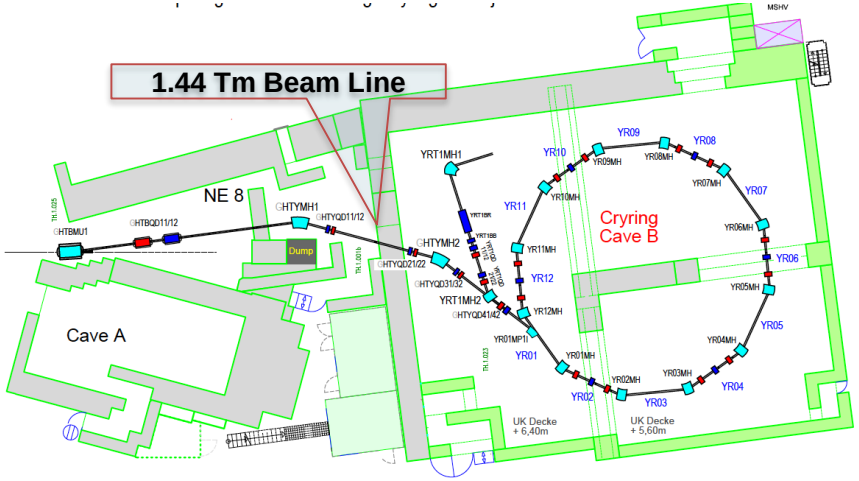
Complementary measurements leading to consistent answers

CRYRING

D. Ondreka, F. Herfurth



12/2014

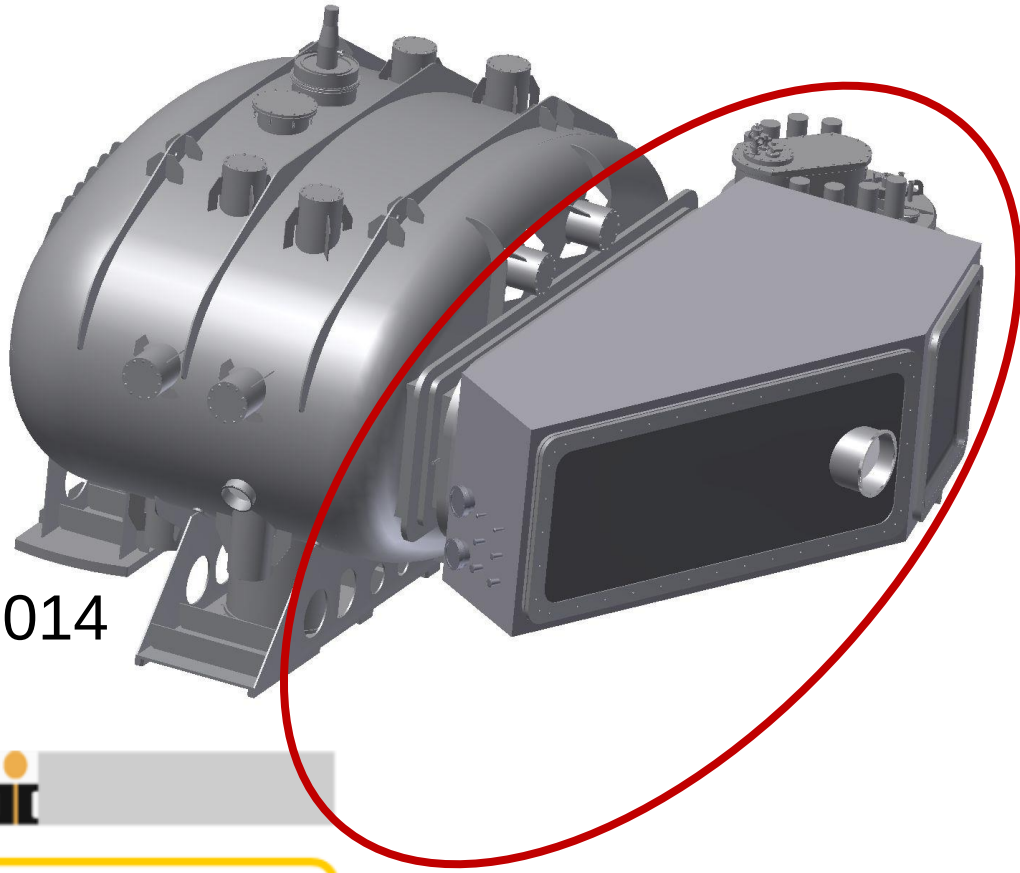


➔Cryring is a FAIR in-kind component

GLAD cryosystem – Emergency Nappy

GLAD - Vacuum Chamber

- Full Tracking in Vacuum
- Few Cubic Meters
- Tendering closed 2.12.2013
  order for technical design
  and construction placed
- Ready in September
- Delivery End of November 2014



GSI Helmholtzzentrum für Schwerionenforschung GmbH

Document Title
Functional specification for the GLAD - vacuum chamber

Document Name
F-DS-VC-43e GLAD Vacuum Chamber_R3B_v1.2.pdf

Date yyyy-mm-dd
2013-10-07

GLAD has arrived and is being installed in Cave-C

- Power supply there and tested
- Crypo plant installed and tested
- Magnet has arrived and passed first series of SAT tests

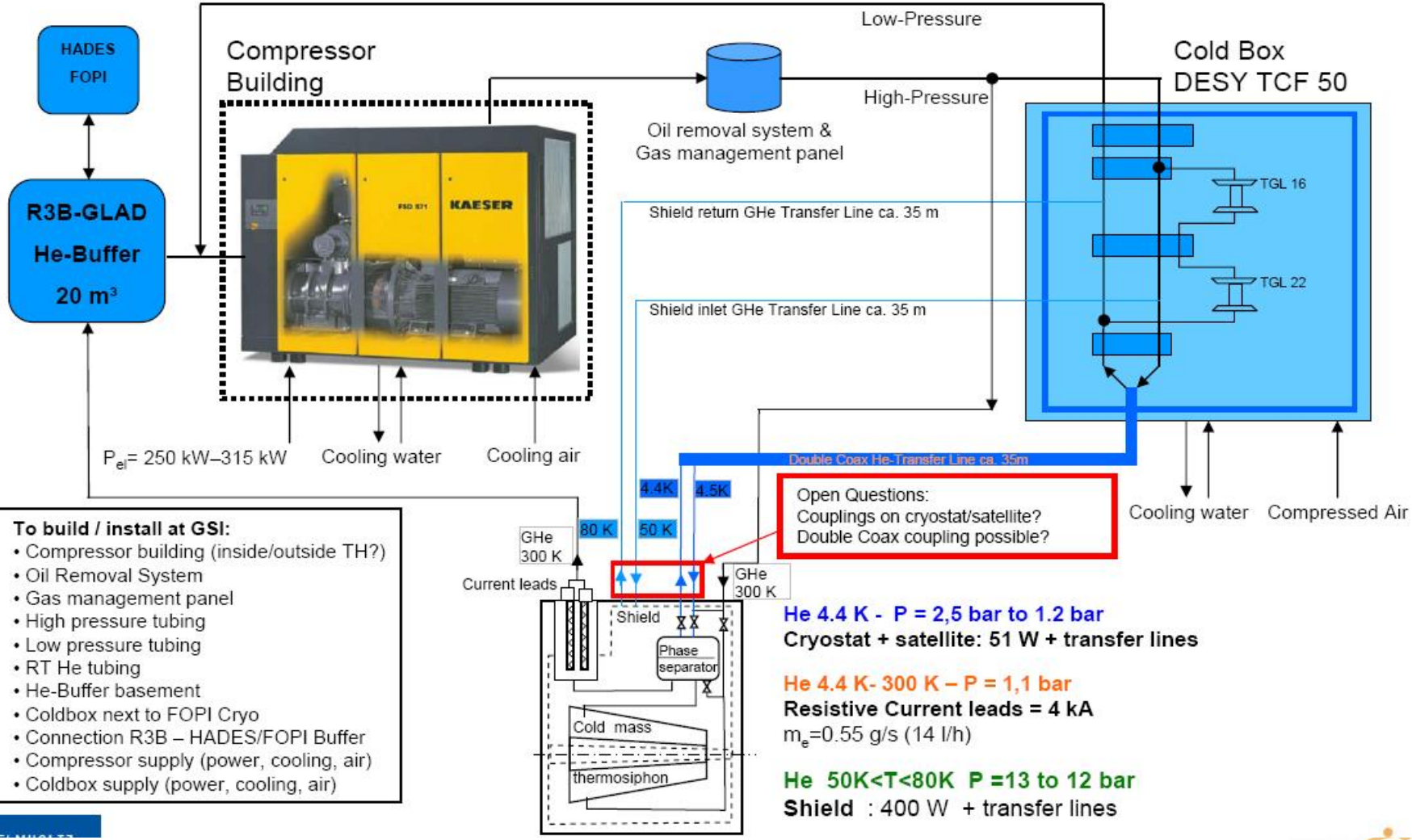
➔ non conformity in the exit flange mitigation in progress

- in-kind contracts with F/D in preparation

- 04/2016 installation of instrumentation and MSS/MCS by CEA
- End 2016 to get magnet into operation!

R3B GLAD Magnet Cryogenics for Cave C

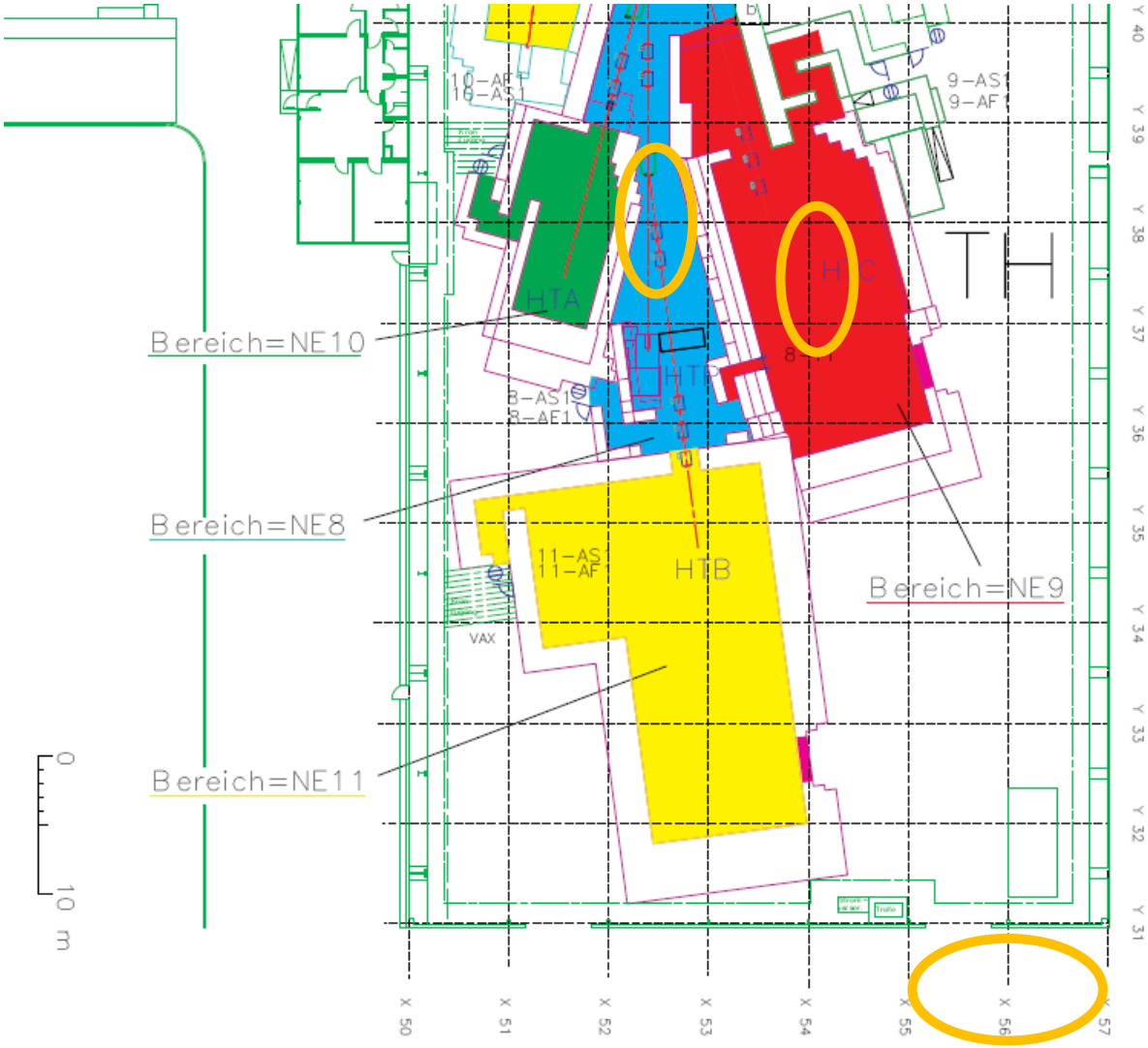
(10.10.2011 Thomas Hackler)

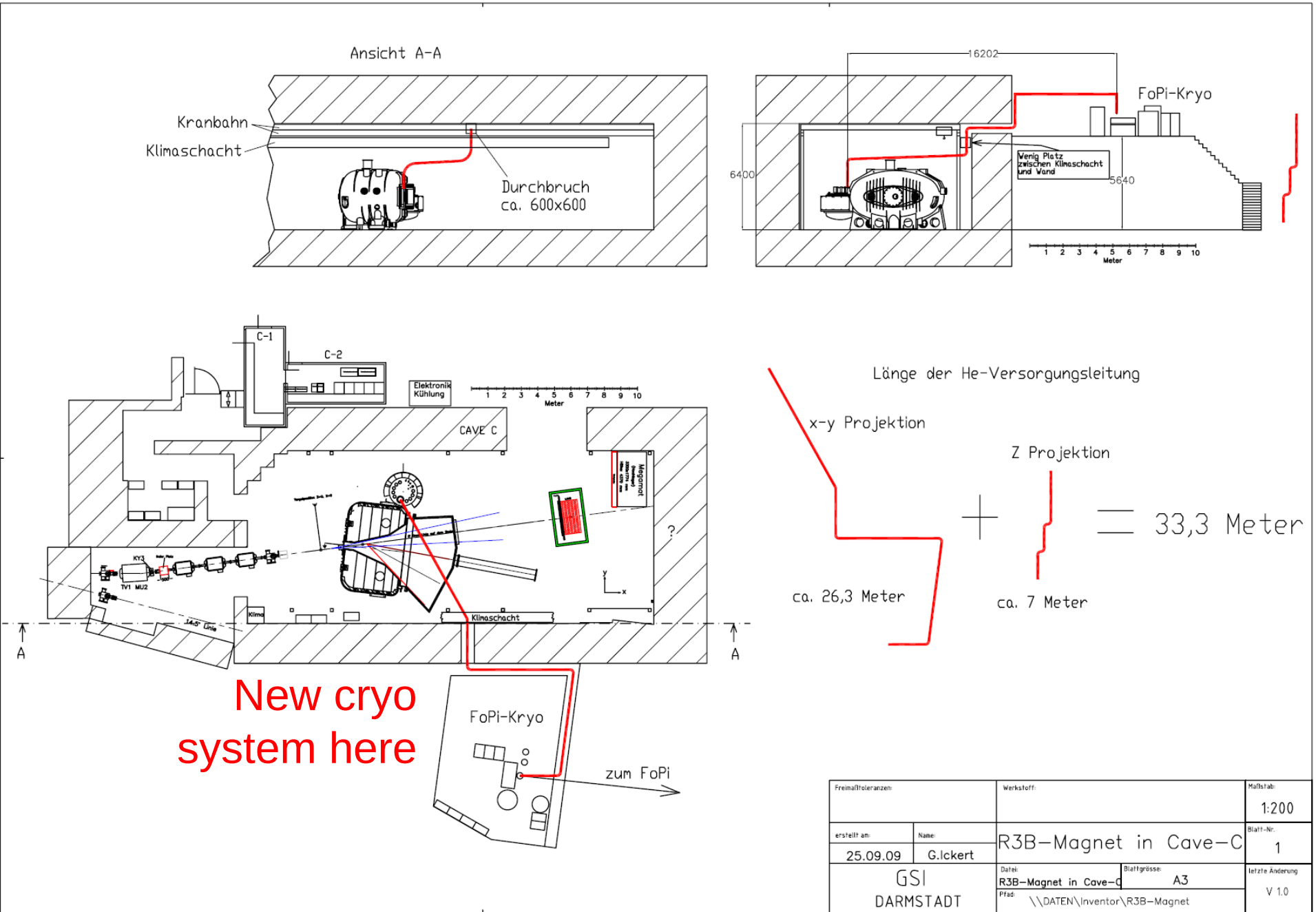


To build / install at GSI:

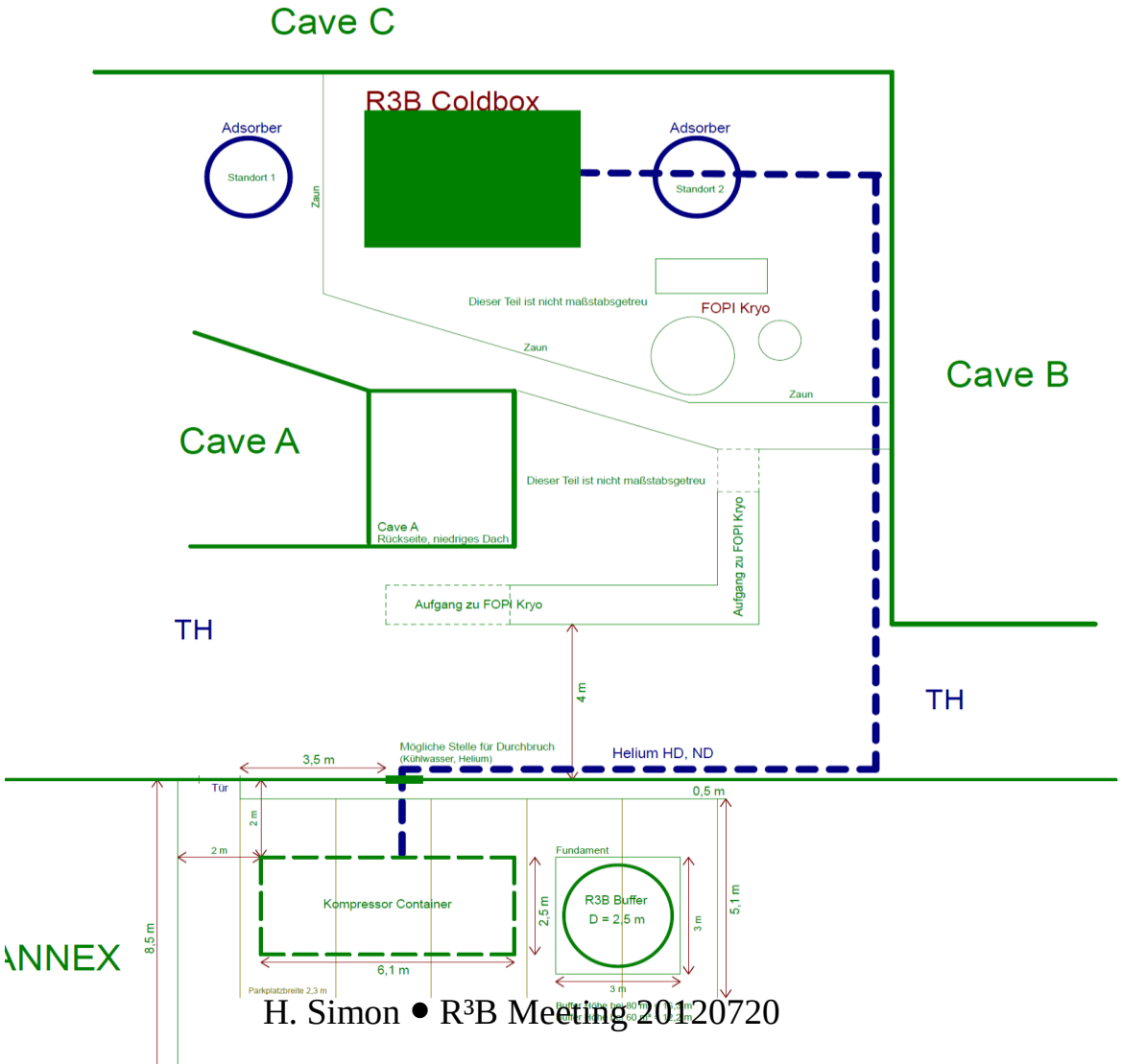
- Compressor building (inside/outside TH?)
- Oil Removal System
- Gas management panel
- High pressure tubing
- Low pressure tubing
- RT He tubing
- He-Buffer basement
- Coldbox next to FOPI Cryo
- Connection R3B – HADES/FOPI Buffer
- Compressor supply (power, cooling, air)
- Coldbox supply (power, cooling, air)

Site preparation




Ansicht A-A
Kranbahn
Klimaschacht
Durchbruch
ca. 600x600
16202
FoPi-Kryo
6400
Wenig Platz
zwischen Klimaschacht
und Wand
5640
1 2 3 4 5 6 7 8 9 10
Meter
C-1
C-2
Elektronik
Kühlung
CAVE C
Magomat
KY3
TV1 MU2
Klima
Klimaschacht
14,5° Linie
A
A
?
New cryo
system here
FoPi-Kryo
zum FoPi
Länge der He-Versorgungsleitung
x-y Projektion
Z Projektion
33,3 Meter
ca. 26,3 Meter
ca. 7 Meter
Freimaßtoleranzen:
Werkstoff:
Maßstab:
1:200
erstellt am:
25.09.09
Name:
G.Ickert
R3B-Magnet in Cave-C
Blatt-Nr.
1
GSI
DARMSTADT
Datei:
R3B-Magnet in Cave-C
Blattgrösse:
A3
Pfad:
\\DATEN\Inventor\R3B-Magnet
letzte Änderung
V 1.0

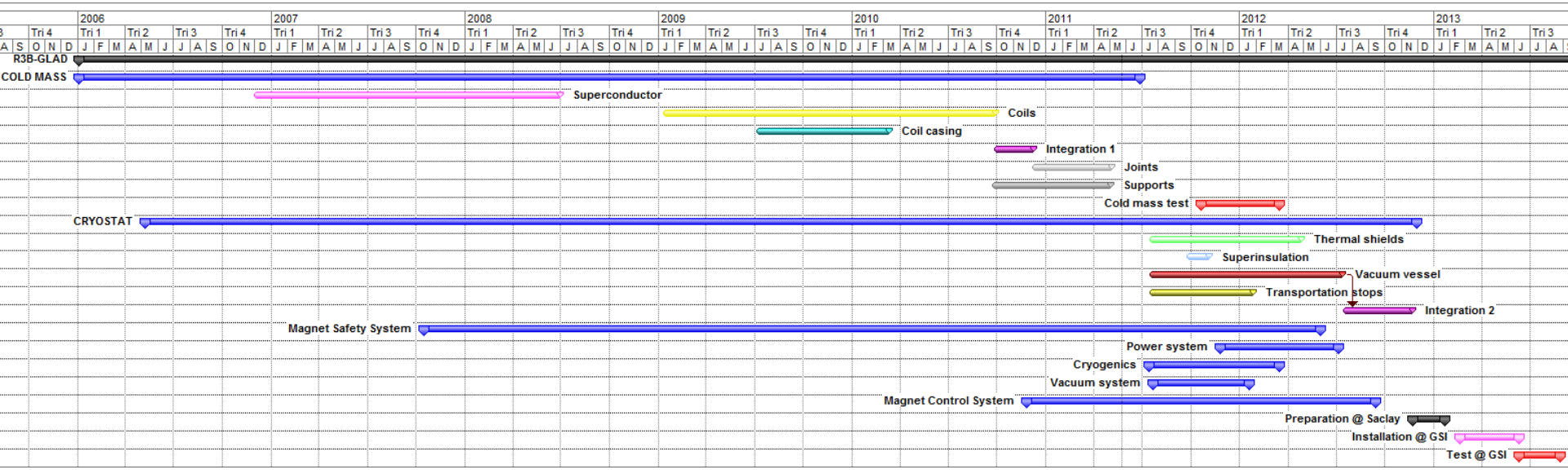
Installation Cryosystem final



Time Schedule (C. Mayri)

R3B-Glad Manufacture schedule *without final test @ Saclay (magnet test @ GSI)*

May 25, 2011



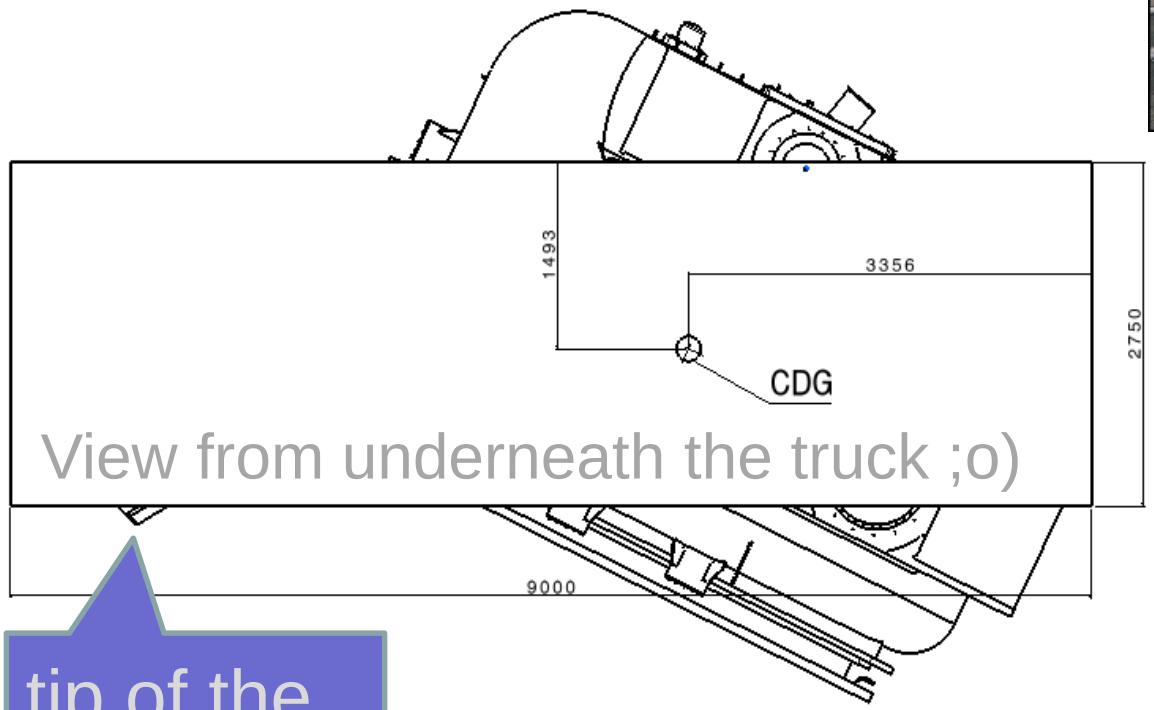
Cryostat order on July 15, 2011

=> Vacuum vessel delivery on July 15, 2012 => Magnet delivery @ GSI in February 2013

- Cryostat Delivery (07/12) ➔ (11 /12)
- CryoPlant@GSI first half 2013
- Magnet Power supply (?)
- Mapping …

Status 07/2012 (C. Mayri)

Transport Issues



tip of the satellite

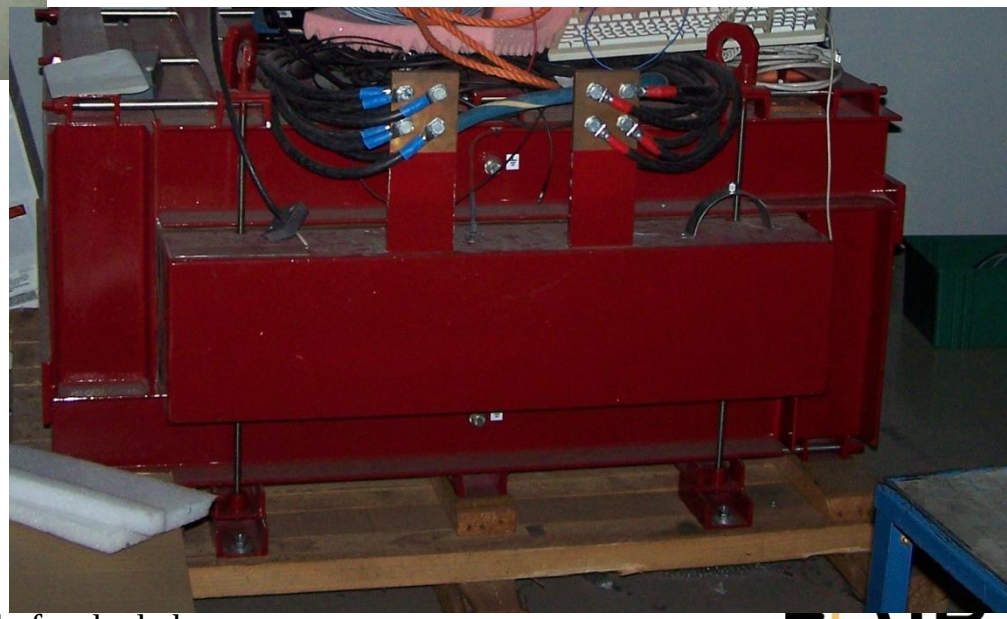
- Magnet (just) fits on a truck ….
  4.3(h)
  x 8.6(l)
  x 5.7(w) m³
- Weight: 58t

Transport: CEA
Unloading: GSI

GLAD power supply – Next Steps

Finalize cabling

Daniel



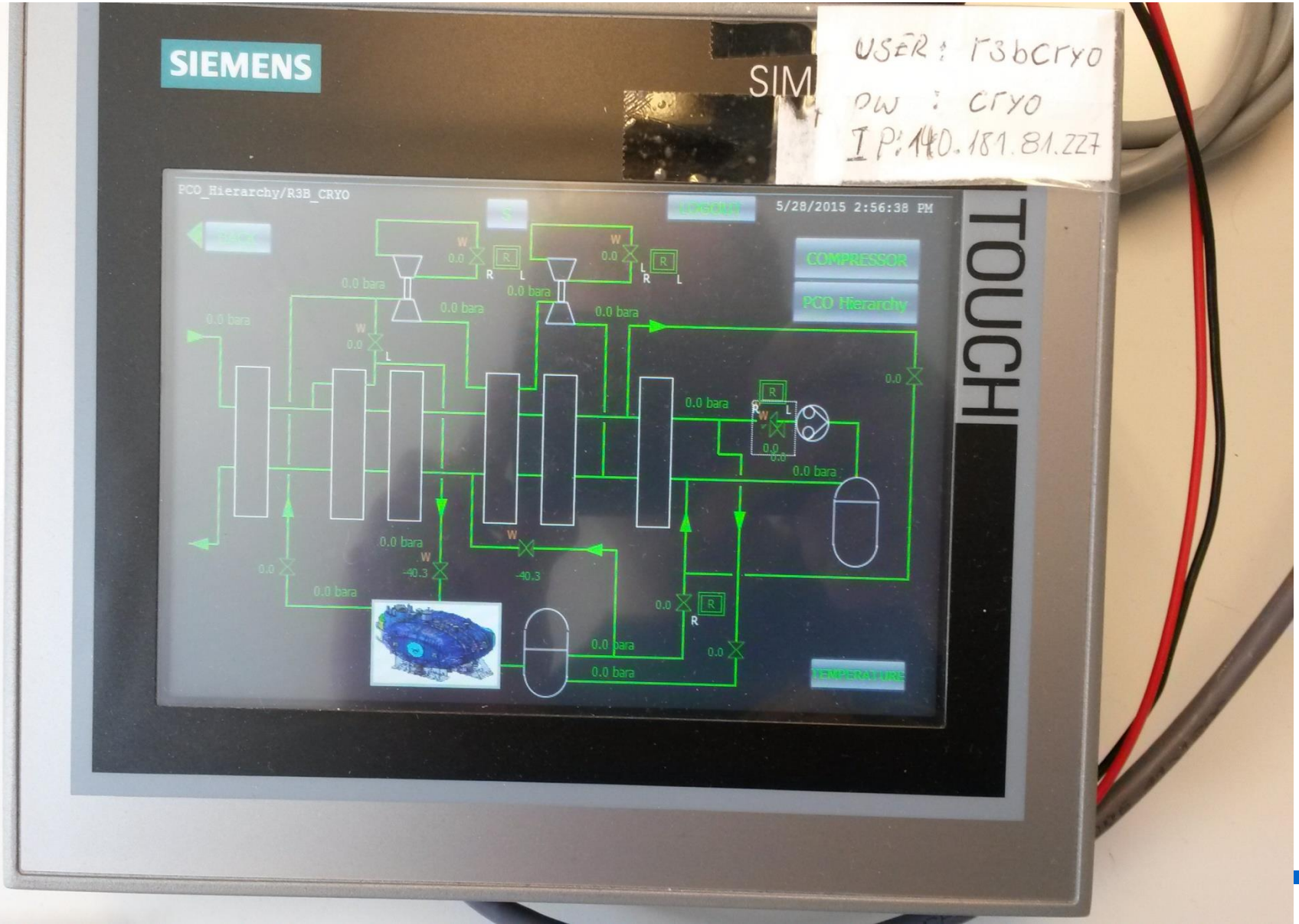
SAT 1a with dummy load

GLAD cryosystem – The kitchen

- Refurbished TCF50 cryo plant from DESY (new compressor)
- Test stand for R³B/GLAD 2014-
- Later use for Plasma physics

- Prototype for FAIR Cryo plants:
  - UNICOS controls
  - Instrumentation
  - PLC

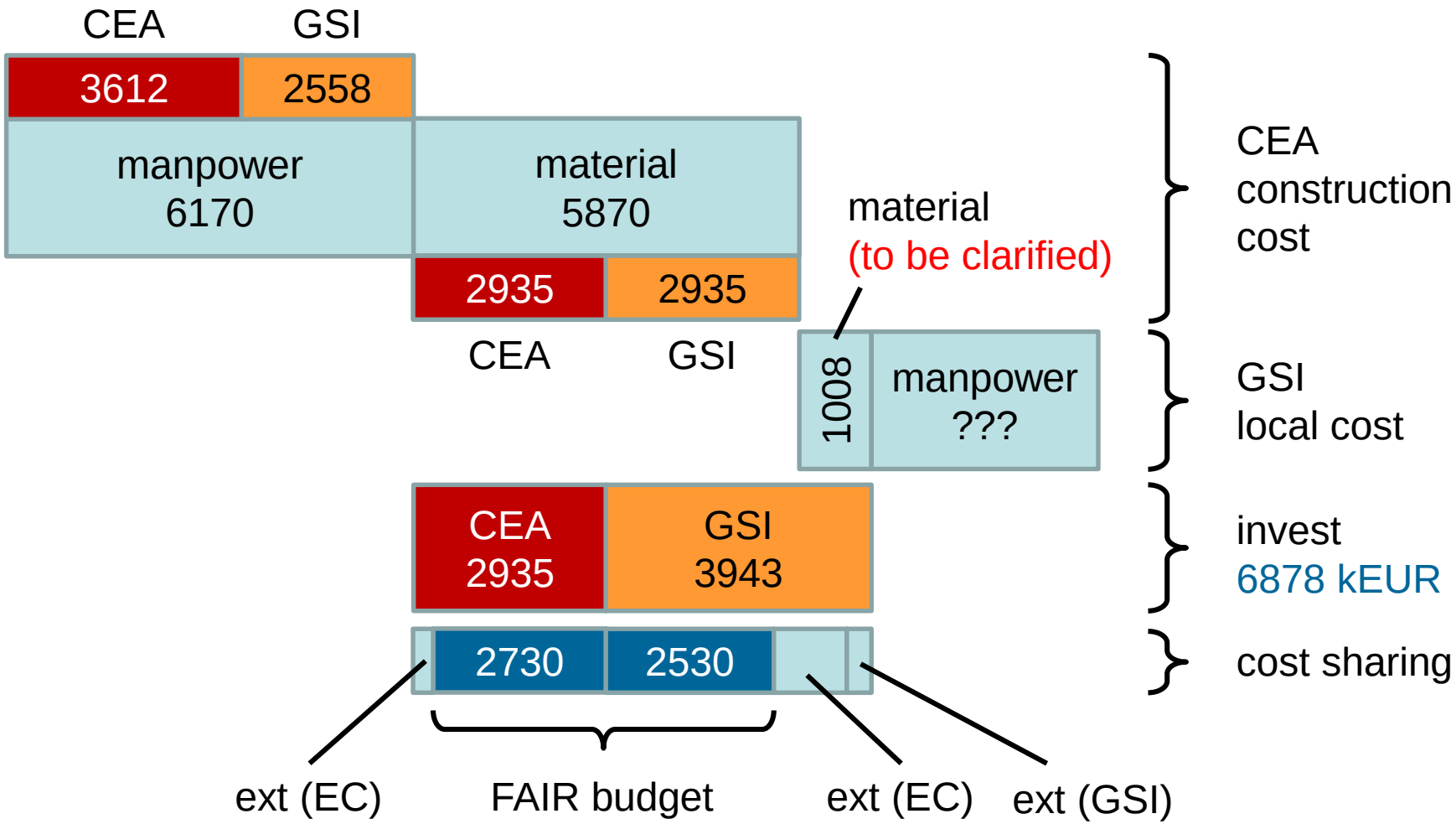
GLAD cryosystem – Local Menu



R³B – GLAD construction cost – update

A. Herlert

- GLAD magnet construction cost (January 2015)
  - Detailed cost overview (CEA Saclay + GSI local cost) in kEUR 2005



GLAD as in-kind: Franco-allemande

- Total value : more than 13 M€ (includes R&D)
- Initial budget: 5.5 M€ (3.5 EU + 1.5 R³B + 0.5 CEA)
- Invest via PMA/Germany ~2.4 M€
- Invest via CEA about the same

- Infrastructure Invest via GSI ~ 0.6 M€
- Infrastructure Invest via R³B collaboration: 25k€

  to come: insurance for transport

FAIR requires specific FAT/SAT procedures & CE ‚readiness' or certificate / pressure vessel / em conformity

Proposed FAT: Cold mass test + tightness report cryostat
Proposed SAT1a: Documents necessary to apply for CE + *magn.*
SAT1b: Functional magnet goes to FAIR Cave?

2015 Collaborative effort to get magnet working @R³B-Cave-C

GLAD as in-kind: Franco-allemande

Sharing of Investments currently under negotiation

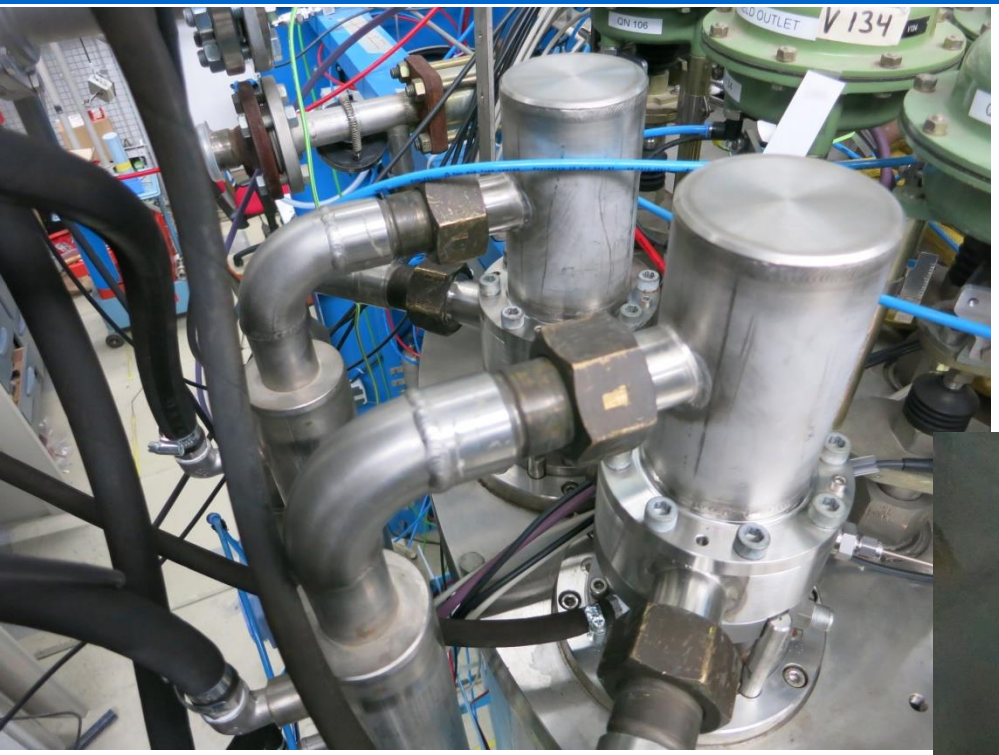
- Add. Infrastructure: vacuum + chamber, cryo-teststand, power supply, air cushion: via GSI
- Add. Infrastructure via R³B collaboration: transport aid to come: insurance for transport

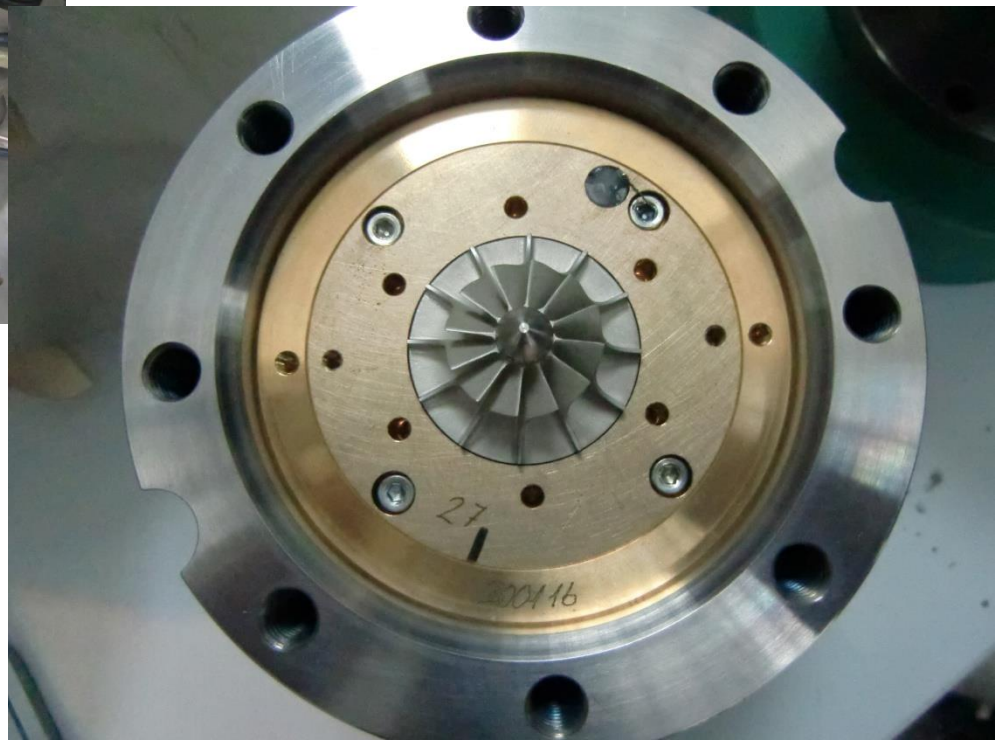
FAIR requires specific FAT/SAT procedures & CE ‚readiness' or certificate / pressure vessel / em conformity, TDR is @FAIR

Proposed FAT: Cold mass test + tightness report cryostat
Proposed SAT1a: Documents necessary to apply for CE + *magn.*
SAT1b: Functional magnet goes to FAIR Cave?

2015 Collaborative effort to get magnet working @R³B-Cave-C
➔ Delivery contract for specification

GLAD Cryosystem- Tests





GLAD - Vacuum Chamber

- Manufacturing @ VA-TEC
- Lifting points
- Adjustable Feet

GLAD - Vacuum Chamber

- Delivery to testing hall
- SAT vacuum test

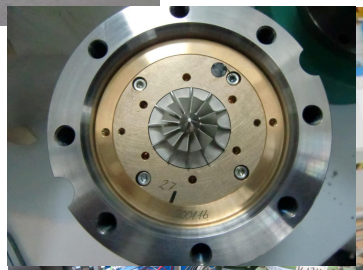
  1st pumping ~10^{-5} mbar / few h (!) GLAD replaced by Al-plate

  ➔ manufacturing geometry double checked

GLAD cryosystem
(test bench @ test stand & Fair component)

T. Hackler

- Refurbished TCF50 cryo plant from DESY (new compressor)
- Test stand for R³B/GLAD 2014-
- Later use for Plasma physics



- Prototype for FAIR Cryo plants:
  - UNICOS controls
  - Instrumentation
  - PLC

- Phase-0 program viable and in preparation
- Major components become all operational

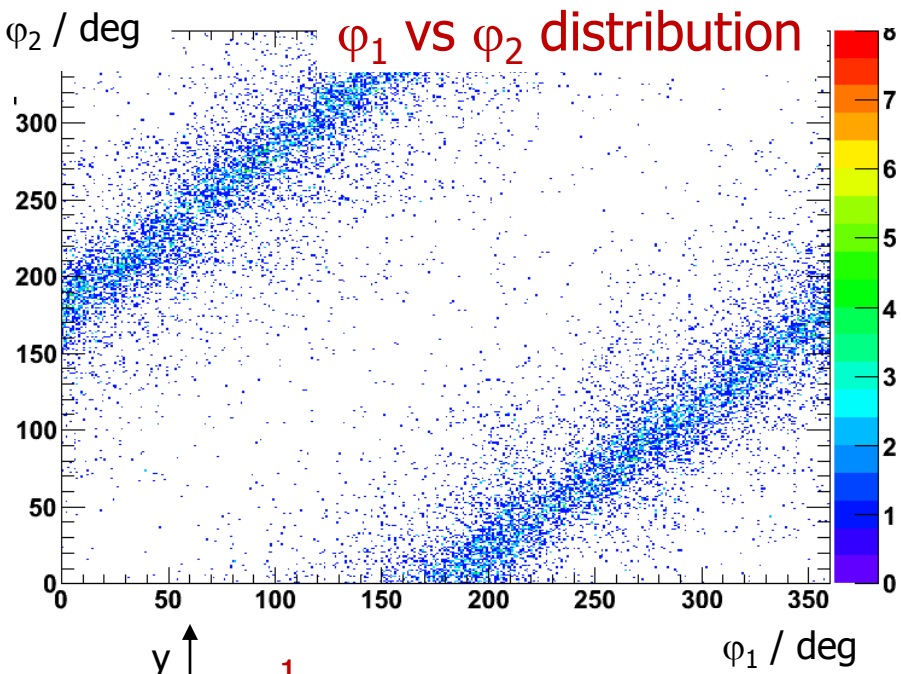
Common developments !
→ Common EDAQ, systems... controls, software ...

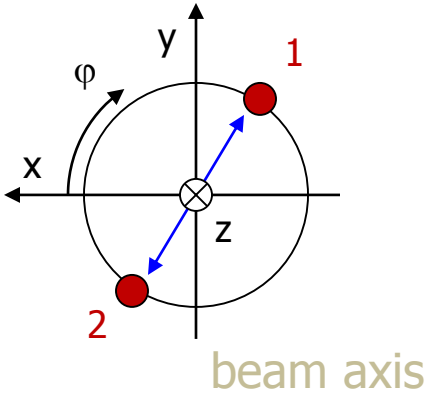
„We'll be ready for 2018 ff"

... stay tuned

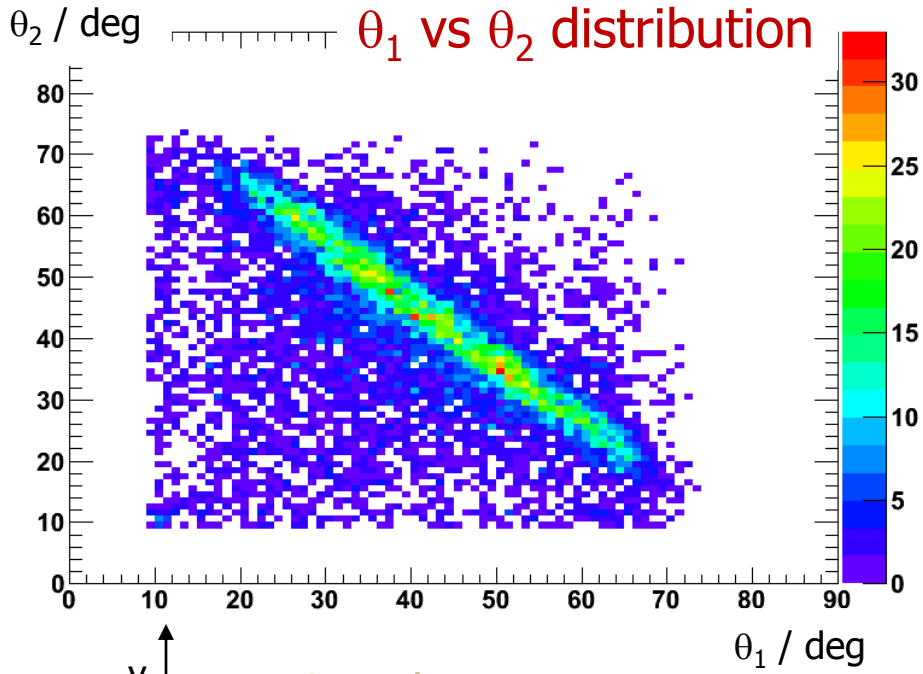
Target Recoil Detection

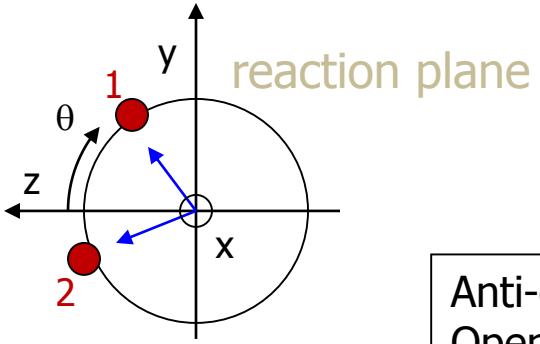
Data: F. Wamers ^{17}Ne(p,2p) @ 500MeV/u, CH_2





Correlation in φ:
Δφ = 180°





Anti-correl. in θ:
Opening angle ≈ 83°

➔ Clear signature for (p,2p) reactions

Incredients for the ^{7}H case

- t + n + n + n + n

PHYSICAL REVIEW C 77, 054317 (2008)

Strong dineutron correlation in ^{8}He and ^{18}C

K. Hagino,[1] N. Takahashi,[1] and H. Sagawa[2]

Core +4n (HFB)

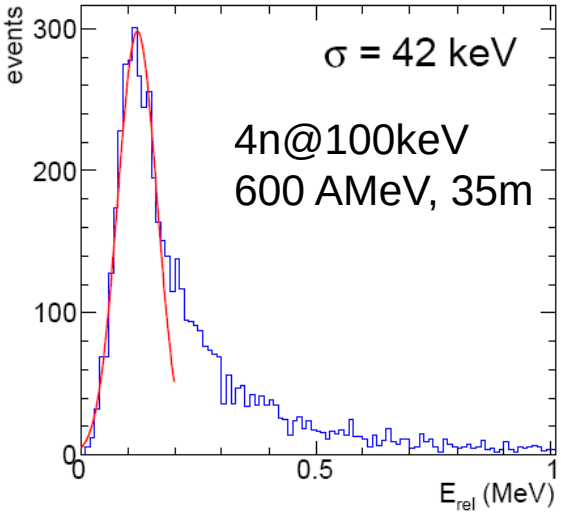
PHYSICAL REVIEW C 80, 021304(R) (2009)

Di-neutron correlations in ^{7}H

S. Aoyama[1] and N. Itagaki[2]

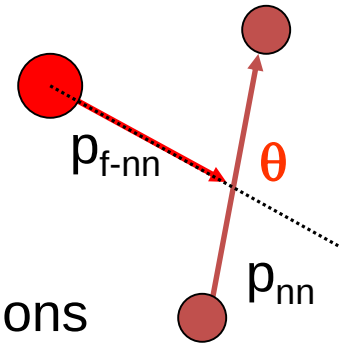
Core +4n

AMD selected snapshots



NeuLAND Simul.

- t + 2n + 2n



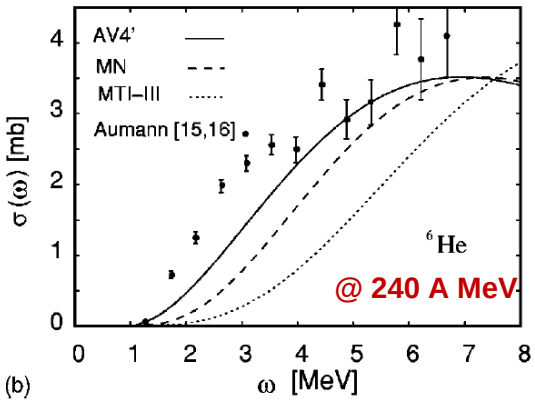
^{11}Li - α → ^{7}H + 2n + 2n

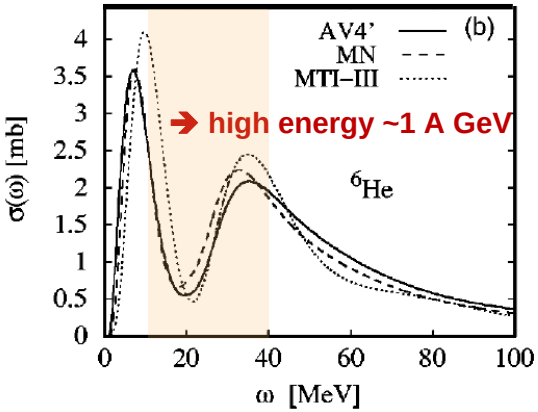
^{8}He – p → ^{7}H + 2n + 2n

➔ Analysis of three body correlations

Dipole strength Distributions in heavy neutron-rich nuclei

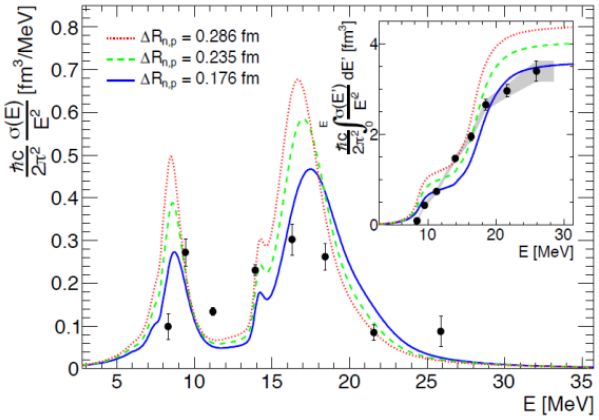
- core vs. neutron skins & halos → density / asymmetry





S. Bacca et al.
PRL **89** (2002) 052502
PRC **69** (2004) 057001

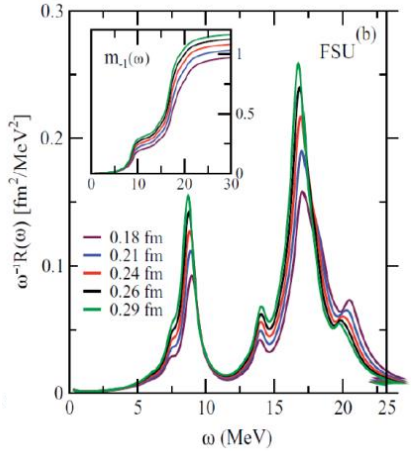
- access to EoS (e.g. neutron star) & low lying E1 strength (r-process)



$$\alpha_D = \frac{\hbar c}{2\pi^2}\int_0^\infty \frac{\sigma(E)}{E^2}dE$$

D. Rossi et al.
PRL **111** (2013) 242503

skin thickness **^{68}Ni**
0.175(21) fm



Pb chain & N=126 isotones

~1 A GeV →
bare ions
Fragment identification

J. Piekarewicz, PRC **83** (2011) 034319

Some Instances are specific

- **LSA :** setting management system, requires physics model of the machine, interface from operator to hardware
  (FRS similar to Super-FRS)

- **Setting Protection System :** intercept dangerous settings before being passed to LSA, requires physic modeling
  (FRS similar to Super-FRS)

- **UNICOS :** industrial solution for FAIR vacuum and cryogenics control ➔ specific adaptation

- **Interlock :** allows or forbids beam in part of the facility depending on hardware status ← conditions, scenarios ➔ model ?

- **Machine Protection System** : fast beam interruption system to avoid damage on the machine in case of beam loss due to hardware failure ← conditions, scenarios ➔ model ?

Intentionally left blank