Status of Korean Initiative

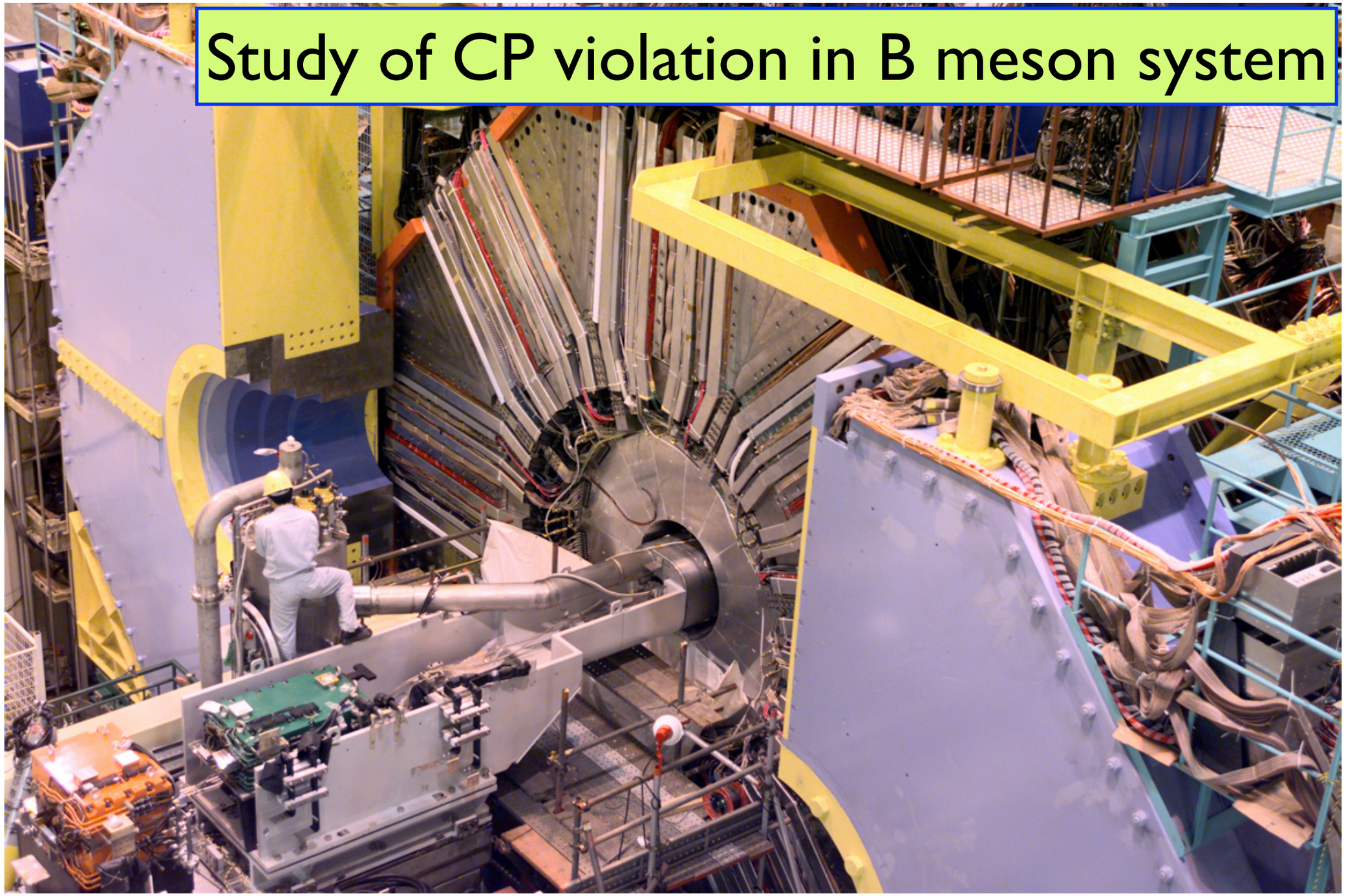
Eunil Won
Korea University

2013. Feb 25

A muSR write-up meeting @ Fermilab

Let me introduce myself...

- I am a high-energy physics experimentalist



Background

The RISP Project

- RISP: Rare Isotope Science Project in Korea

- Korea is building a rare isotope accelerator
- The construction is to be finished in 2017 according to RISP people

- The key beam parameters
  - 600 MeV and 660 uA for proton beam ("continuous")

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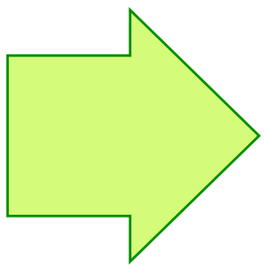
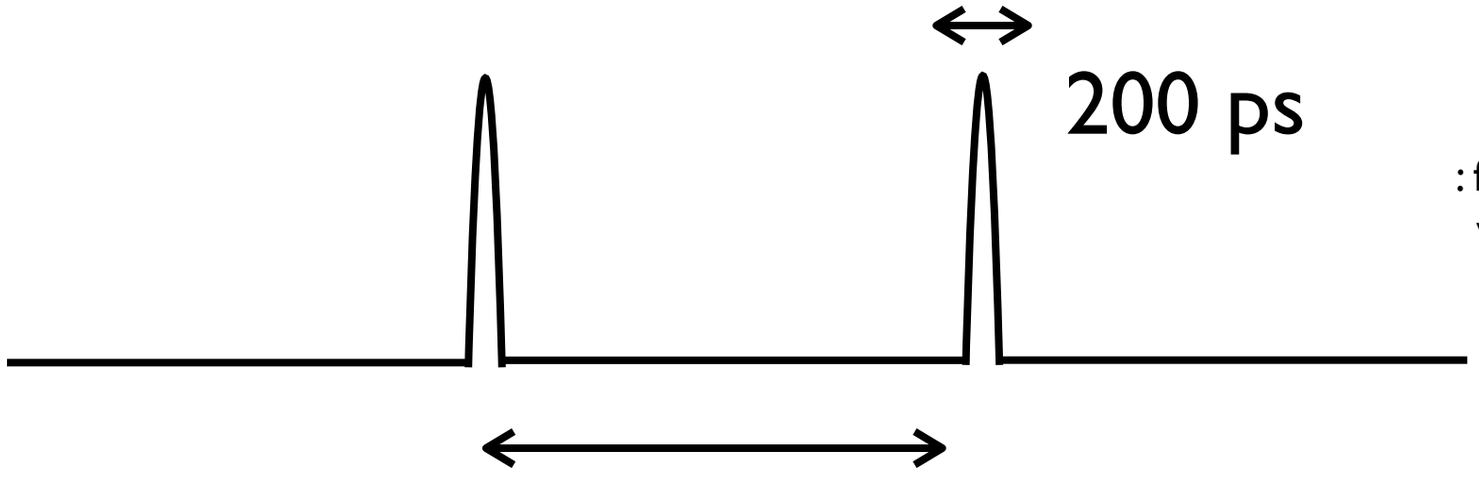


Several particle physicists in Korea are trying to utilize the RISP accelerator to do particle physics experiments

Time Structure

- The key beam parameters
  - 600 MeV and 660 uA for proton beam ("continuous")

- Beam structure (related to thermalizing muon)



: from private communication
with E. S. Kim @RISP/KNU

Our Activities

- Jan. 2012 - May 2012: particle physics Task Force

  - We (particle physicists) investigated physics cases with RISP accelerator and made a report to RISP

- Oct. 2012

  - We had a symposium (under KPS) with Japan/US experts

Muon Science in the project X era (Bob Tschirhart/Fermilab)
Overview of Muon Physics at J-PARC (Naohito Saito/KEK)
Baseline Design of the RISP Accelerator Facility (Yongkyun Kim/RISP)

HEP only

MEG+COMET (Satoshi Mihara/KEK)
Charged Lepton Flavor Violation at Fermilab (Bob Bernstein/Fermilab)
DeeMee (Masaharu Aoki/Osaka)

The Next muon g-2 Experiment (Bob Bernstein/Fermilab)
Muon g-2/EDM (Tsutomu Mibe/KEK)
Mu HFS (Koichiro Shimomura/KEK)

Our Real Activities

RISP Status and Plan

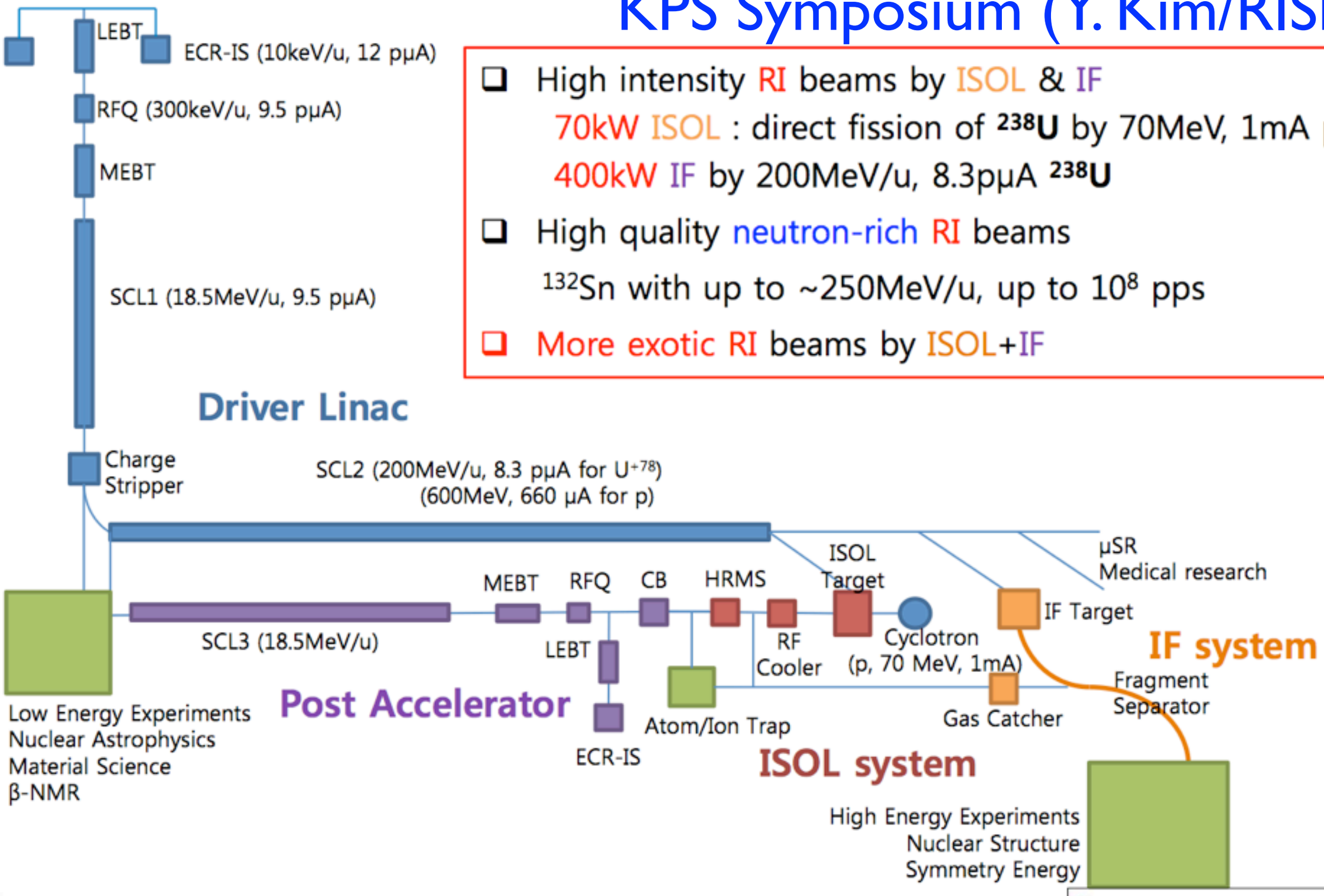
KPS Symposium (Y. Kim/RISP)

- **Conceptual Design report (Mar. 2010 - Feb. 2011)**
- **IAC review (Jul. 2011 – Oct. 2011)**
- **Rare Isotope Science Project started in IBS (Dec. 2011) Director Prof. Sunkee Kim**
- **RISP Workshop on accelerator systems (May 6 – 9, 2012)**
- **TAC (May 10, 2012)**
- **Conceptual Design of the Building and Conventional Facilities (May 2012)**
- **Baseline Design Summary (by July 2012) – Base line parameters**
- **RISP Workshop on Advanced Experimental Techniques using RI Beams – Today 16, July**
- **IAC (July 26-27, 2012)**
- **Technical Design Report (by Jun. 2013)**
- **Ground Breaking (2014)**

RAON: RISP Accelerator Complex

KPS Symposium (Y. Kim/RISP)

- High intensity RI beams by ISOL & IF
  - 70kW ISOL : direct fission of ^{238}U by 70MeV, 1mA p
  - 400kW IF by 200MeV/u, 8.3pμA ^{238}U
- High quality neutron-rich RI beams
  - ^{132}Sn with up to ~250MeV/u, up to 10^8 pps
- More exotic RI beams by ISOL+IF



Development Plan

2009

LoIs from domestic users

- **Science program** with RI beams up to 200 AMeV
- **83 LoI's**

(nuclear/astrophysics, nuclear data, standard model, biomedical, mass measurement, material science, ERD analysis)

2010 ~ 2011

Science classification

- Nuclear science
- Atomic & Molecular science
- Material science
- Medical & Bio science

2011 ~ 2013

Facility specifications

- Beam specifications (energy, intensity, pulse width ...)
- Specifications of experimental facilities

We are here!!!

R&D and Installation

- Spectrometer
- Detection system
- Beam line
- Apparatus for applied sciences

Day-1 experiments

Upgrade and extension

2013 ~ 2017

2017

Refinement

- Based on Realistic modification of specifications
- **LoIs for specified experiments (domestic + foreign)**

2012 ~ 2013

Recent Activities

- Nov. 2012: RISP asked us to design multiple muon beam lines

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- Nov. 2012 - present

  - We are designing two beam lines : one for muSR and the other for HEP experiments

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Who are we? (all experimental high energy physicists)

Eunil Won, Suyong Choi, ByeongRok Ko (Korea Univ)
Seonho Choi (Seoul National Univ)
Hyunsoo Lee (Ewha Womans Univ)

Organization

muSR beam line

Eunil Won, ByeongRok Ko (Korea Univ)

HEP beam line

Suyong Choi, Yeonjeong No (Korea Univ)

HEP program

Hyunsu Lee (Ewha womans Univ)

Target

Seonho Choi (Seoul National Univ)

In reality, a lot of overlap exists

Short Term Plan

- By Summer 2013

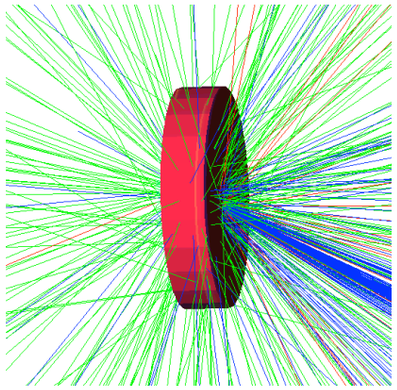
  - We would like to give inputs to RISP on muon beam lines performance, geometry, requirements for their TDR

  - muon beam line for HEP
    physics case
    target, muon beam line design, collection efficiency, beam emittance

  - muon beam line for muSR
    target, muon beam line design, collection efficiency, beam emittance
    moderation of surface muons
    ultra-cold muon beam transport for muSR
    kicker, spin rotation

Key Components

Muon production

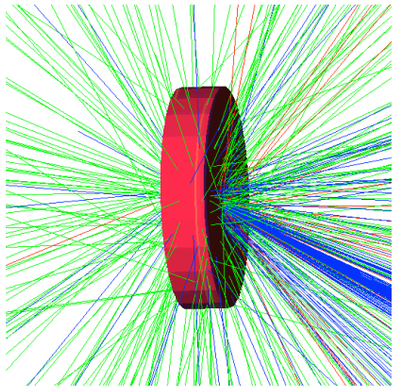


~10^{-5} surface muons/proton

Key Components

Muon transport

Muon production



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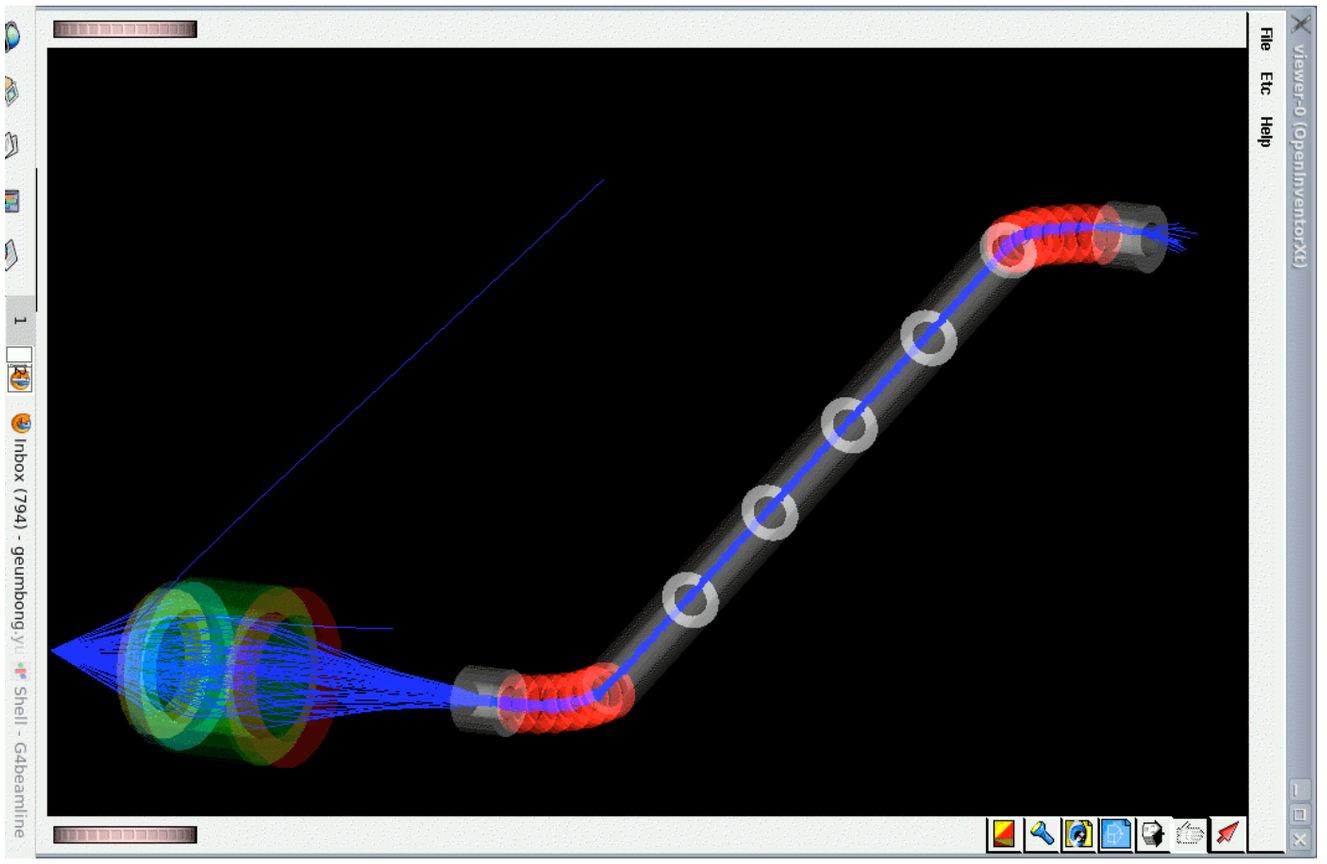


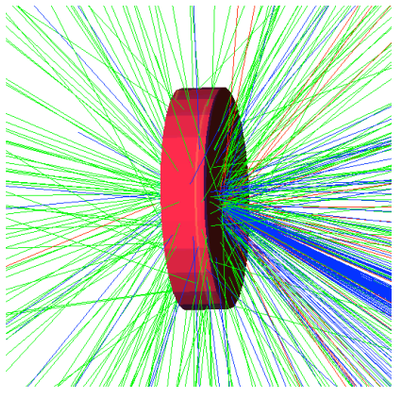
ε(collection)~O(3x10^{-2})

ε(transport)~O(1-0.1)

Key Components

Muon transport

Muon production



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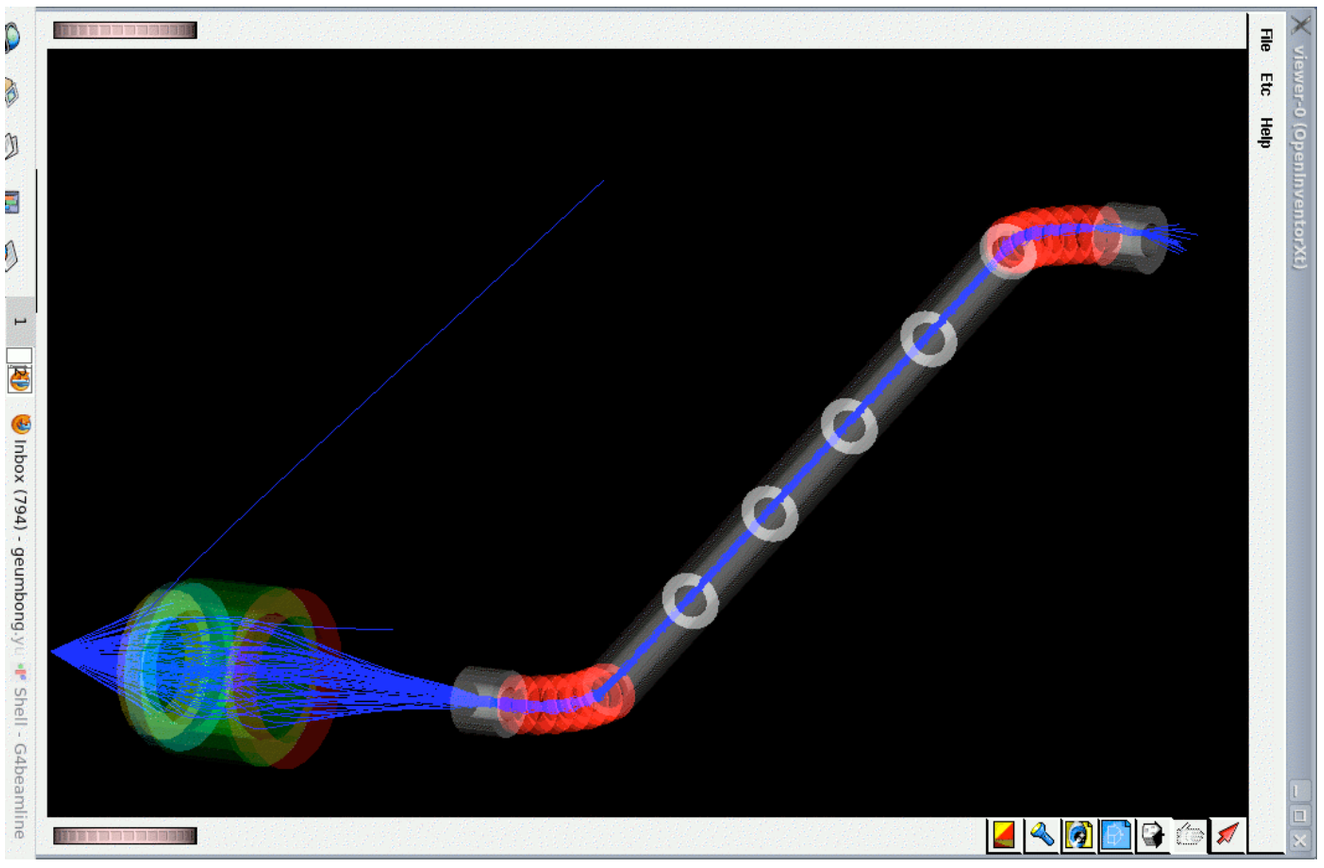

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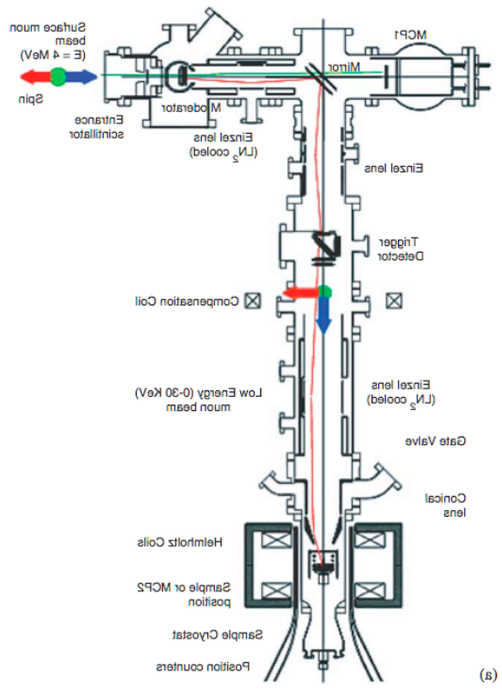
Muon thermalization

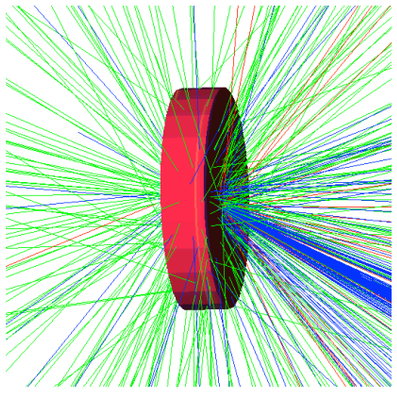


ε(thermalize)~10^{-5}

Key Components

Muon transport

Muon production



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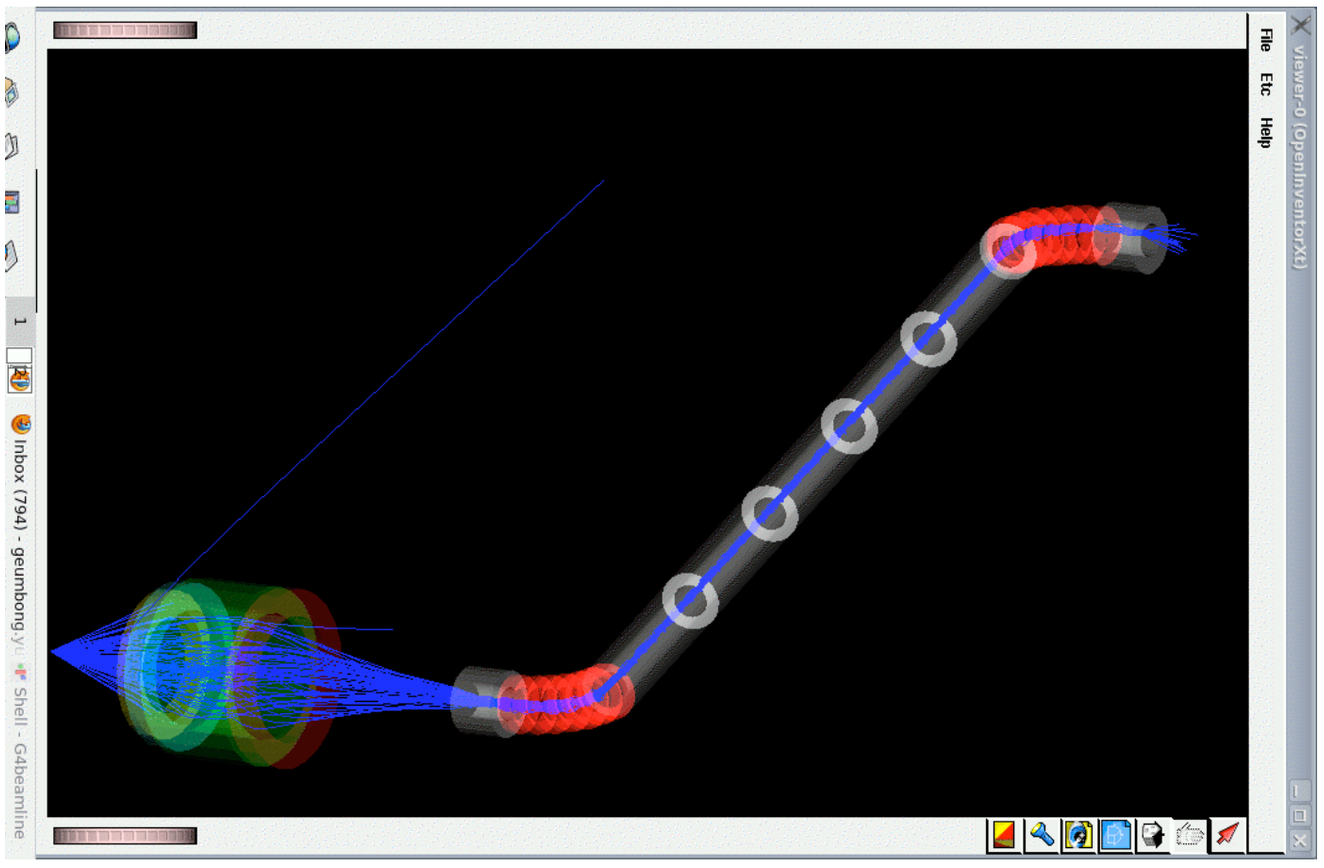

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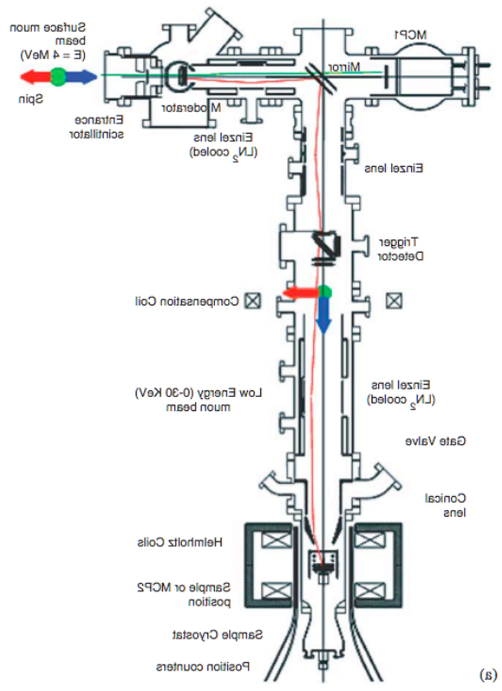


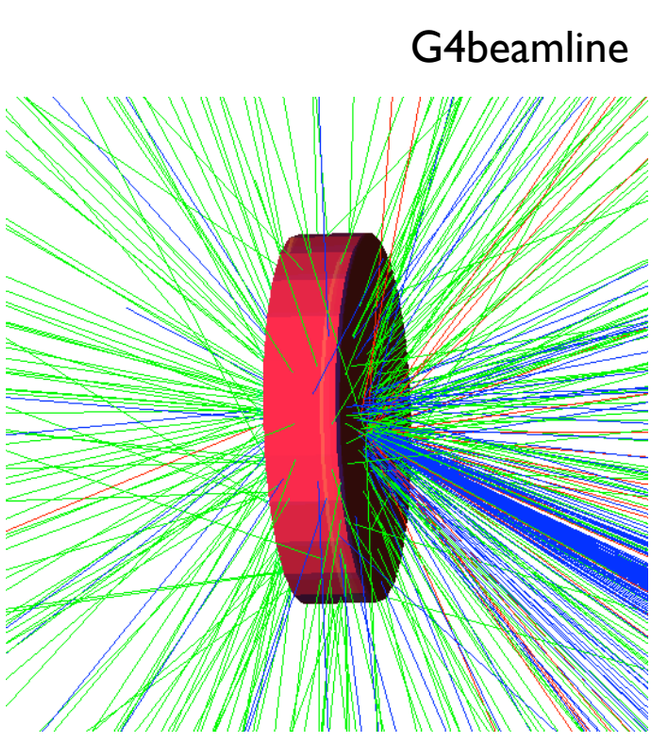
ε(thermalize)~10^{-5}

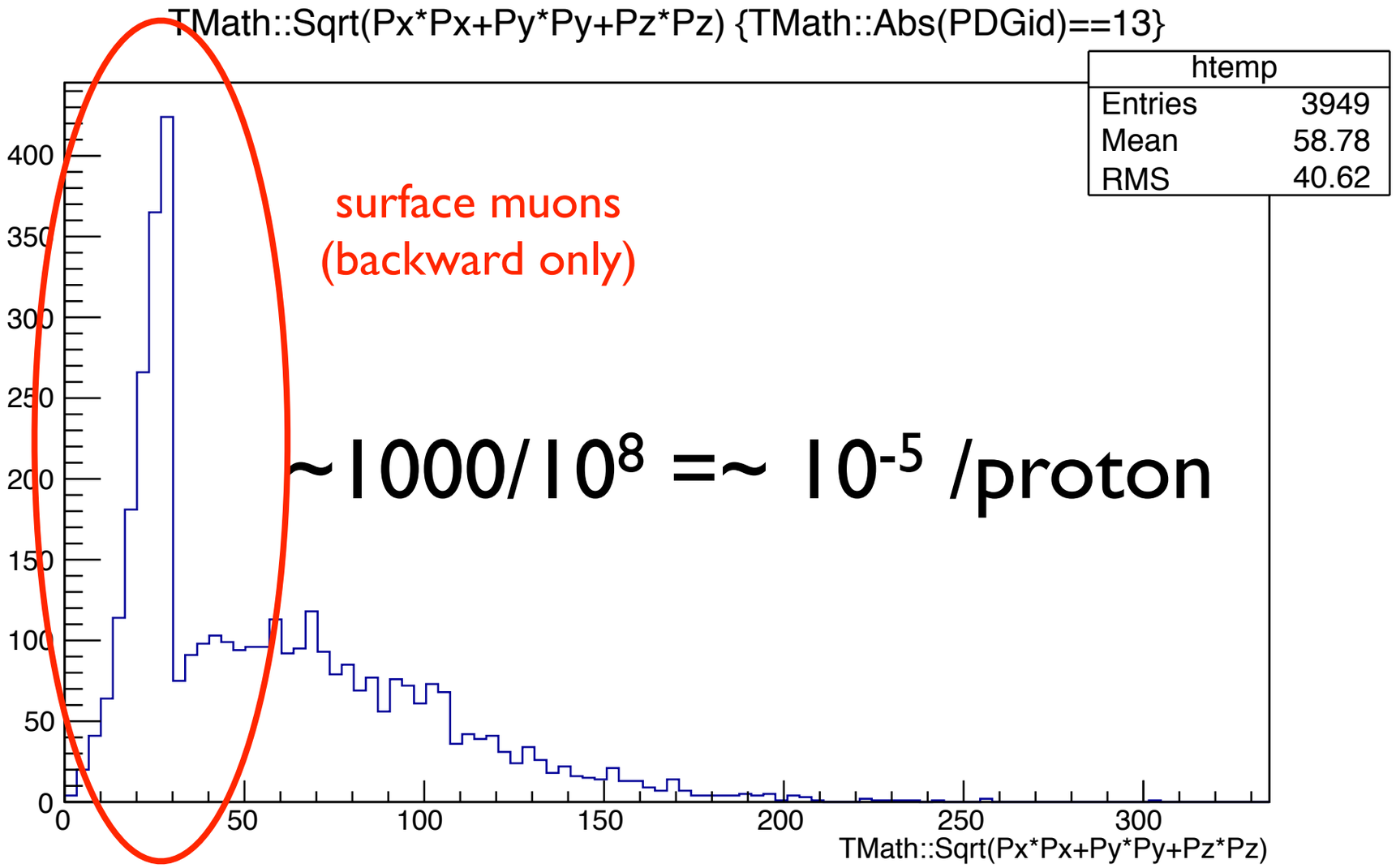
4×10^{15} protons/s (660 uA) ⇒ 10^{4} thermalized muons/s

Surface muon Production

Graphite target: 20 mm thick, incident angle 45 degree
- Max. momentum of surface muon ~ 29 MeV/c

E.Won/KU



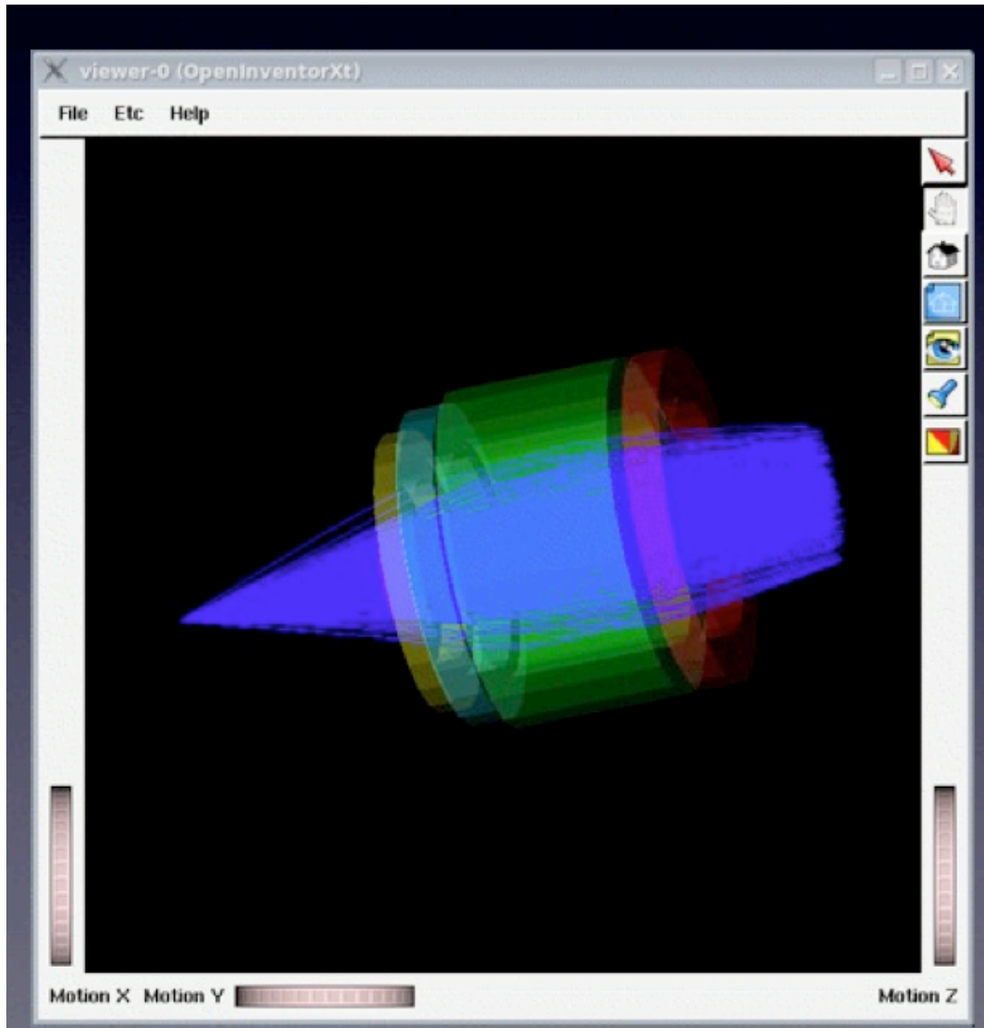


Surface muon beam line

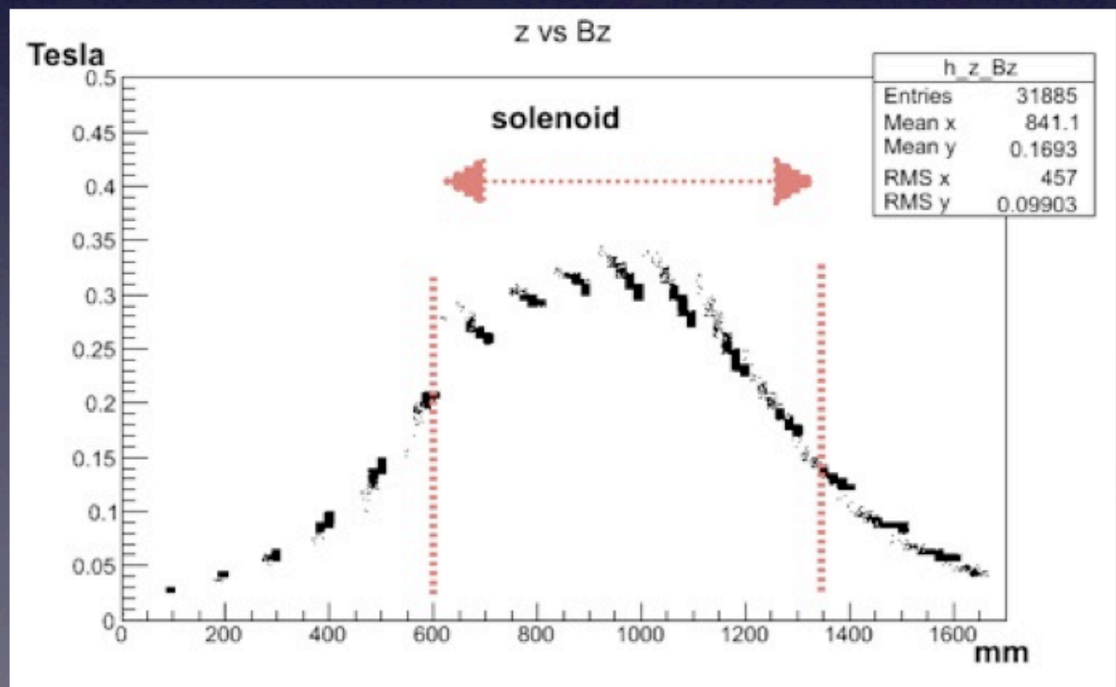
We are at very early stage of designing

- Collection efficiency is one of important parameters
- Usually normal conducting (only for this solenoid) due to radiation

Geombong Yu/KU



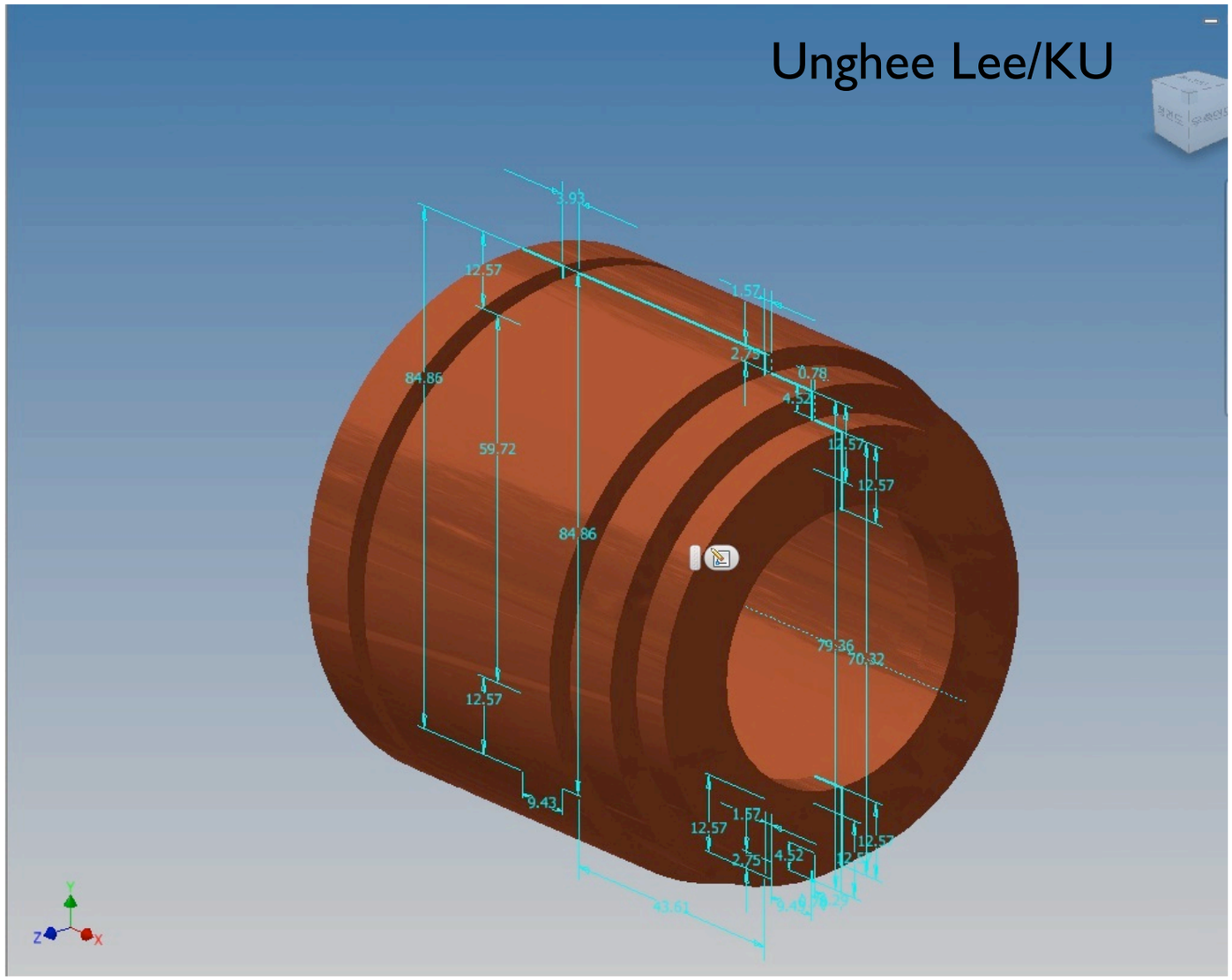
Maximum current ~1500A
Normal conducting solenoid ~0.3T



Surface muon beam line

- CAD drawing work in progress

CAD drawing of the collecting solenoid



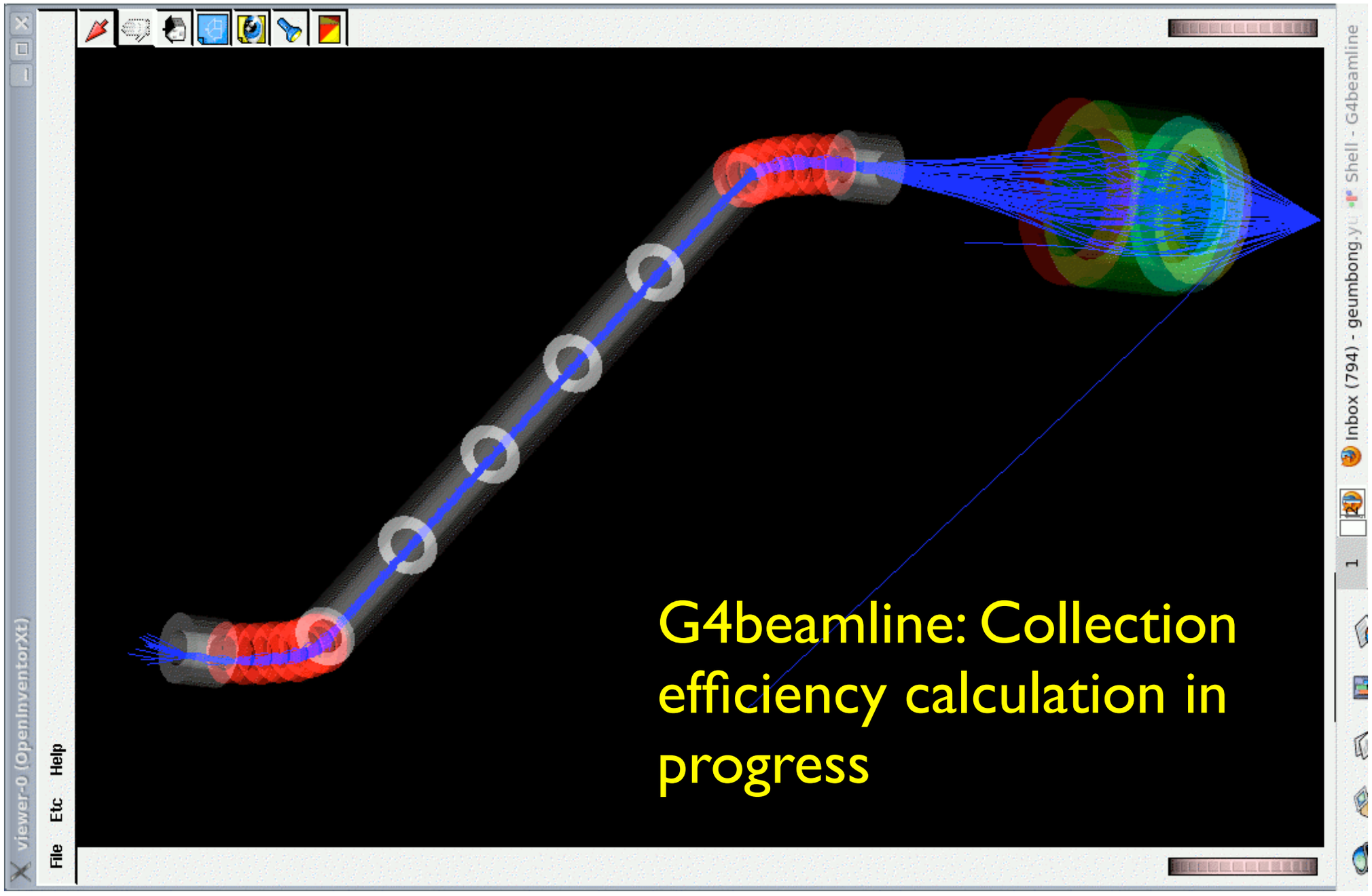
Solid angle : 380 mSR
- 60 cm from target

ε(collection)~0.38/(4x3.14)~3%

Surface muon beam line

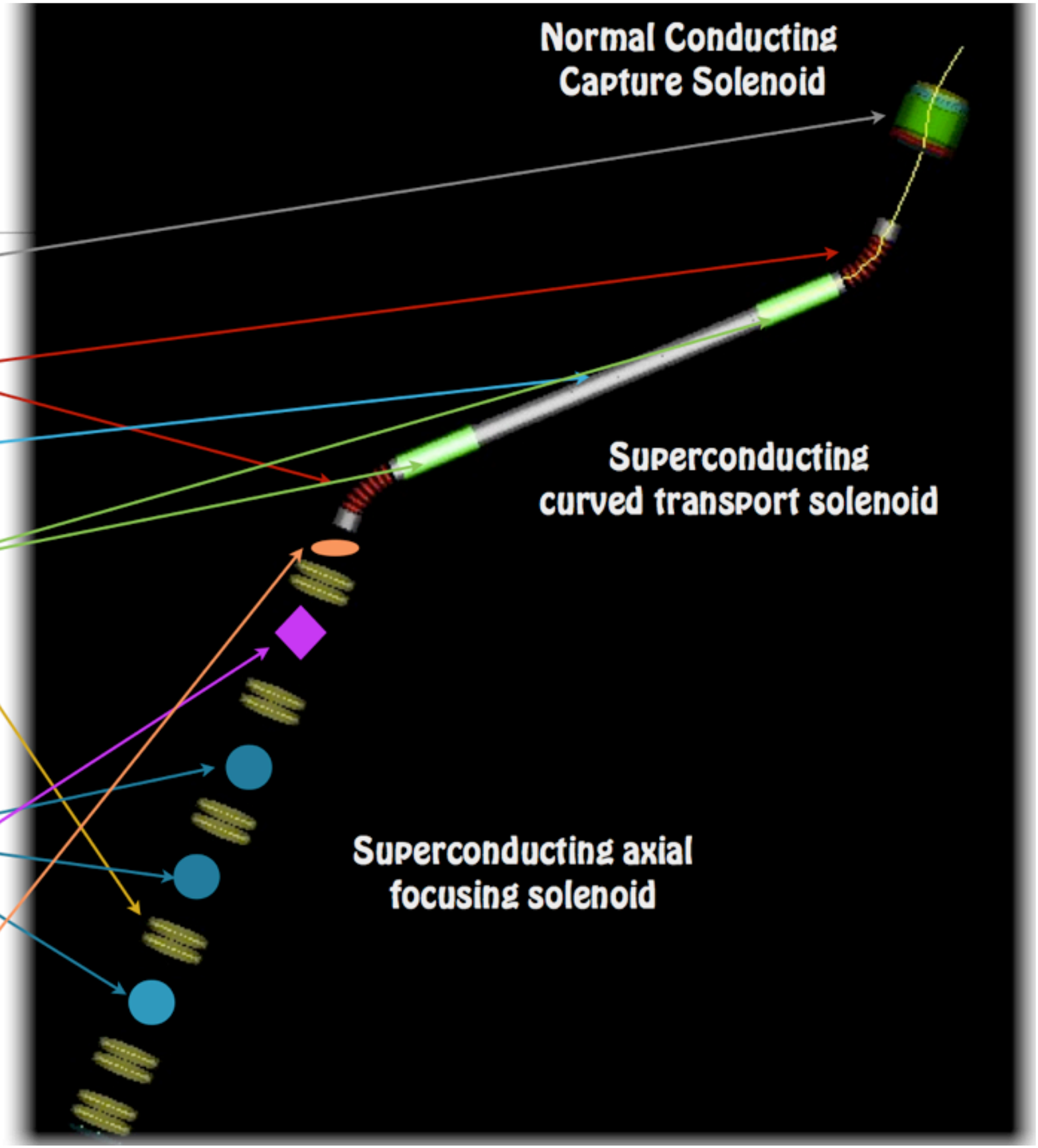
- Muon beam transport ("all solenoid option")

Geombong Yu/KU



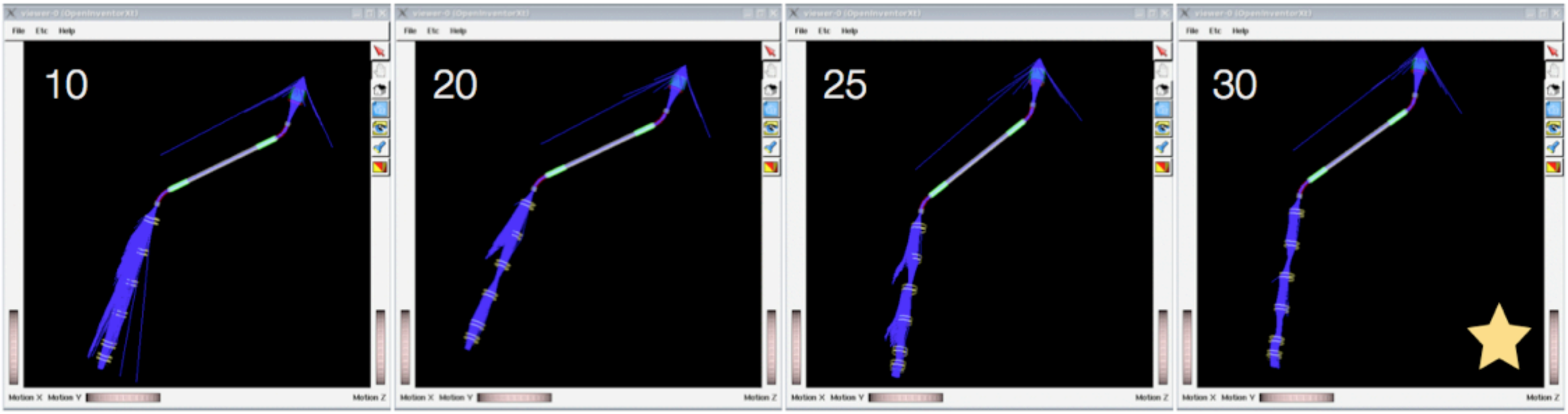
Integration of magnets

- Capture Solenoid
- Curved Solenoid (45°)
- Straight line (6m)
- Magnetic Dipole (0.15T)
- Axial Focusing Solenoid
- Missing parts:
  - Positron Separator
  - Beam Blocker
  - Steering dipole coils?
  - cooling materials, etc.

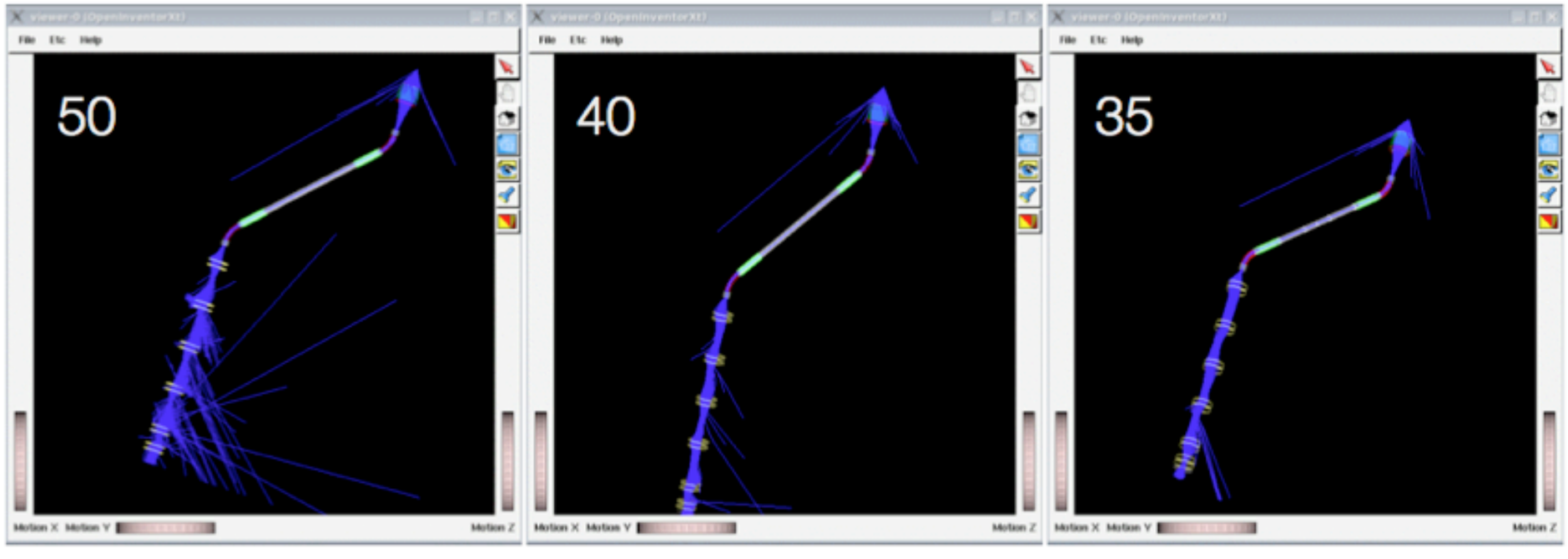


Rough study for focusing solenoids

Geombong Yu/KU



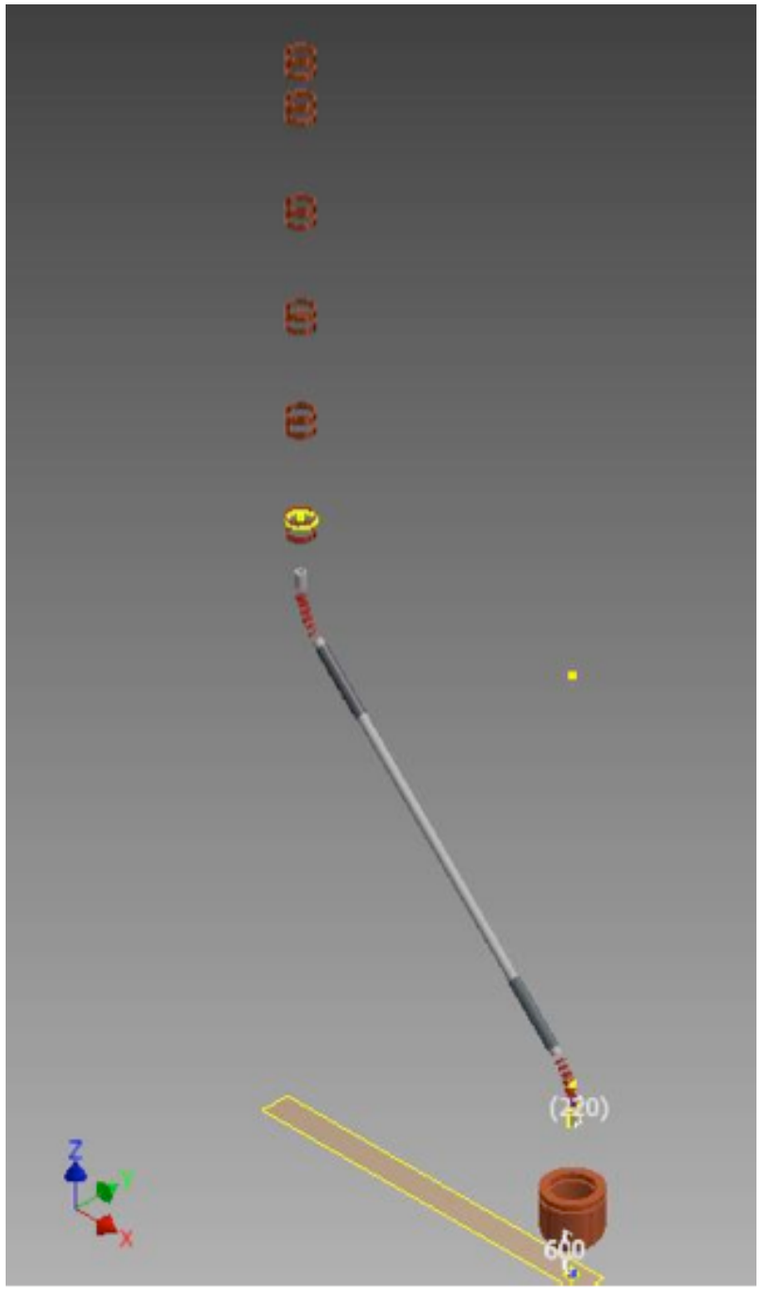
Change current density input: 10-50

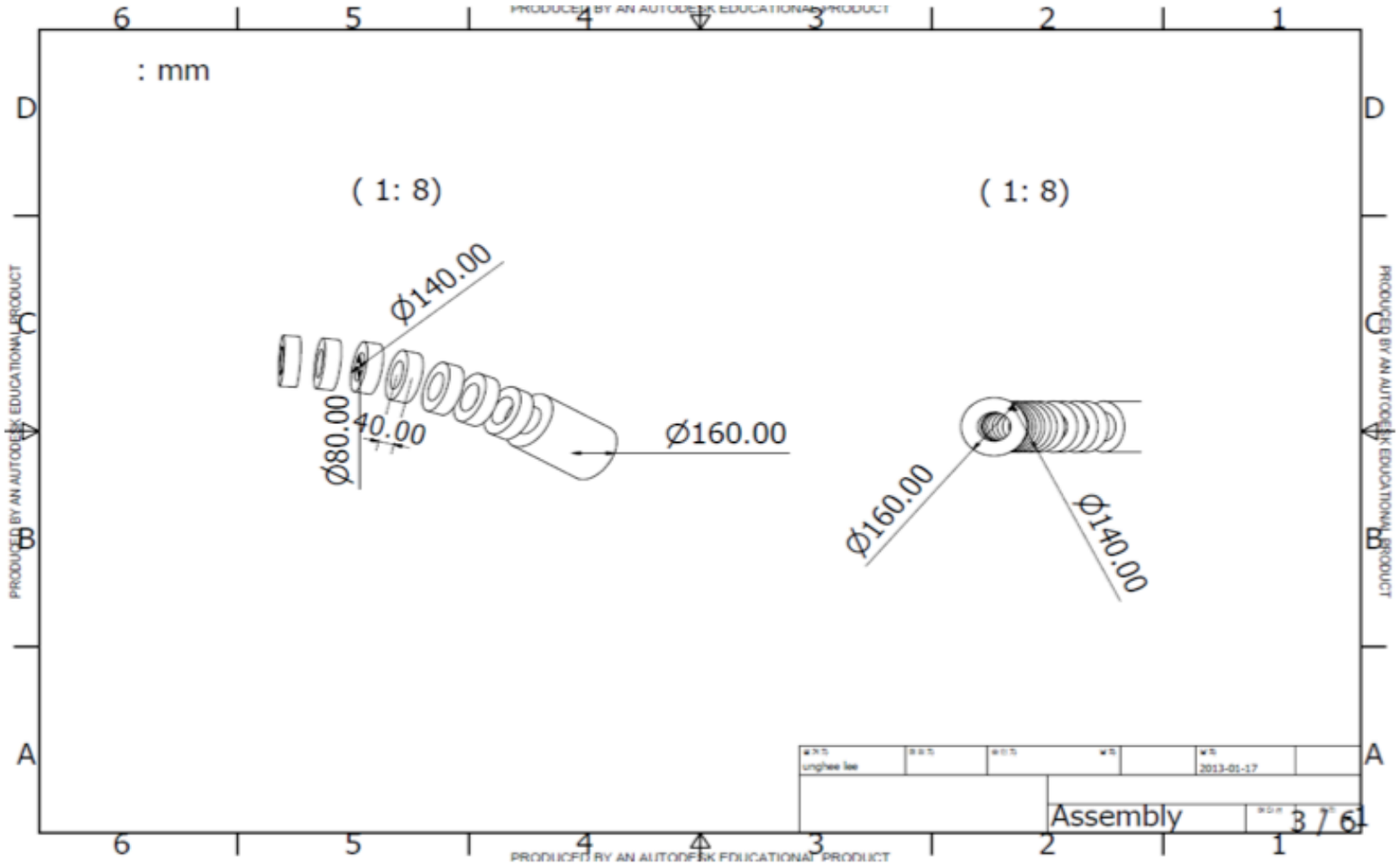


Surface muon beam line

- Muon beam transport (CAD drawing)

Unghee Lee/KU





Thermalizing Muons

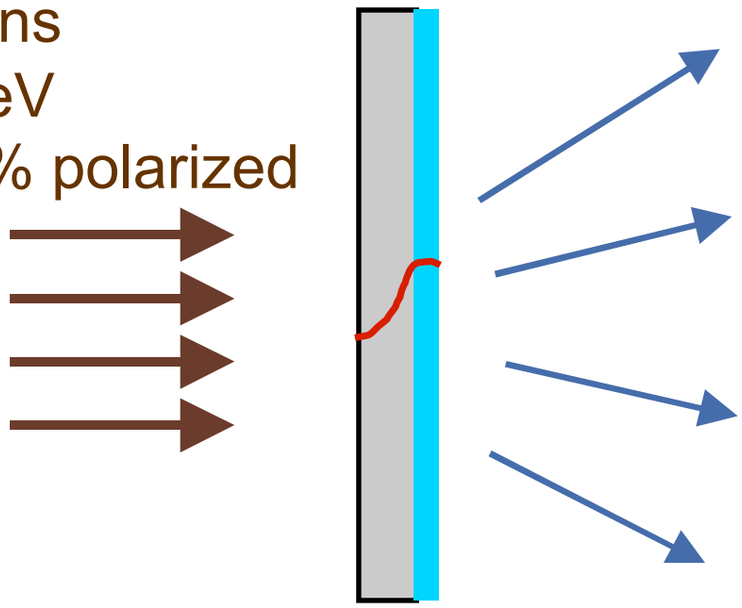
There are two ways so far:

- Low temp. moderation: PSI way

- Hot tungsten + laser resonant ionization of thermal Mu atom

Generation of polarized epithermal muons by moderation

Surface Muons
~ 4 MeV
~ 100% polarized

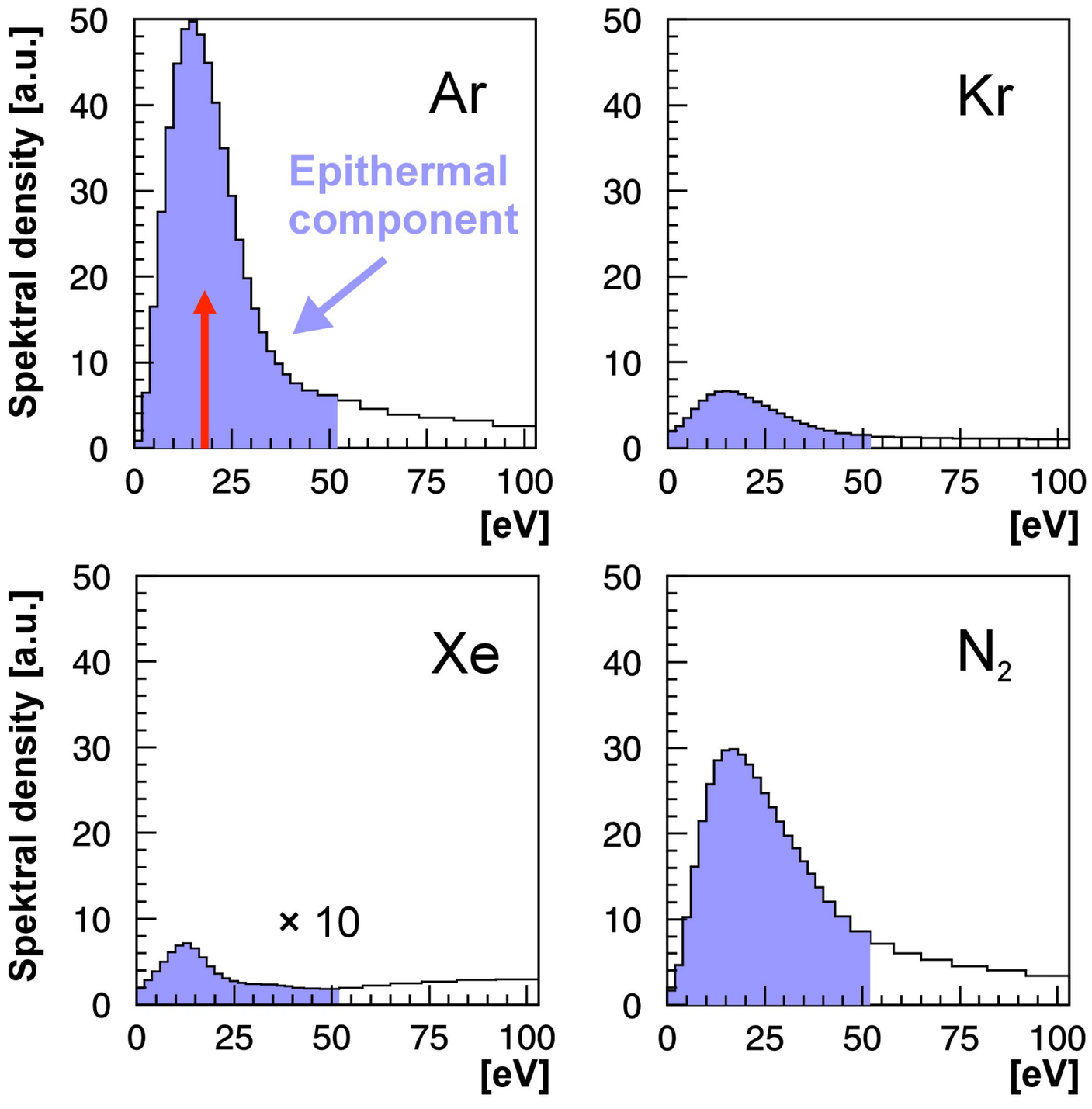


~100 μm Ag

~500 nm s-Ne, Ar, s-N_2

< 6 K

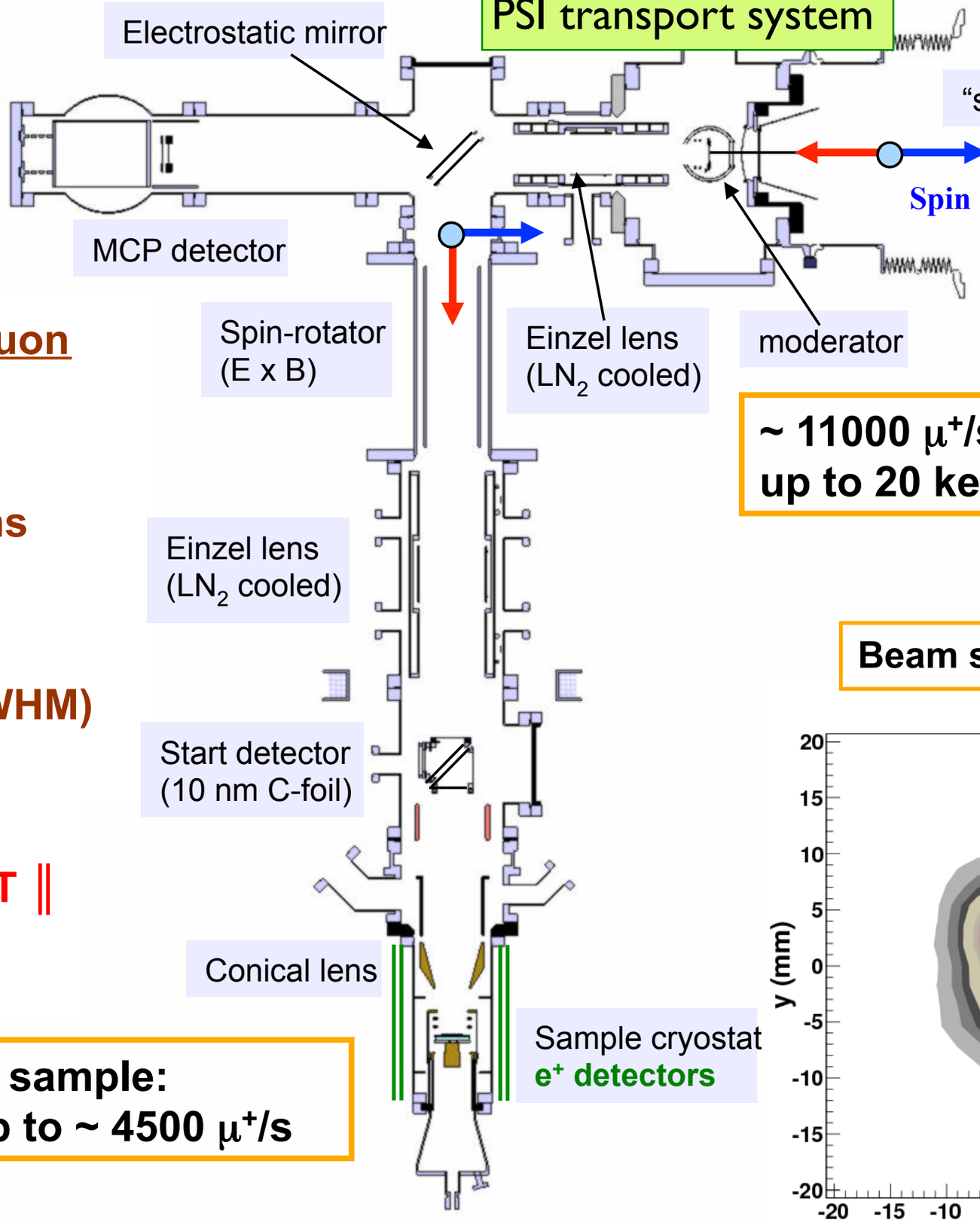
@ cryogenic temperature



D. Harshman et al., Phys. Rev. B36, 8850 (1987)
E. Morenzoni et al. J. Appl. Phys. **81**, 3340 (1997).

- UHV system, 10^{-10} mbar
- some parts LN_2 cooled

PSI transport system



"surface" μ^+ beam, ~4 MeV

Spin

~1.9 • 10^8 μ^+/s

~ 11000 μ^+/s; accelerate up to 20 keV

at sample: up to ~ 4500 μ^+/s

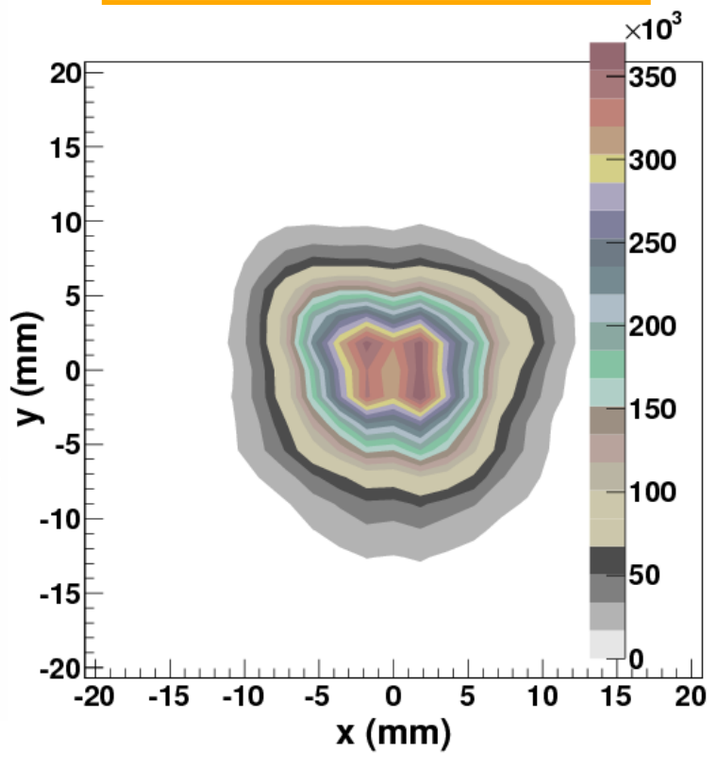
Polarized Low Energy Muon Beam

Energy: 0.5-30 keV
ΔE, Δt: 400 eV, 5 ns
Depth: 1 – 300 nm
Polarization ~100 %
Beam Spot: 12 mm (FWHM)

Sample environment:

B = 0 – 0.3 T $\perp$, 0 – 0.03 T $\parallel$ sample surface
T = 2.5 – 320 K

Beam spot at sample

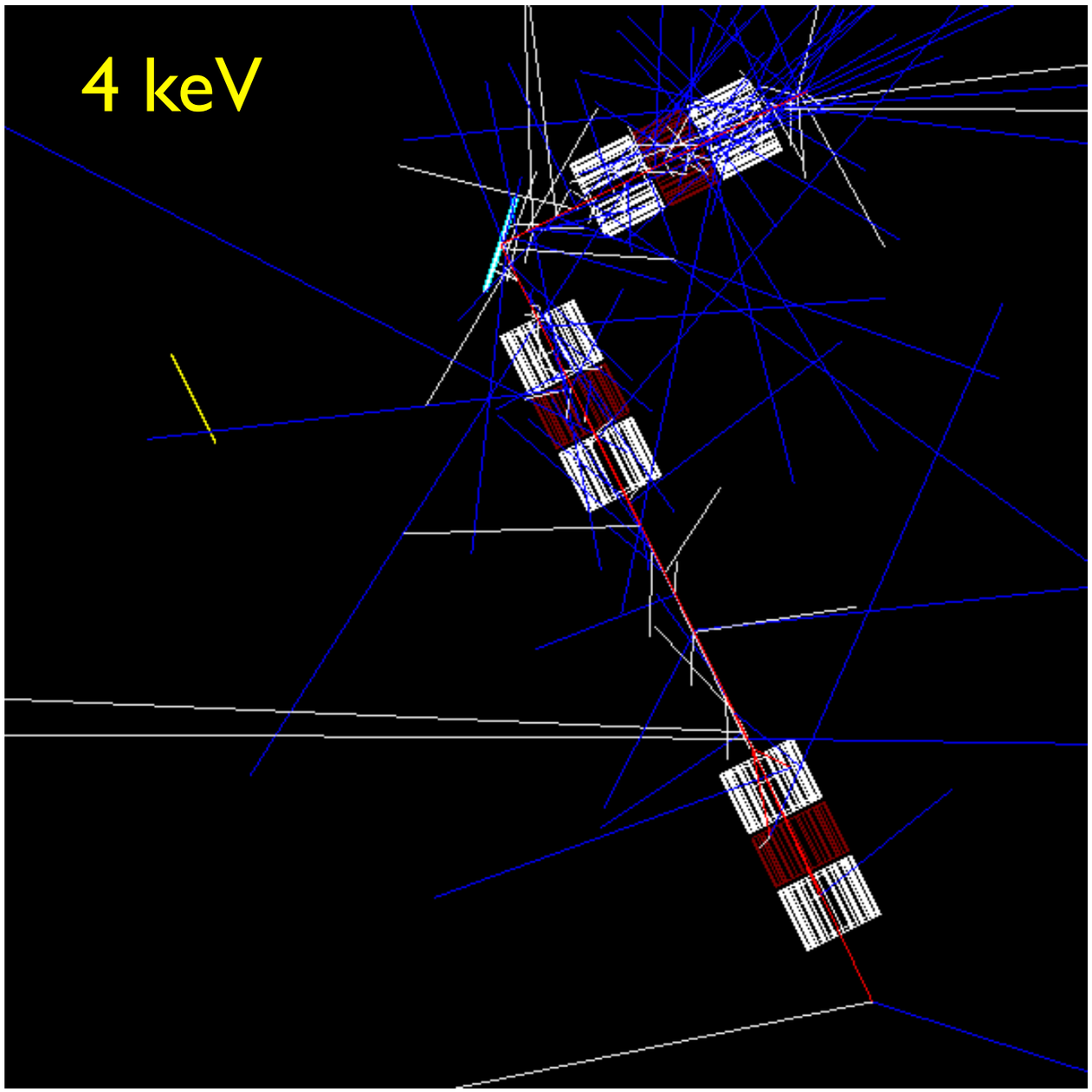


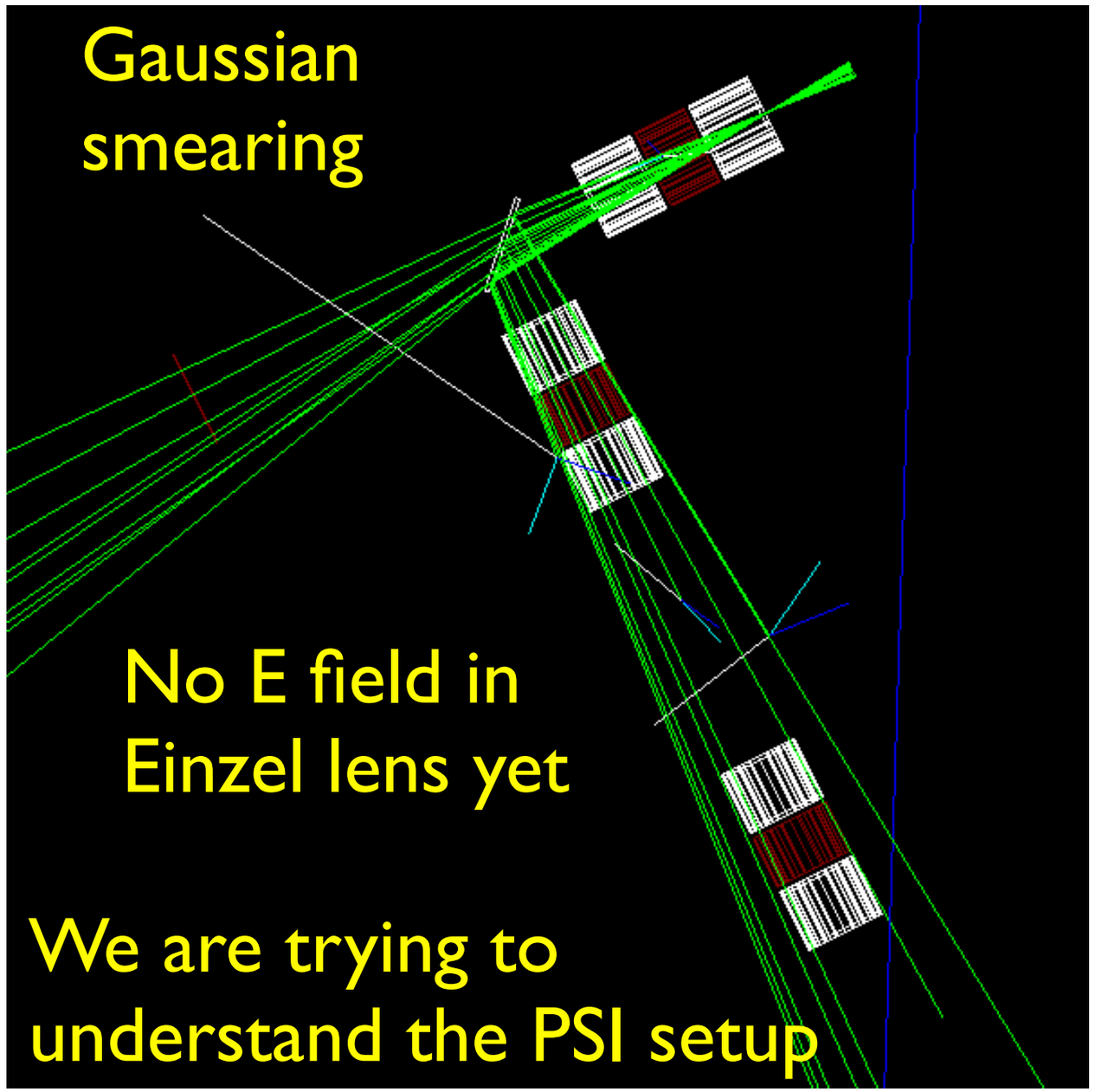
Some of them can be explored by GEANT4 simulation

Ultra-cold μ-beam line

- Ultra-cold Muon beam transport

PSI GEANT4
ByeongRok Ko/KU

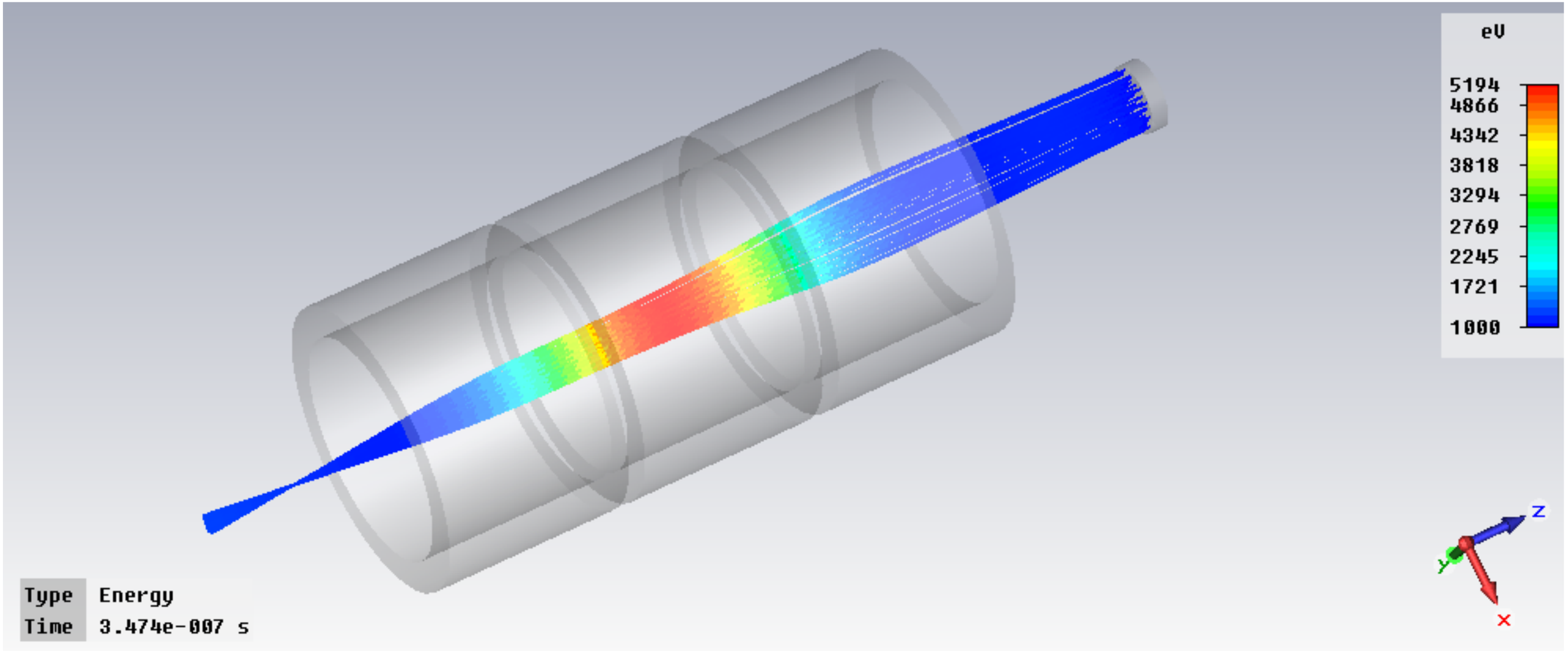




Ultra-cold μ-beam line

- Einzel lens design (CST)

Kyungmin Lee, Jihoon Choi/KU



Methods of μ^+e^- production in vacuum

- Formation via muons in flight
  - energy determined by charge exchange cross sections
  - P.R. Bolton et al., Phys. Rev. Lett. 47, 1441 (1981).
- Applied to μ^+e^- (Mu) Lamb shift
  - C.J. Oram et al., Phys. Rev. Lett. 52, 910 (1984)
  - A. Badertscher et al., Phys. Rev. Lett. 52, 914 (1984).

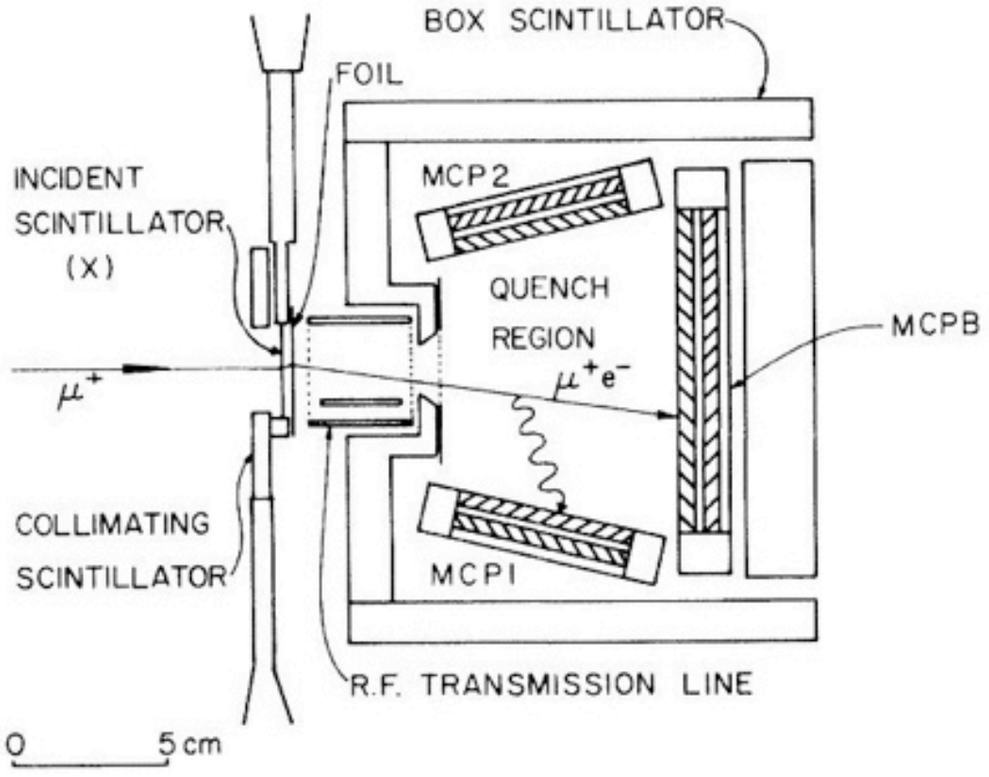


FIG. 2. A schematic of the apparatus, showing a good event in which a Lyman α photon is detected in microchannel plate (MCP1) from deexcitation of $\mu^+e^-(2S)$ in the quench region.

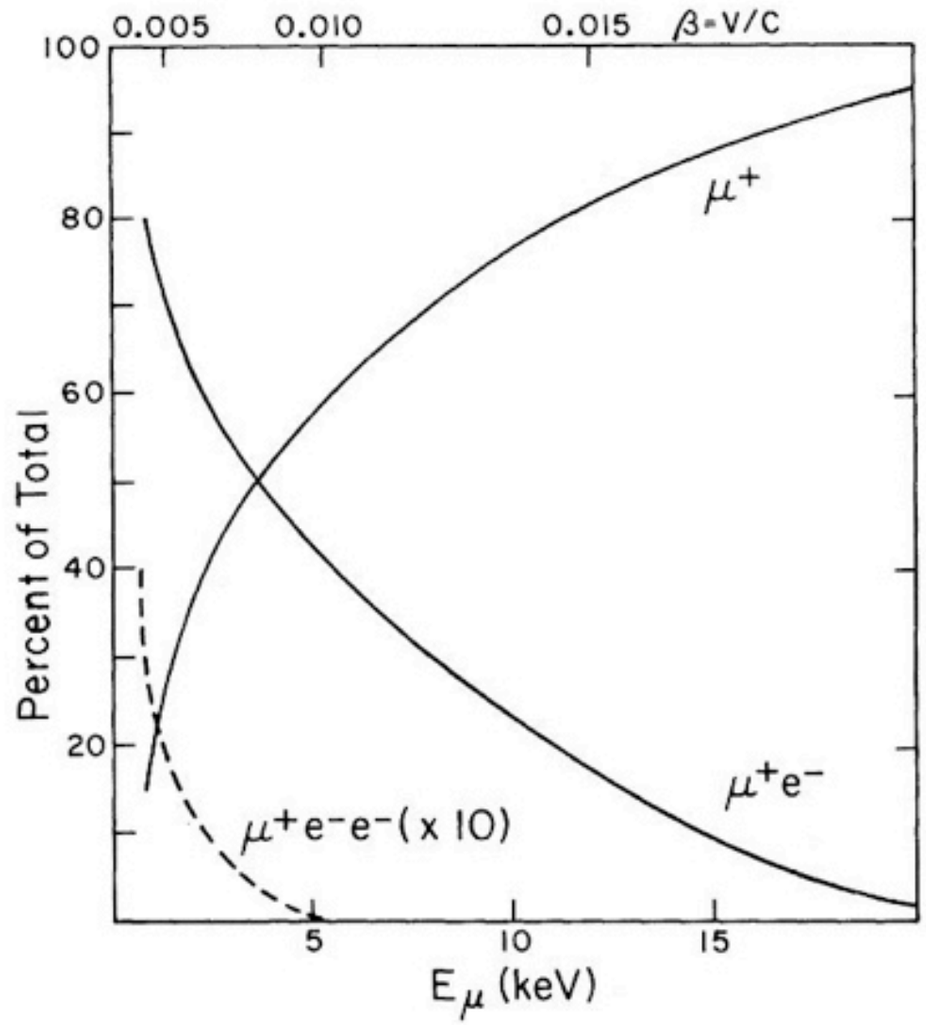


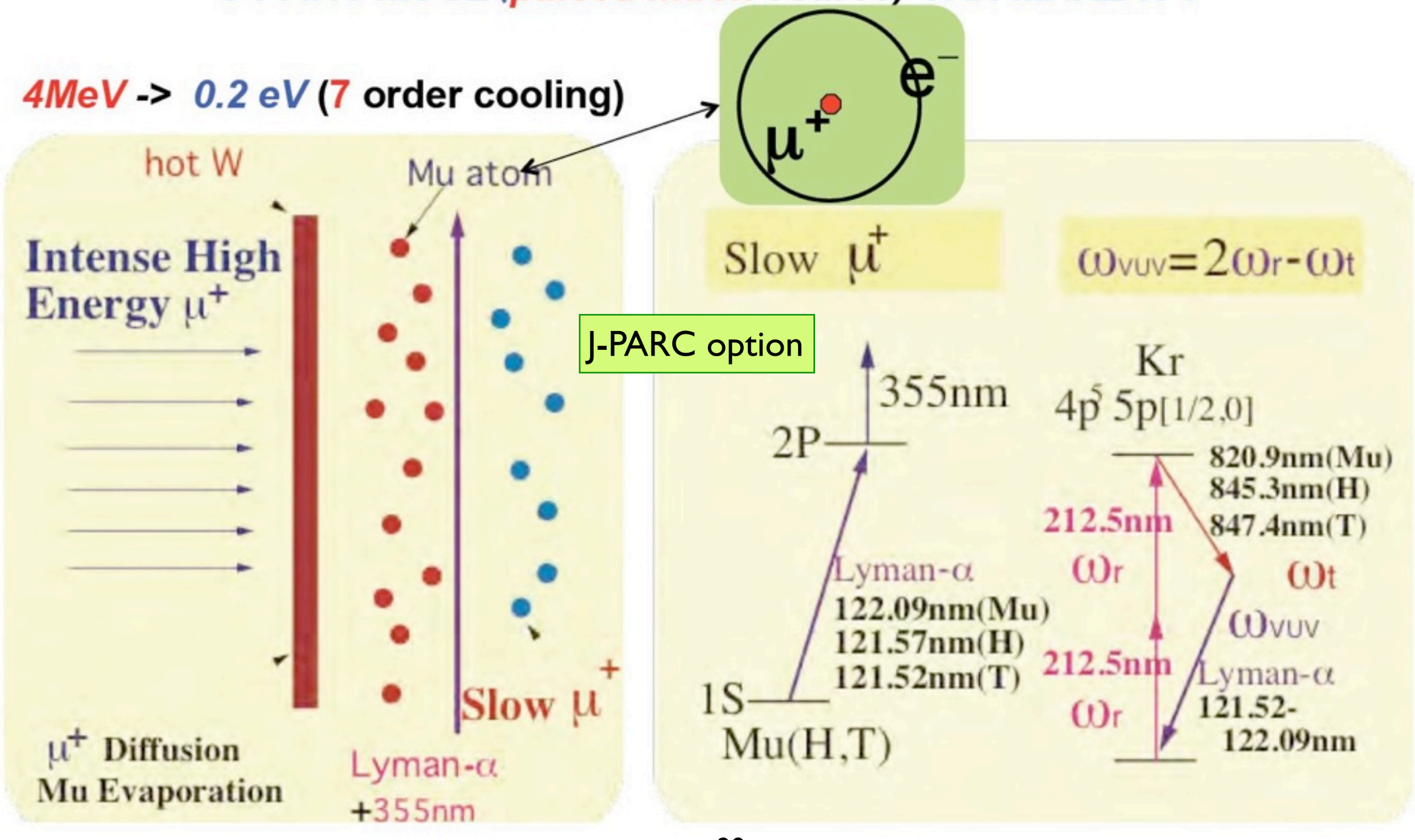
FIG. 1. Expected charge-state distribution for muons emerging from foil targets.

Concept of ultra slow μ^+ generation by laser resonant ionization of thermal Mu from hot tungsten

Can be realized by synchronizing intense pulsed muon and pulsed laser

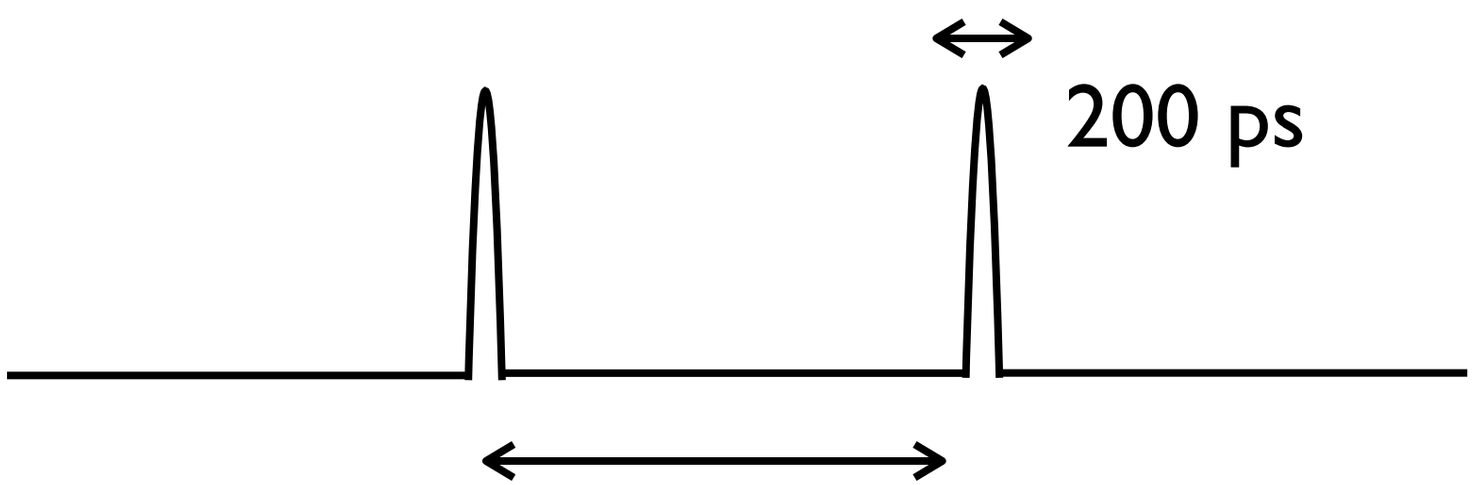
J-PARC MUSE (pulsed muon source) CAN MAKE IT !

4MeV **->** ***0.2 eV*** **(7 order cooling)**



Laser resonant ionization @ RISP?

- Beam structure (related to thermalizing muon)



Repetition rate might be OK
but the laser power seems an issue

Longer Term Plan

- There is no longer term plan yet

  - After TDR, RISP plans to call for LoI on experiments

  - We are trying to define the next step after TDR

Discussion Items

1) Plans on muSR in Korea

2) Fundamental physics experiments w/ muons at home or at foreign country

HEP muon beam line

- We think of a design that can be competitive to

$\mu \to eee$ or muonium oscillation experiments

We feel that g-2, mu2e, $\mu \to e\gamma$ might be tough.

Lamb shift/Hyperfine structure/muon+ lifetime are other potential considerations (?)

[22] arXiv:1301.6113 (cross-list from physics.ins-det) [pdf, other]

Research Proposal for an Experiment to Search for the Decay μ -> eee

A. Blondel, A. Bravar, M. Pohl, S. Bachmann, N. Berger, M. Kiehn, A. Schöning, D. Wiedner, B. Windelb
M. Hildebrandt, P.-R. Kettle, A. Papa, S. Ritt, A. Stoykov, G. Dissertori, C. Grab, R. Wallny, R. Gredig, F

Comments: Research proposal submitted to the Paul Scherrer Institute Research Committee for Particle Physics at the Ring C

Subjects: **Instrumentation and Detectors (physics.ins-det)**; High Energy Physics - Experiment (hep-ex)

We may end up with similar beam line as for the muSR experiment

Muon Beamline Design for RISP

Suyong Choi (KU)

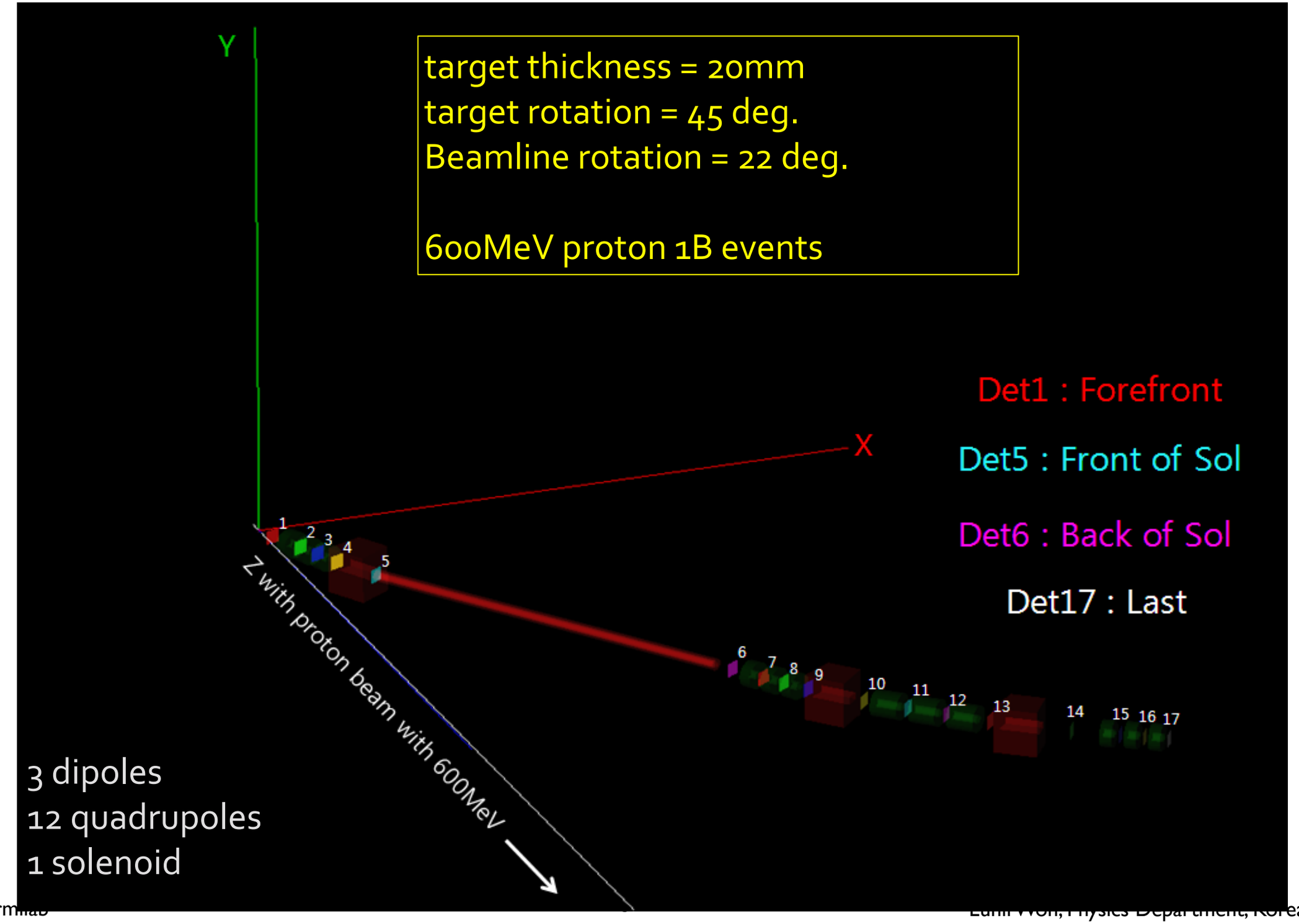
- Transport pion to long decay solenoid
  - p_0=200 MeV/c
- After the solenoid, transport muons <150 MeV/c
  - Small momentum overlap with π^+
  - High polarization
- Conventional design without restrictions for space
  - Sign selection achieved by reversing dipole polarity
  - Higher rate through thicker target

G4 Beamline Simulation Setup

Suyong Choi (KU)

target thickness = 20mm
target rotation = 45 deg.
Beamline rotation = 22 deg.

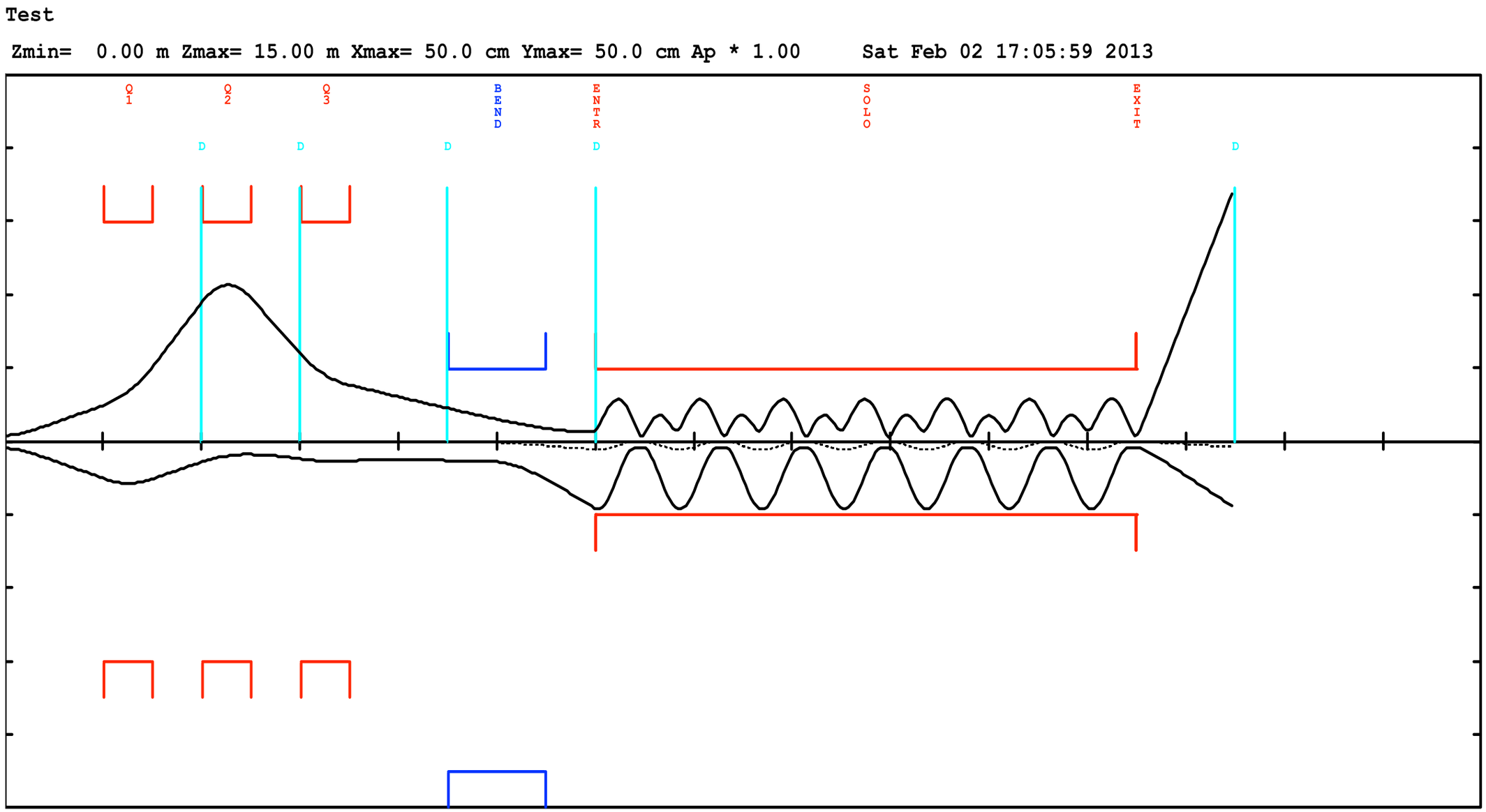
600MeV proton 1B events



3 dipoles
12 quadrupoles
1 solenoid

Pion transport line

Suyong Choi (KU)



Muon Rates

Suyong Choi (KU)

- 10^9 protons $\longrightarrow$ 100 muons
  - For 600μA beam, 4x10^8 μ^+/s, 10^7 μ^-/s
  - For 200 MeV/c muon transport (not optimal)
  - With optimized layout, higher rate achievable

Short Term Plan

- By Summer 2013

  - We would like to give inputs to RISP on muon beam lines performance, geometry, requirements for their TDR

  - muon beam line for HEP

    physics case

    target, muon beam line design, collection efficiency, beam emittance

  - muon beam line for muSR

    target, muon beam line design, collection efficiency, beam emittance

    moderation of surface muons

    ultra-cold muon beam transport for muSR

    kicker, spin rotation

Longer Term Plan

- We would like to converge on (a) HEP program(s) for RISP

  - Application to RISP call for LoI

  - Eventually, we hope to join foreign muon HEP programs (under discussion)

Summary

- A baseline, "solenoid only" muon beam-line design for muSR in progress

- Presently, we are woking on the "PSI method" for the cooled muon transport

- HEP physics case under study

- Another muon beam-line for HEP under study

Comments

- EW visited J-PARC on Jan. 30 2013
  Met Yasuhiro Miyake (J-PARC MLF Muon section leader)

We discussed a possibility of a workshop
- Sometime in April/May(?) @ RISP/J-PARC?
- Will inform you in case you are interested in