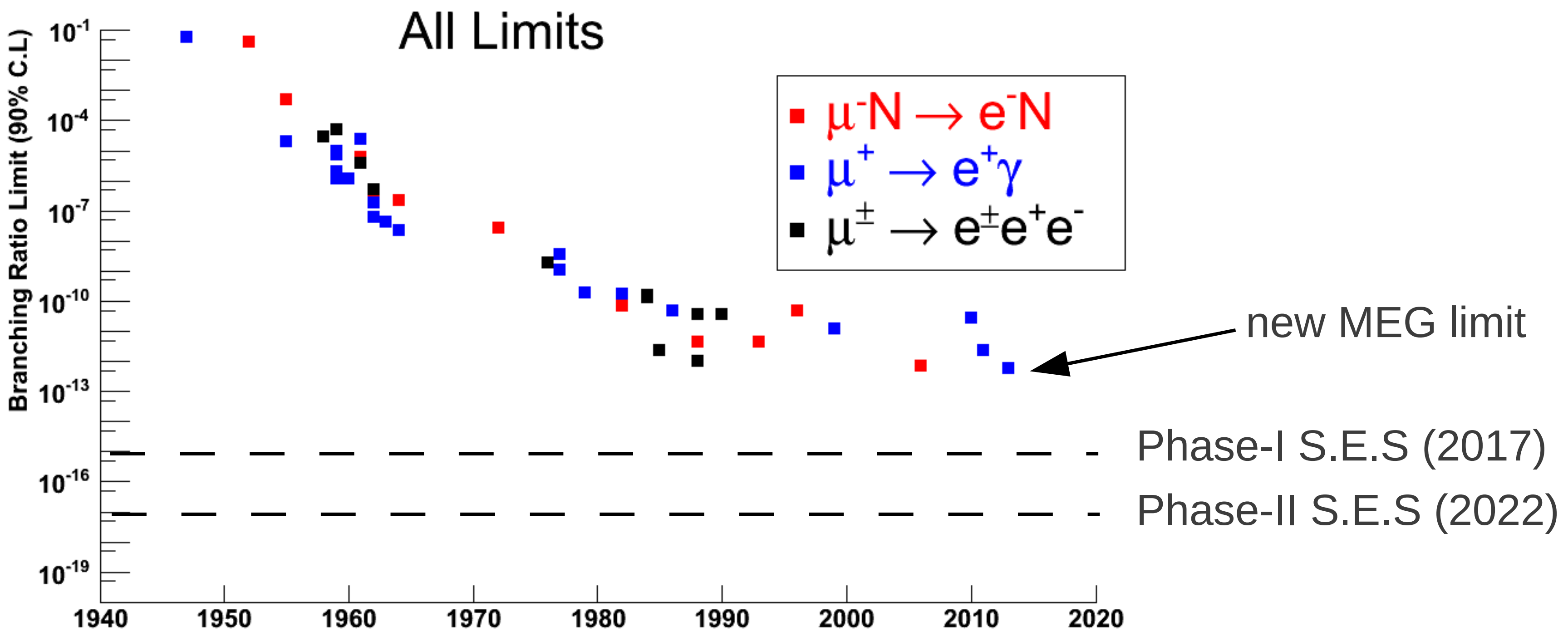
COherent Muon to Electron Transition (COMET)

Andrew Edmonds (UCL)
on behalf of the COMET collaboration

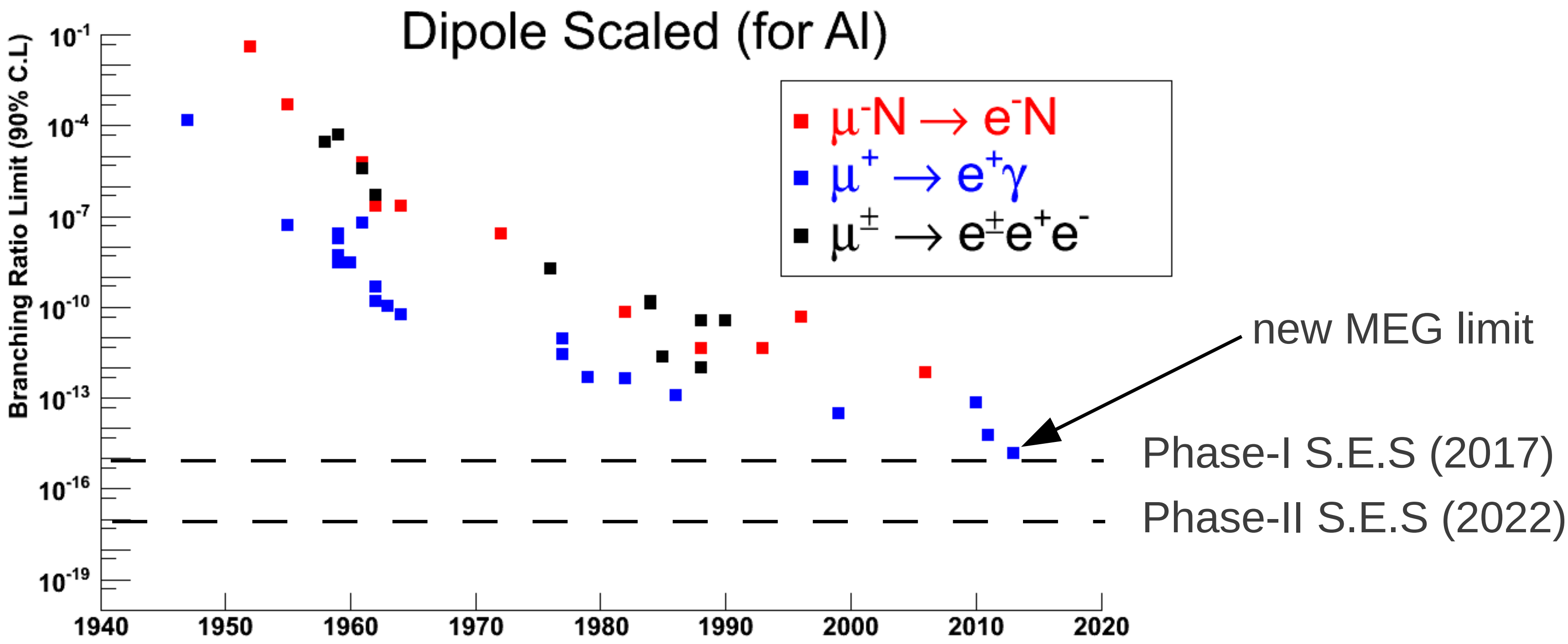
Current Limits

- COMET limits in relation to historical limits



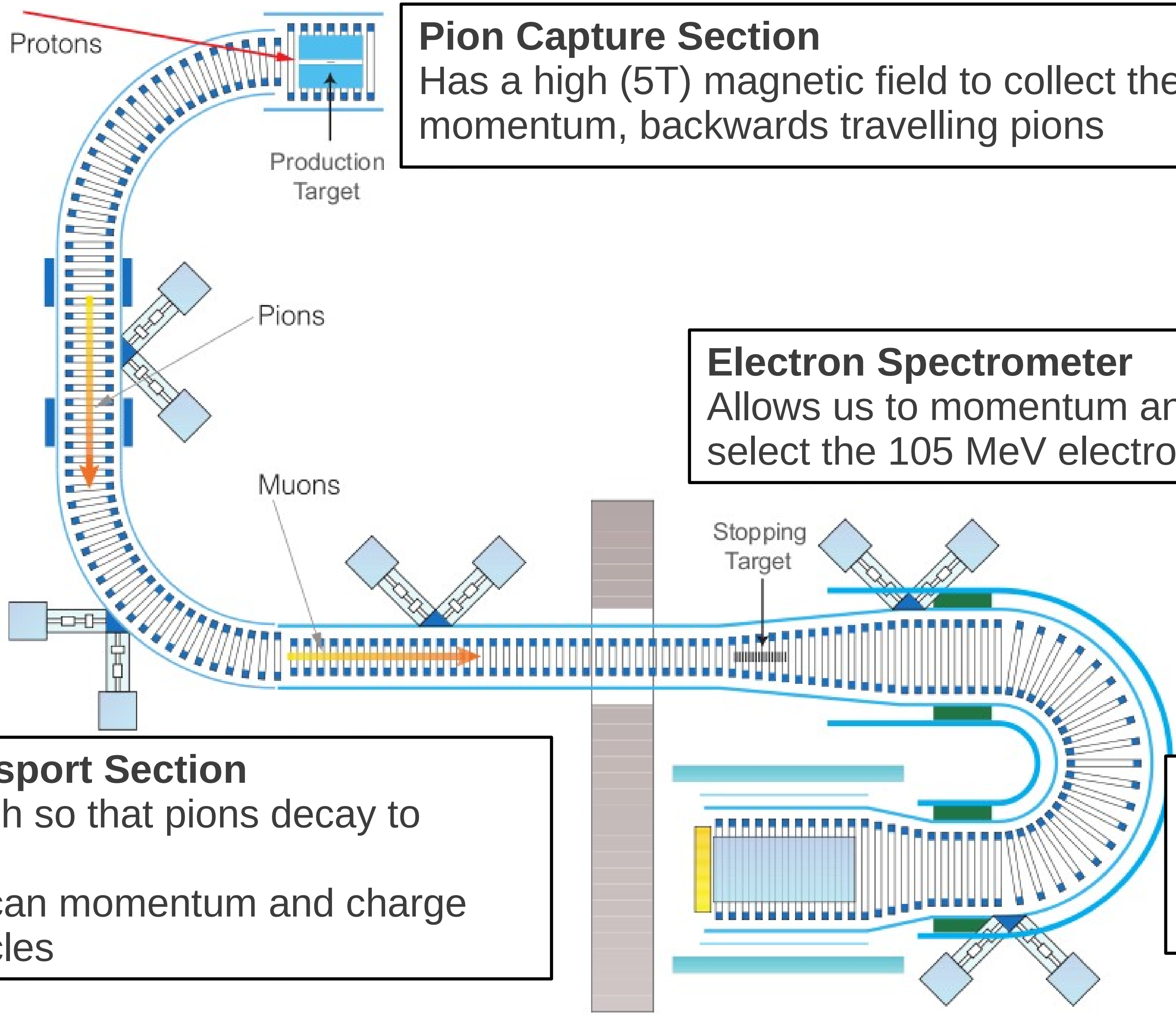
Current Limits

- For dipole interactions an extra factor of 1/389 occurs for Al



Starting in 2020
Measurement in 2022
S.E.S = 3×10^{-17}

COMET (Phase-II)



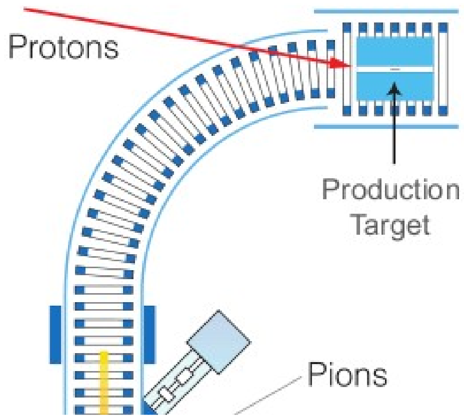
Pion Capture Section
Has a high (5T) magnetic field to collect the low momentum, backwards travelling pions

Electron Spectrometer
Allows us to momentum and charge select the 105 MeV electrons

Muon Transport Section
Long enough so that pions decay to muons
Curved so can momentum and charge select particles

Detector
Straw tube tracker and ECAL

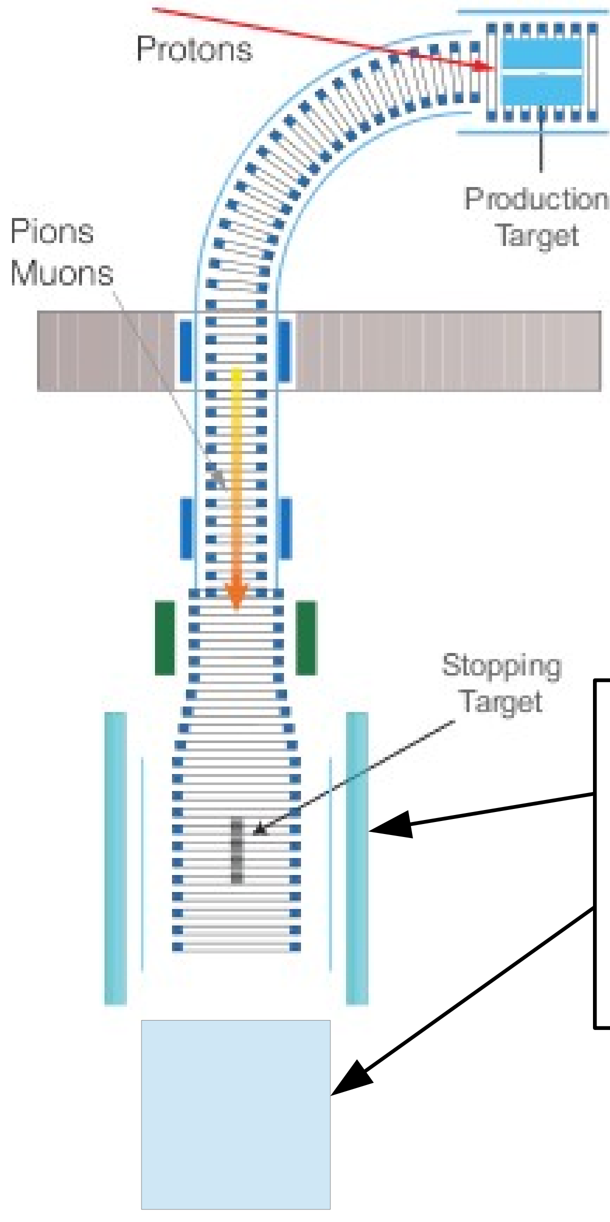
COMET (Phase-I)



Pion Capture Section
Has a high (5T) magnetic field to collect the low momentum, backwards travelling pions

Starting in 2016
Measurement in 2017
S.E.S = 3×10^{-15}

COMET (Phase-I)

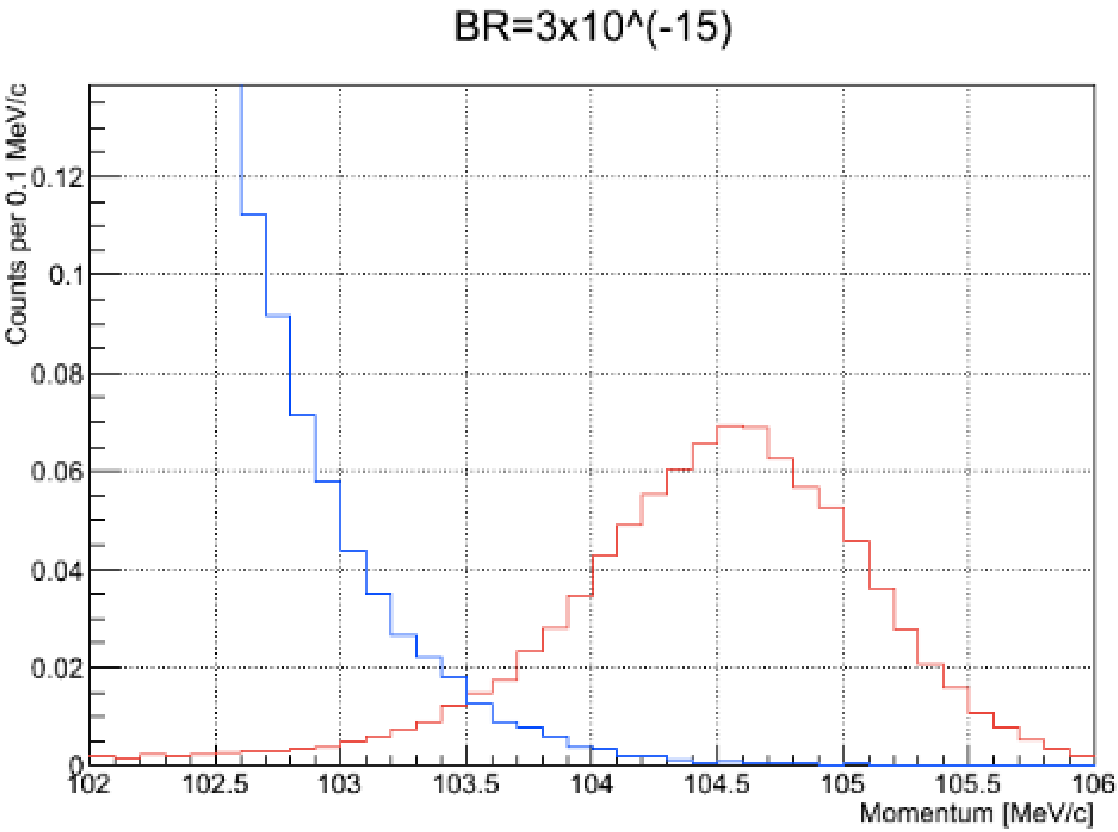


Phase-I Aims
Search for μ-e conversion process with a S.E.S of 3×10^{-15}
Study the backgrounds for Phase-II

Phase-I Detector
A cylindrical drift chamber (CDC) for the μ-e conversion search
A prototype ECAL and straw tube tracker for the background studies

Signal

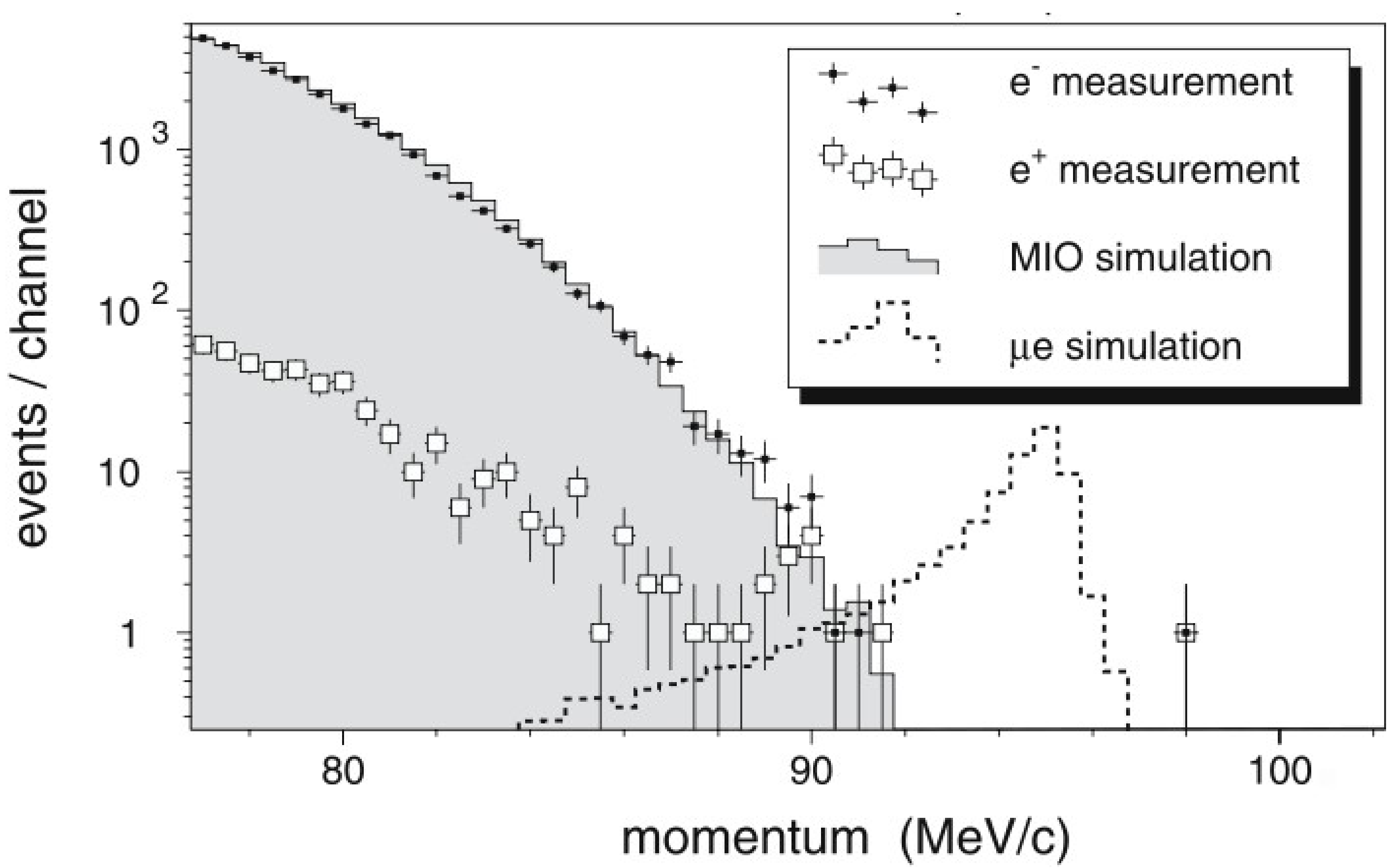
- Signal is a monoenergetic electron of ~105 MeV (for Al)



Expected signal (red) and DIO (blue)

Signal

- Actually see something like this:



SINDRUM Plot
μ-e conversion in Au (Signal energy = 95 MeV)

Background Estimates

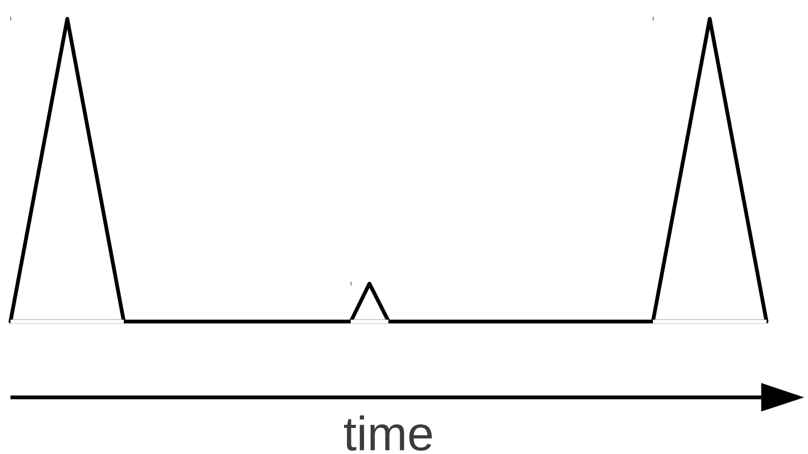
- For Phase-I we expect 0.03 background events per signal event for BR = 3×10^{-15} and 1.5×10^{6} s running

Background	Expected Number of Events
Decay In Orbit (DIO)	0.01
Radiative Pion Capture (RPC)	0.01*
All others	0.01

Detector

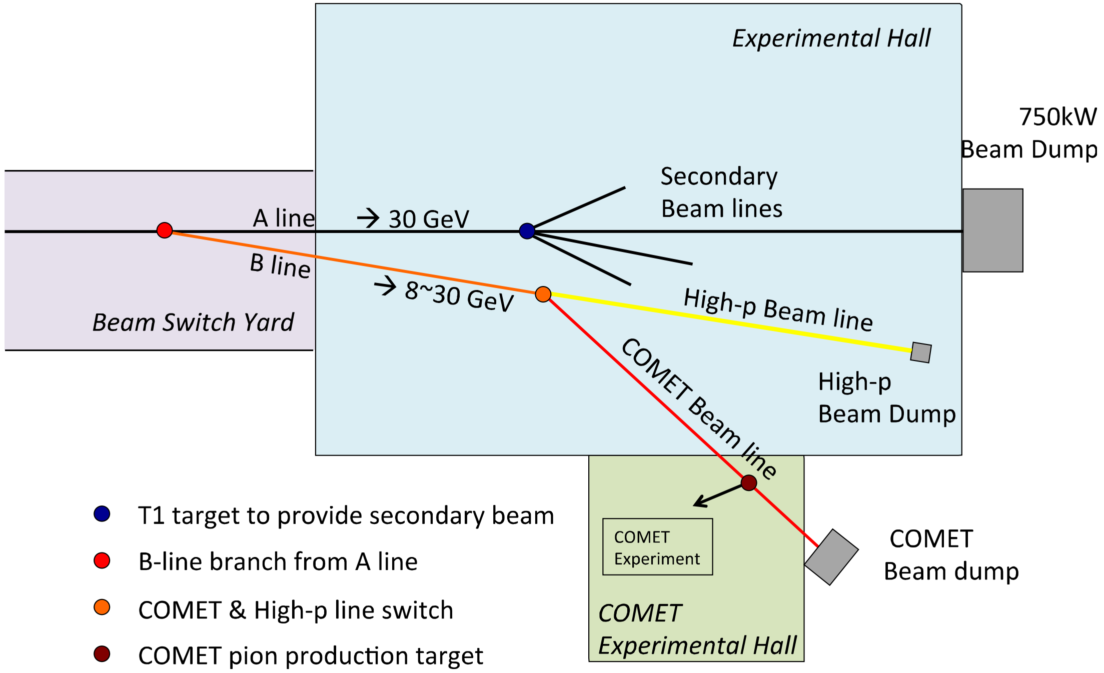
Accelerator

* Assuming proton beam extinction factor of 3×10^{-11}



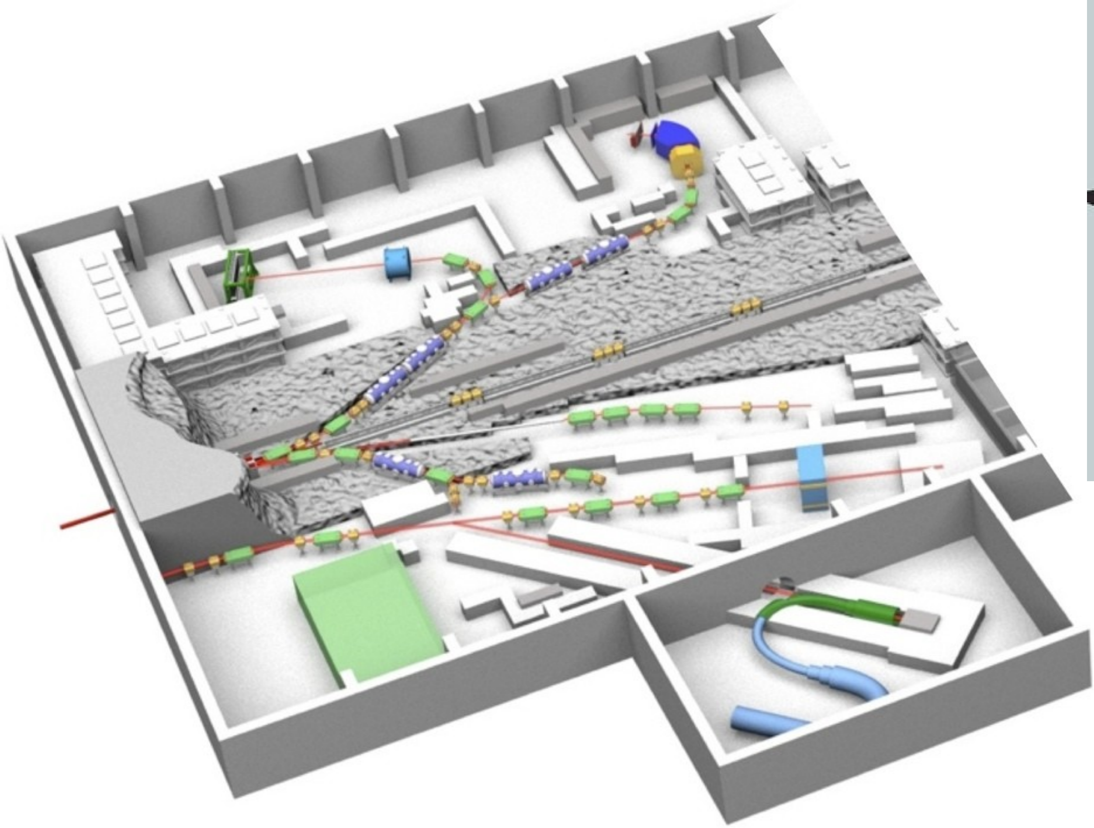
Beamline Construction

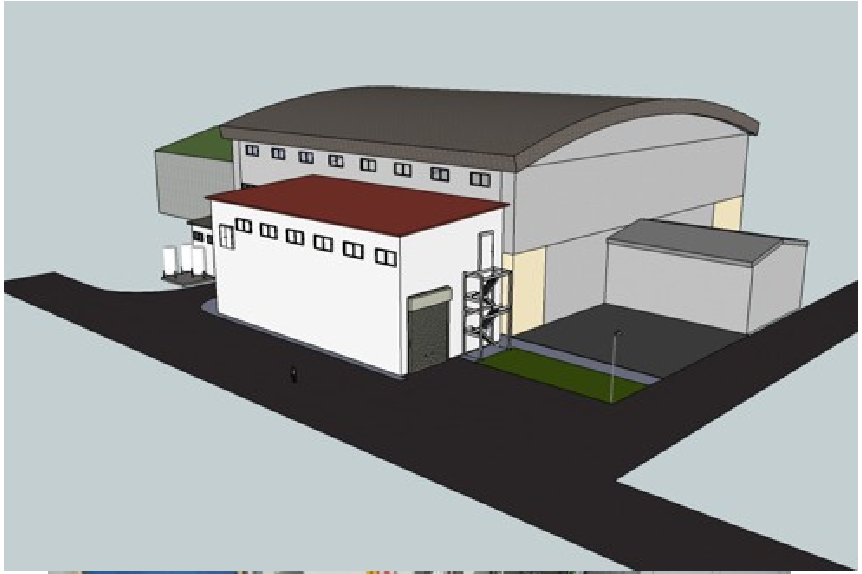
- $35M funding from KEK in the JFY 2012 supplementary budget for new beam lines
  - Will be completed in spring 2015



Facility Construction

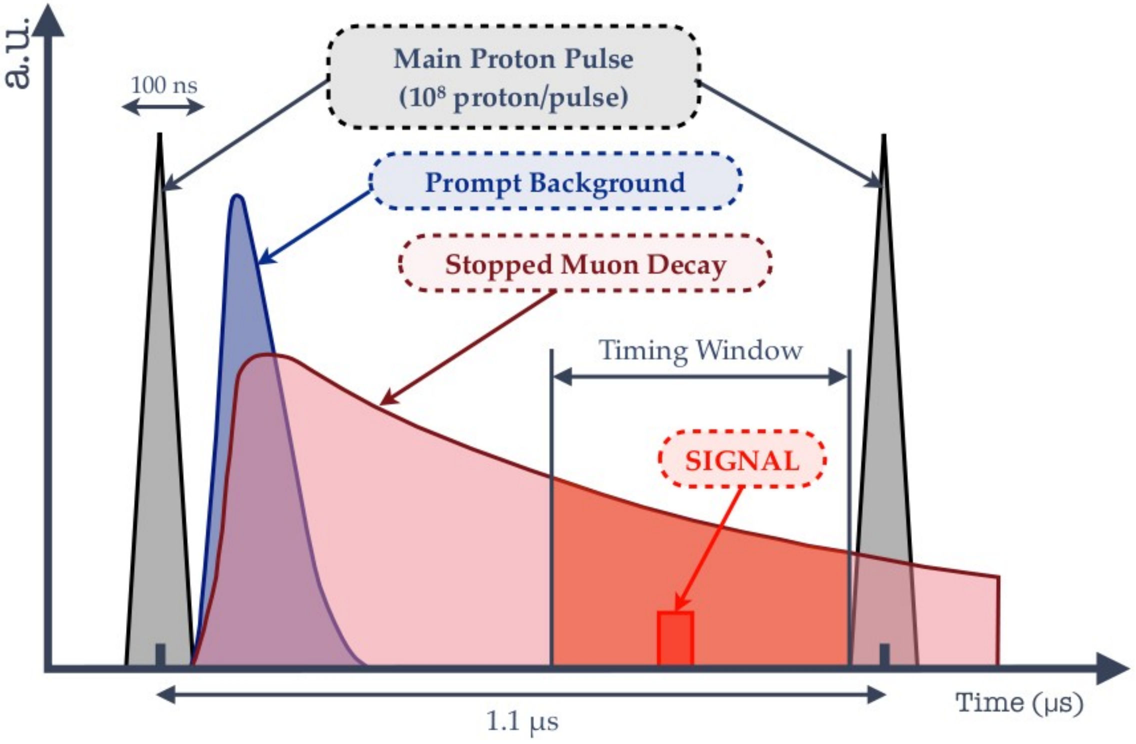
- Work already under way on the facility construction



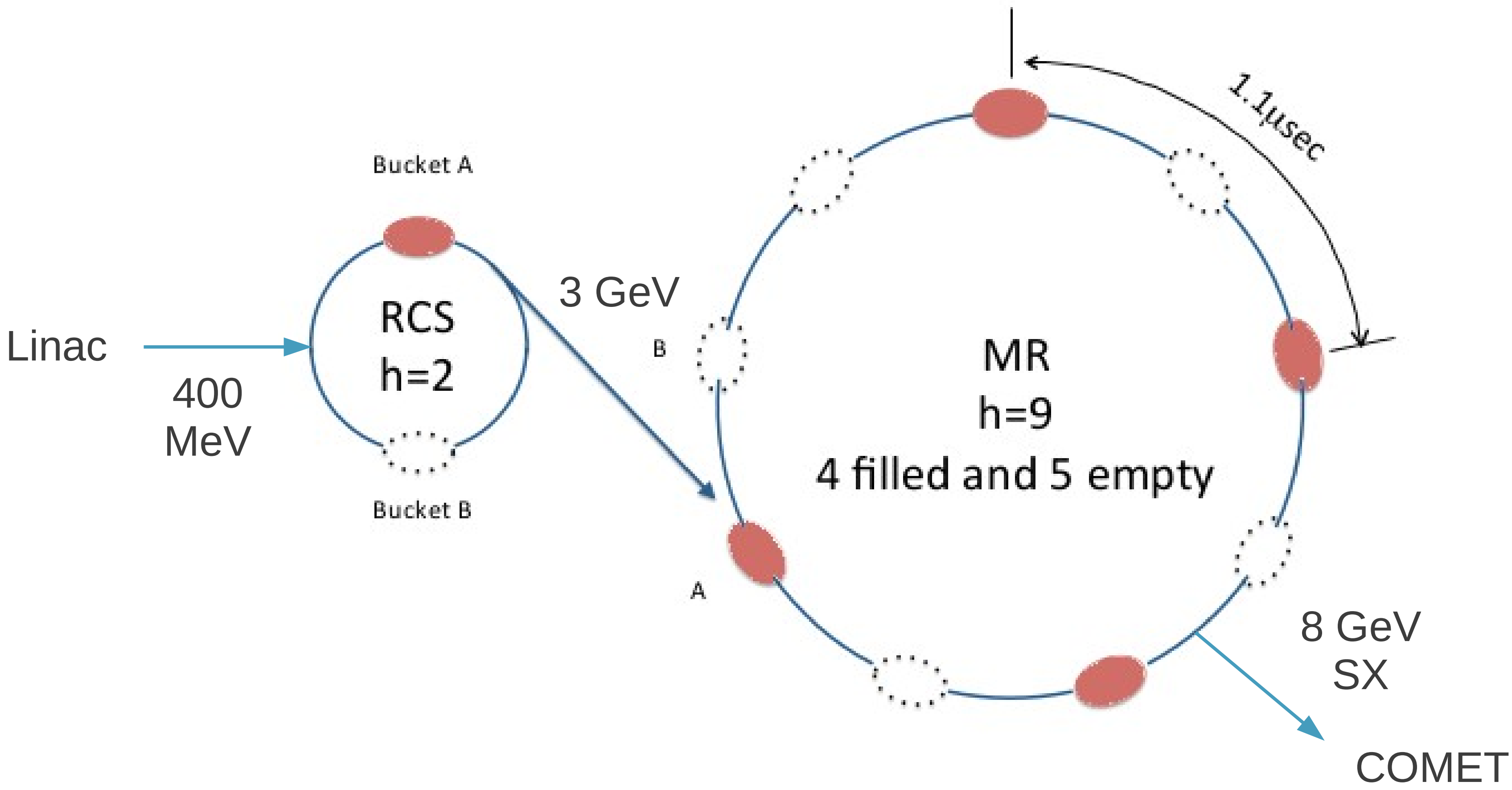


Proton Beam

- Energy: 8 GeV
- Power: 3.2 kW / 56 kW (Phase-I/Phase-II)
- Pulsed
  - Allows us to measure in a timing window and reduce beam-related backgrounds



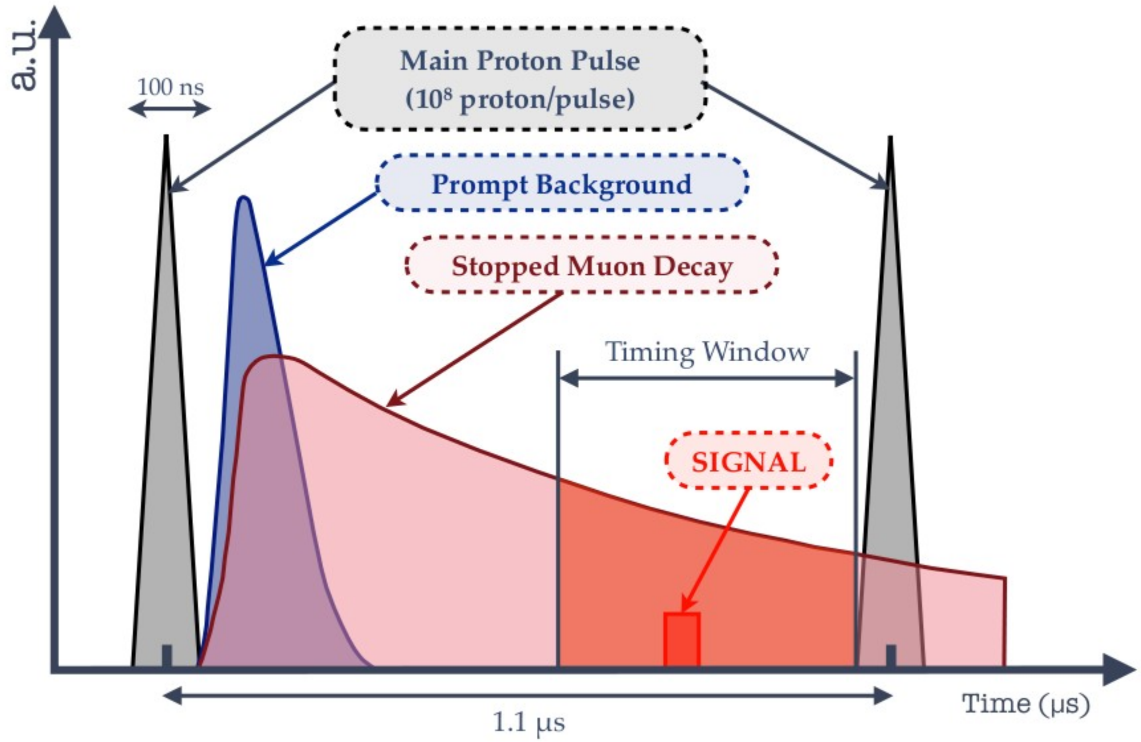
Proton Beam Acceleration



Proton Beam Extinction

- Extinction is the residual protons between pulses

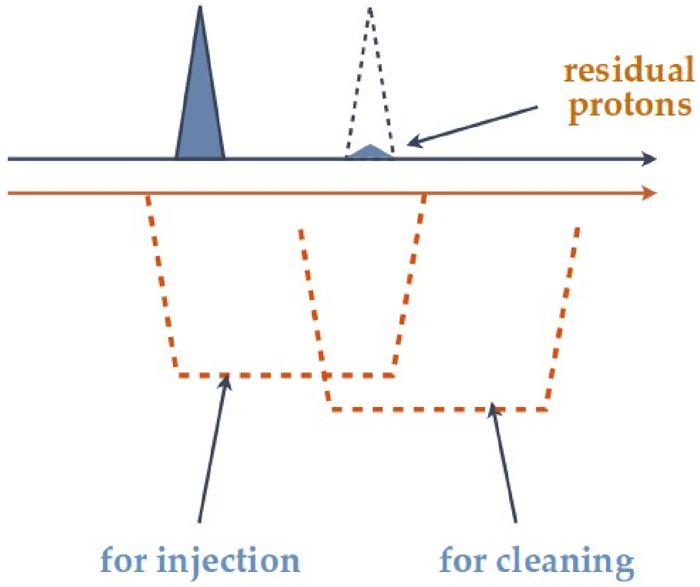
$$extinction = \frac{number\ of\ protons\ between\ pulse}{number\ of\ protons\ in\ pulse}$$



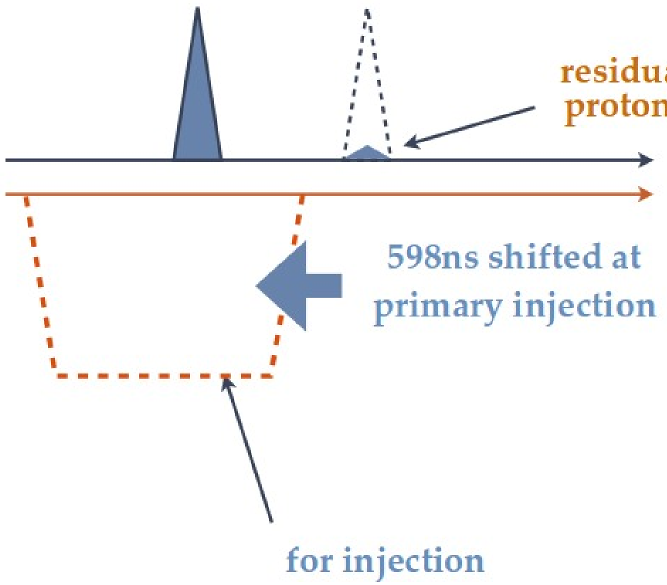
Proton Beam Extinction

- Plan to use a novel kick injection method such that residual protons don't enter MR

Double Kick Injection

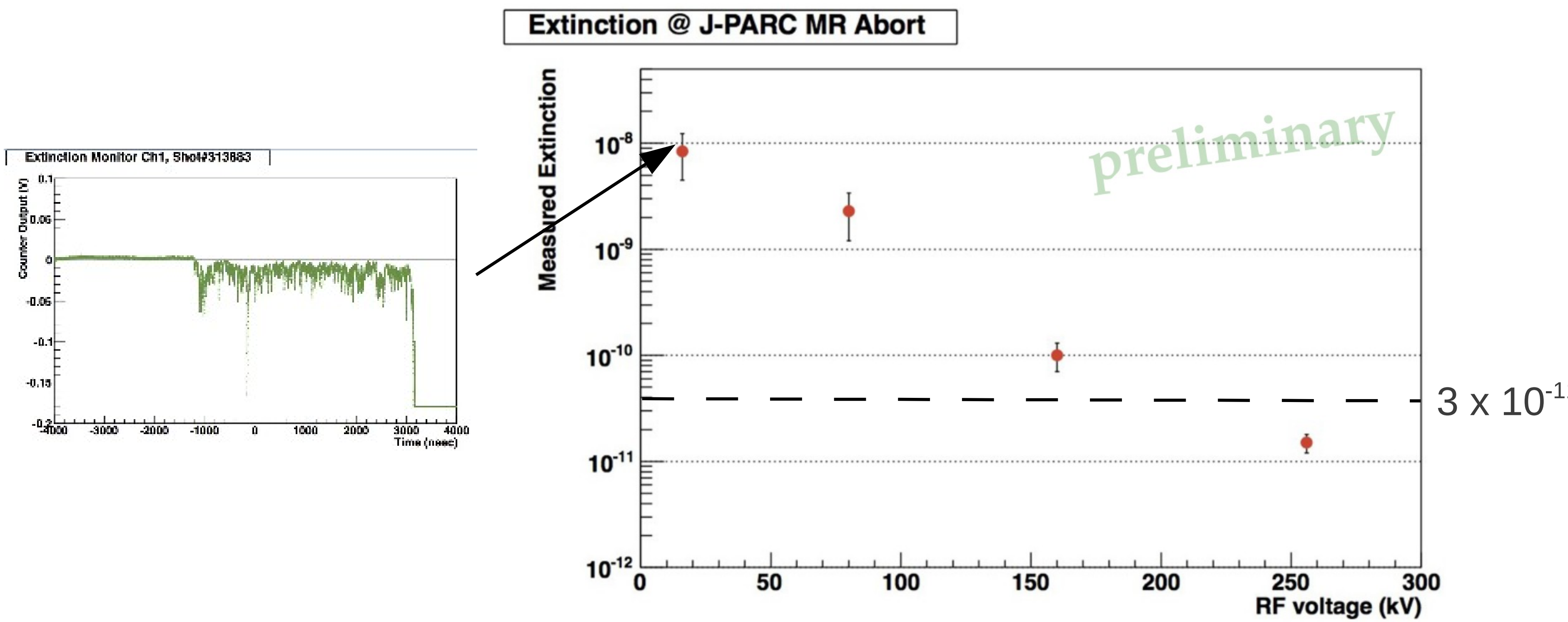


Single Bunch Kick Injection



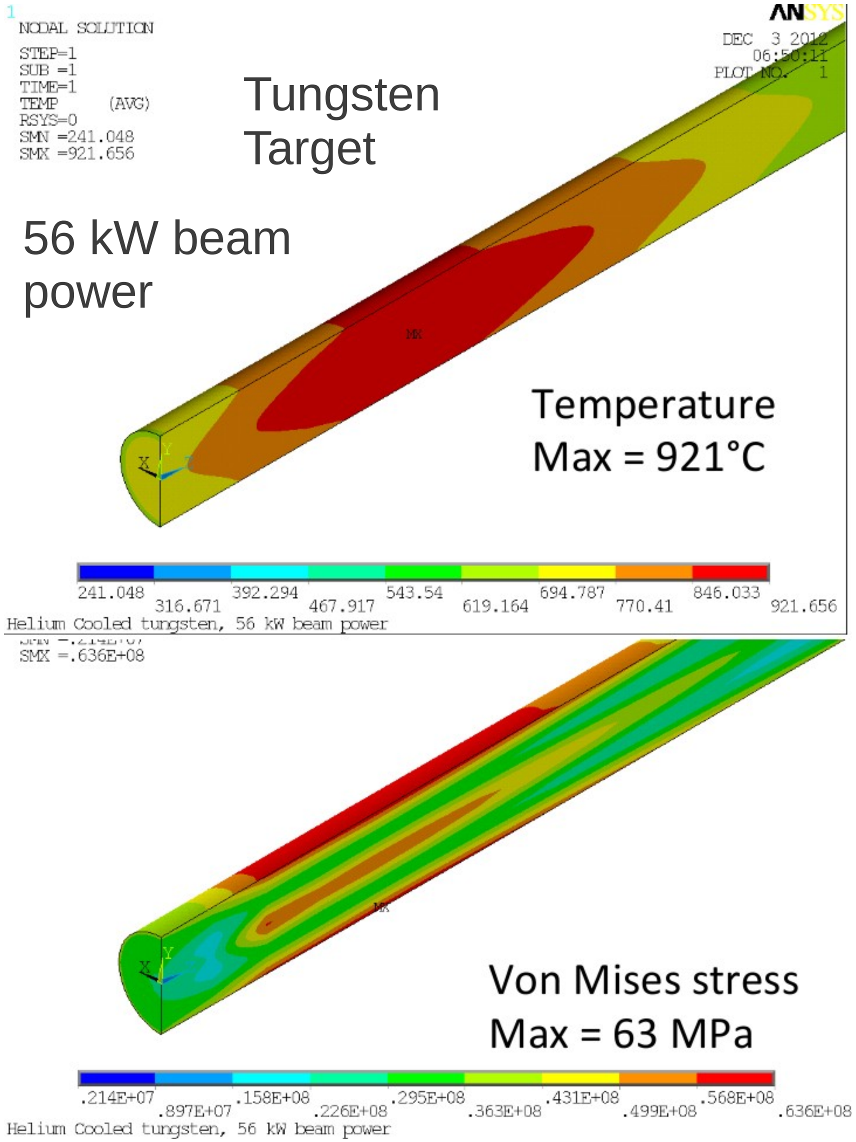
Proton Beam Extinction

- Single bunch kick injection method successfully demonstrated in June 2012 at J-PARC



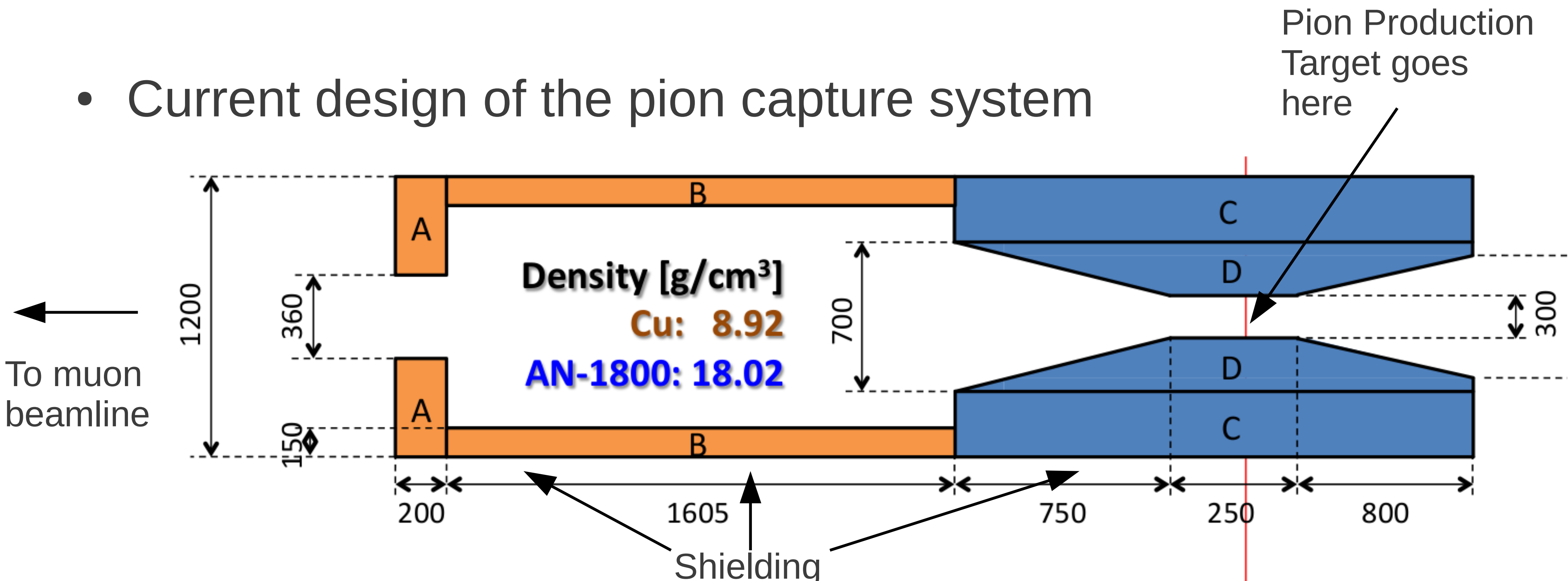
Pion Production Target

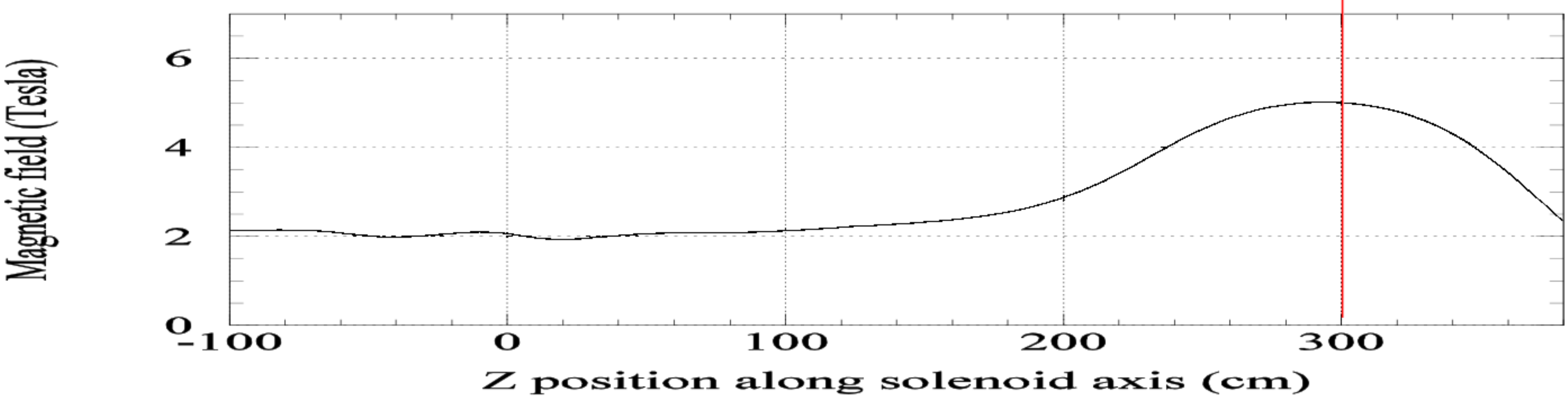
- For Phase-I will use a graphite target
  - Radiation cooling
- For Phase-II will move to a tungsten target
  - Greater pion yield
  - Requires helium cooling



Pion Capture Solenoid

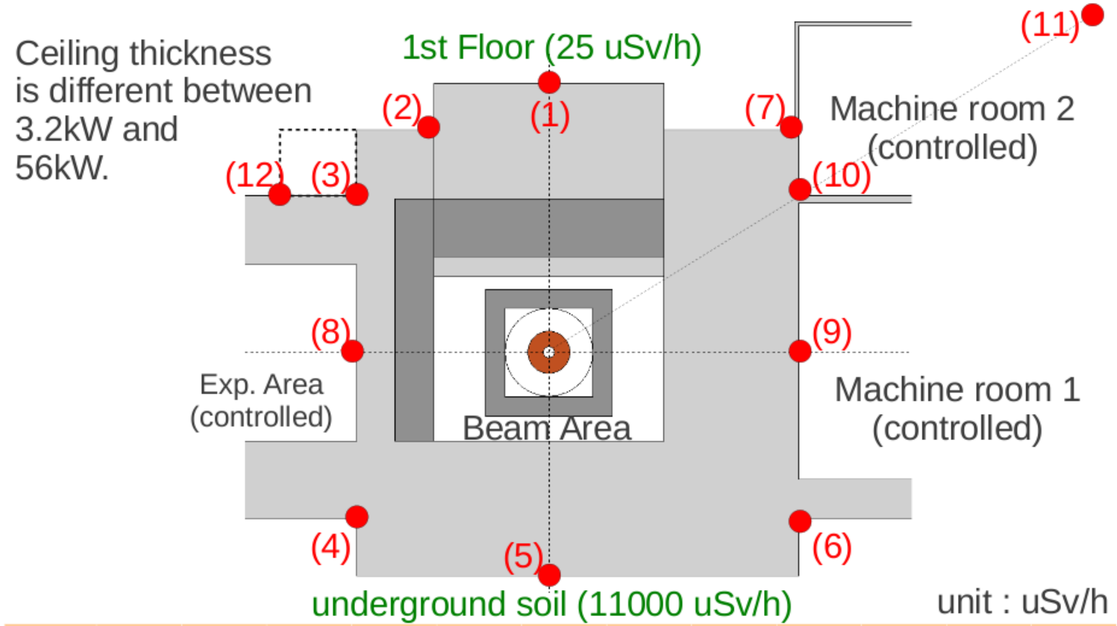
- Current design of the pion capture system





Neutron Backgrounds

- Regulations
  - < 25 μSv/h at 1F
  - < 11 mSv/h in underground soil
- Performed calculation with Moyer model (very preliminary)
- Will calculate with PHITS and MARS



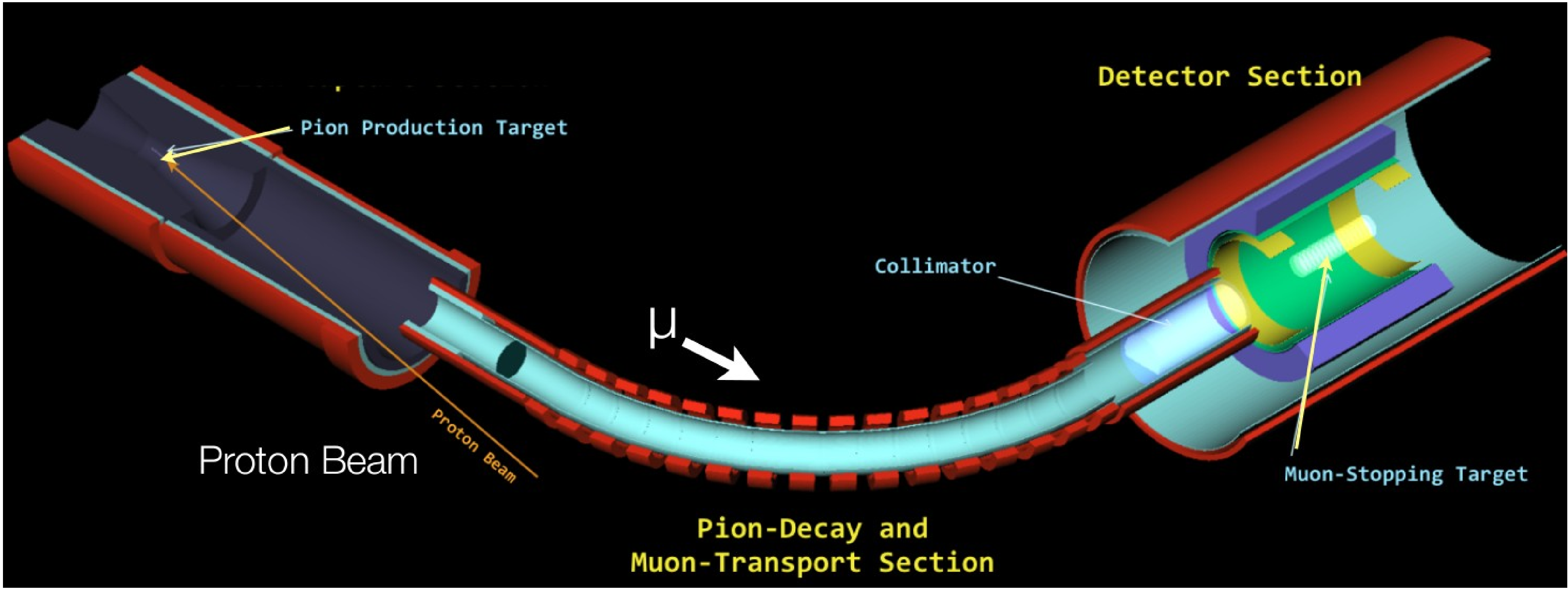
unit : uSv/h

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
3.2kW	4.8	3.5	6.9	248	360	42	1.2	378	485	83	1.3	1.1
56kW	4.4	6.9	56.8	2038	2964	345	9.7	3107	3988	683	10.3	9.2

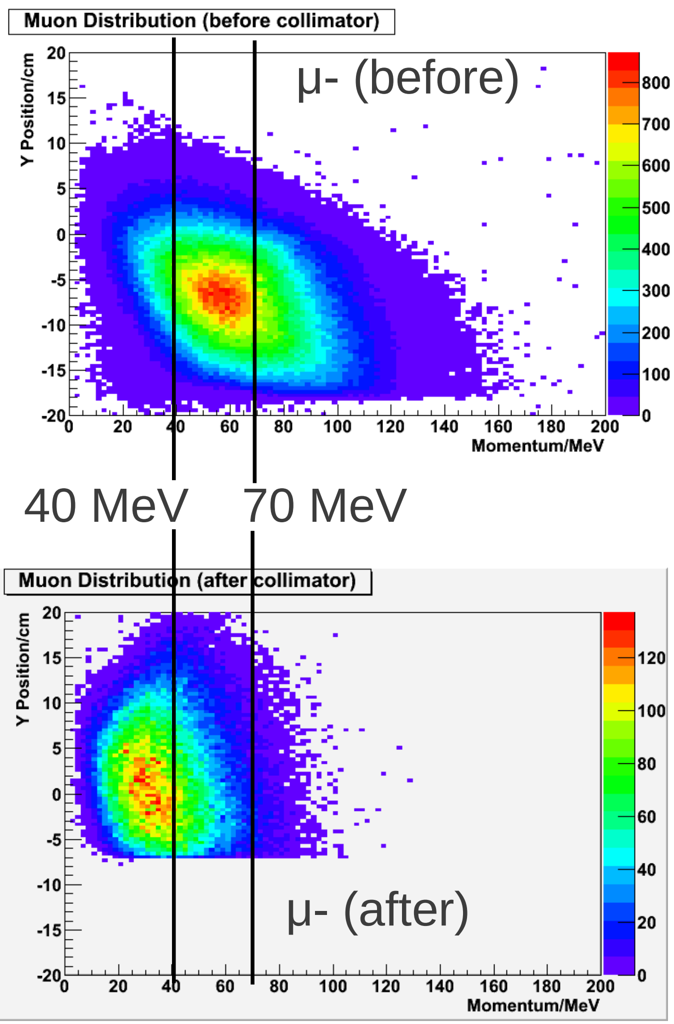
Moyer Model Calculation

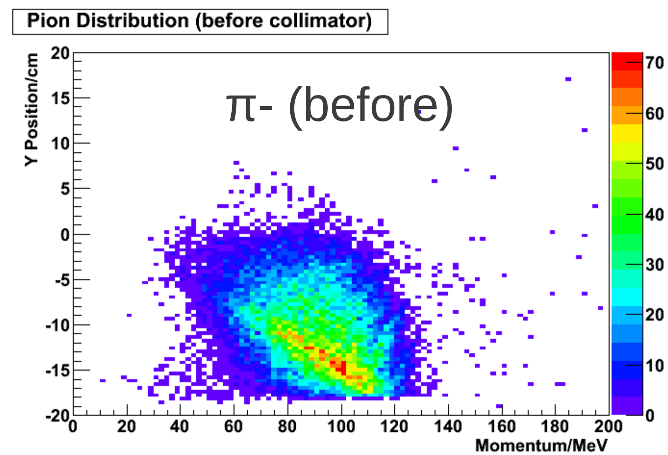
Muon Transport

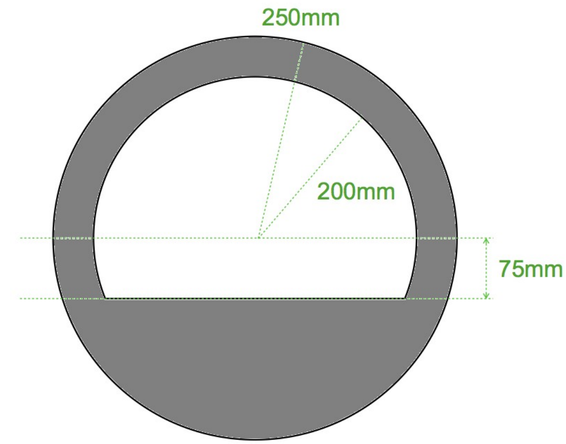
- For Phase-I need a collimator to reduce high momentum muons and all pions



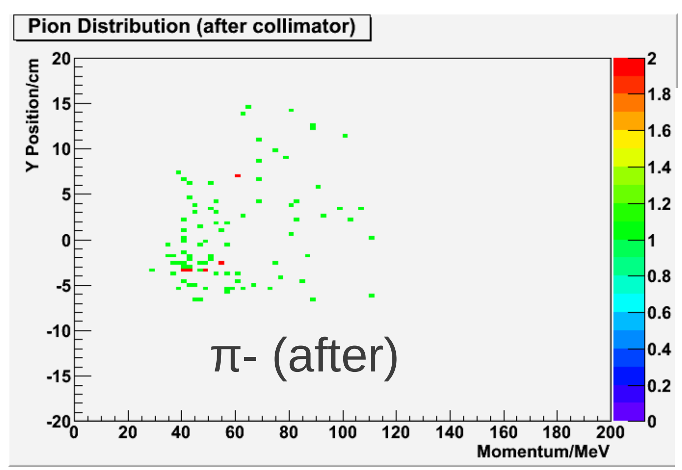
Muon Transport

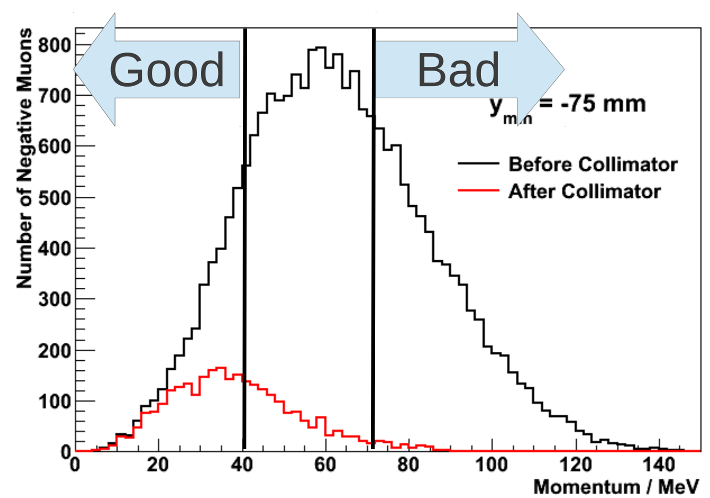




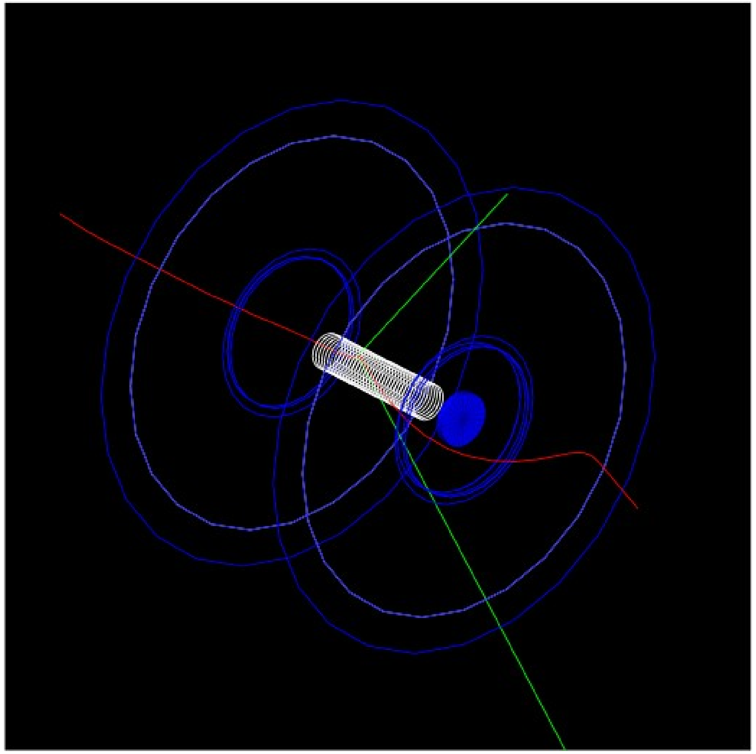


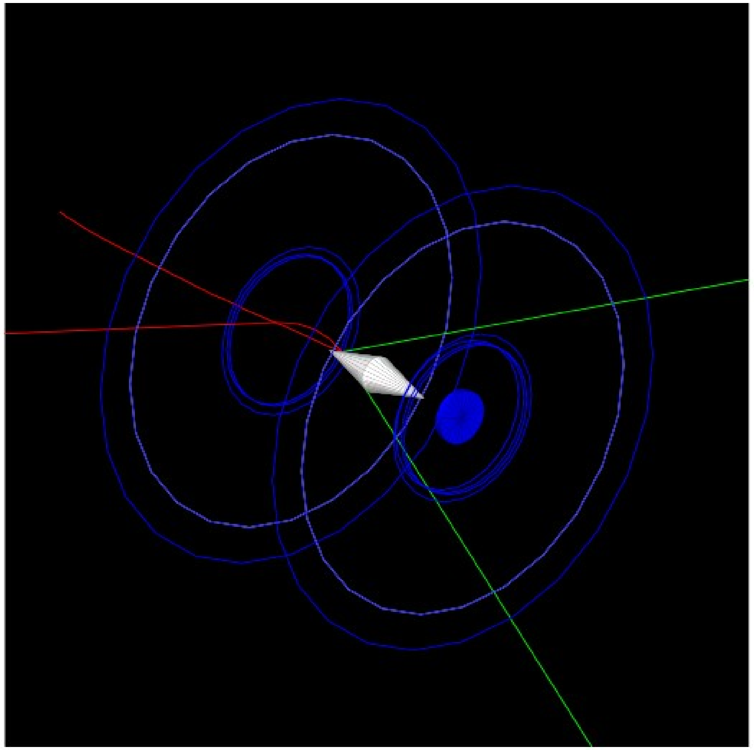
Shape of Collimator





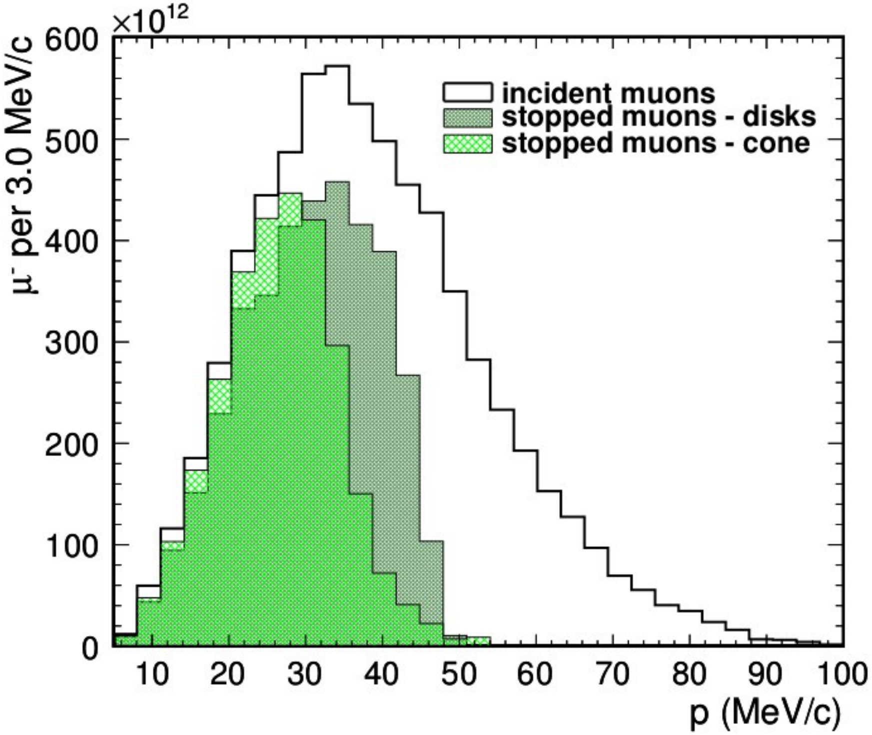
Stopping Target



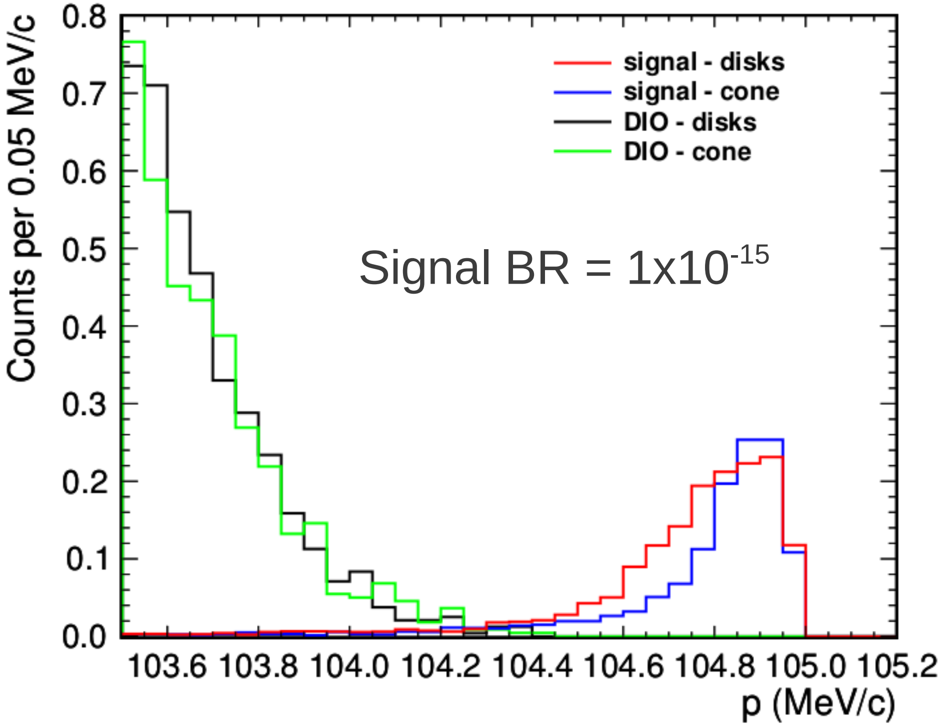


- Currently 17 Al disks but also looked at double cone
- Radius: 10 cm, Thickness: 200 μm, Length: 80 cm

Stopping Target



Plot of stopped muon momentum distribution

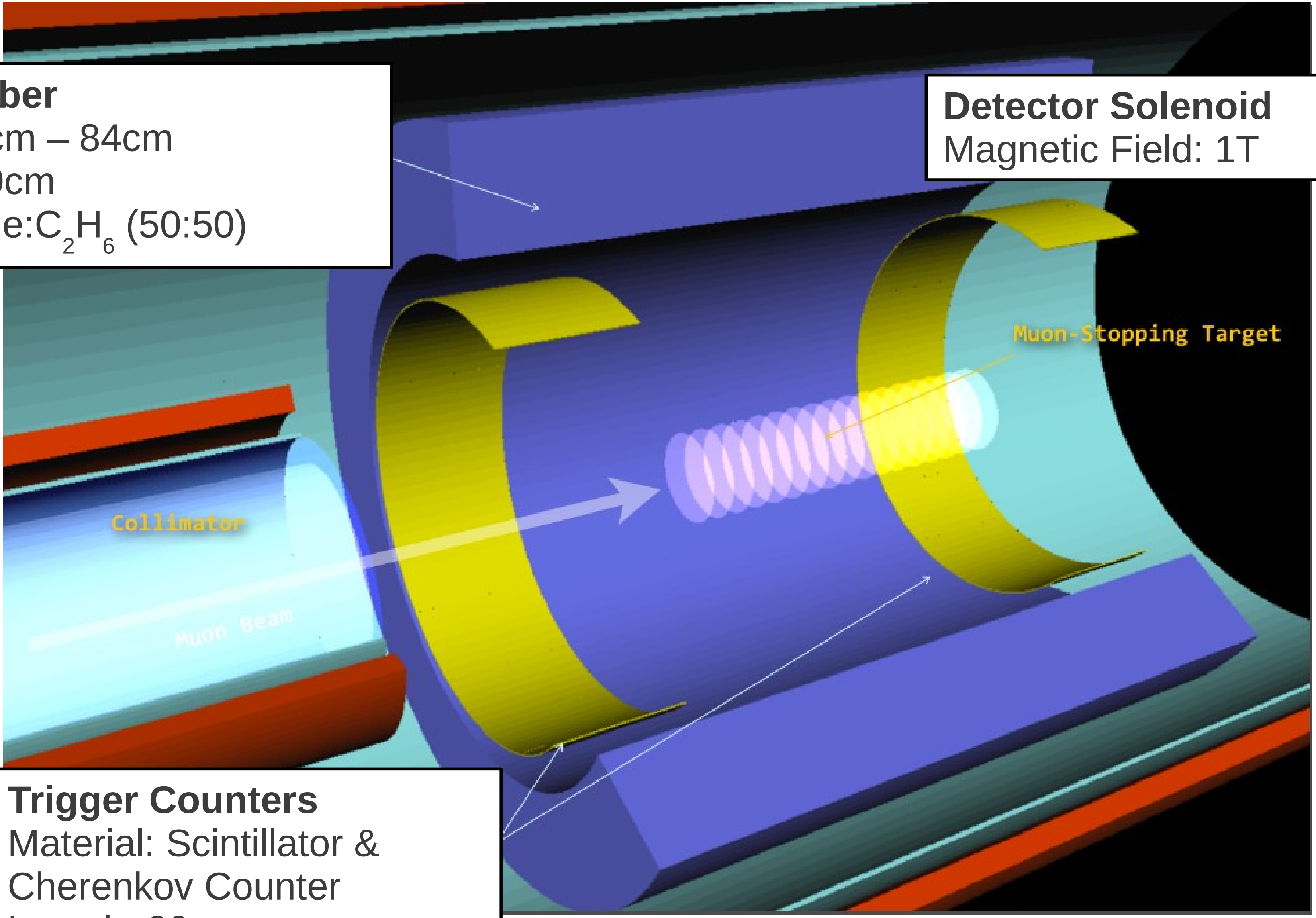


Plot of signal shape

Stopping Target	Stopping Efficiency
Disks	0.66
Cone	0.42

Stopping Target	# Events (p > 104.4 MeV)
Disks	1.14
Cone	1.45

Cylindrical Drift Chamber



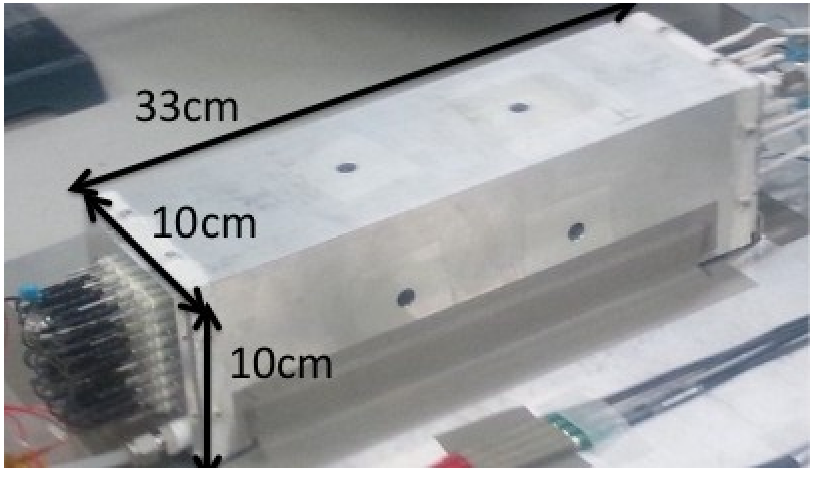
Drift Chamber
Radius: 55cm – 84cm
Length: 150cm
Drift Gas: He:C_2H_6 (50:50)

Detector Solenoid
Magnetic Field: 1T

Trigger Counters
Material: Scintillator & Cherenkov Counter
Length: 20cm
Thickness: 5mm

Cylindrical Drift Chamber

- Requirements
  - Gas gain: > 10^5
  - Position resolution (x, y): < 150 μm
  - Position resolution (z): < 2mm
  - Reduce multiple scattering for good momentum resolution
- Small prototype at Osaka shows that this is achievable



Cylindrical Drift Chamber

- But proton emission from muon capture greatly increases the detector rates

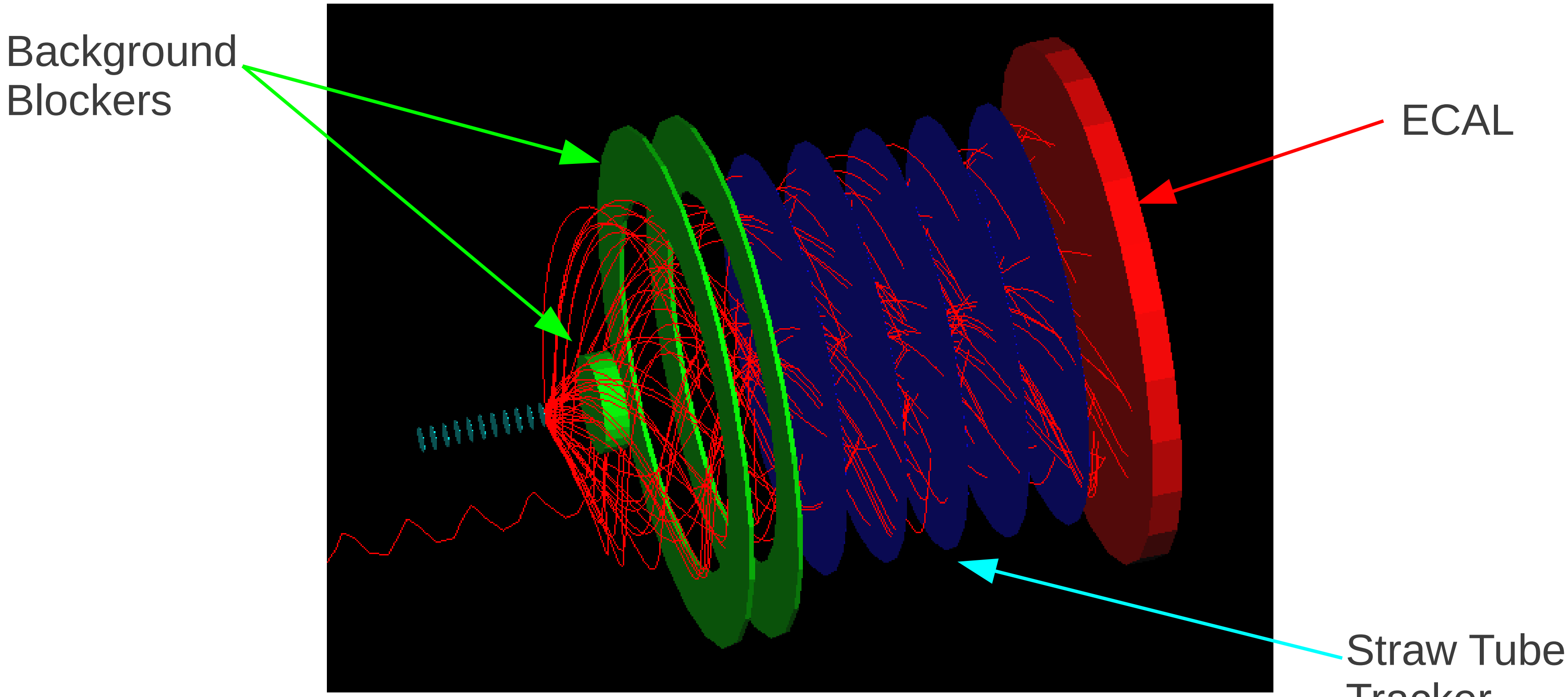
Source	Optimisation	Hit Prob.	Rate† / wite
DIO electrons	Minimum radius 55cm	8.6×10^{-7}	270 Hz
Protons after muon capture*	Inner wall (CFRP) thickness 0.4mm	1.1×10^{-3}	40kHz

* Assume 15% per capture † No. of wires at innermost layer = 330

- Current simulation suggests the resolution will be ~510 keV/c

Final Phase-II Detector

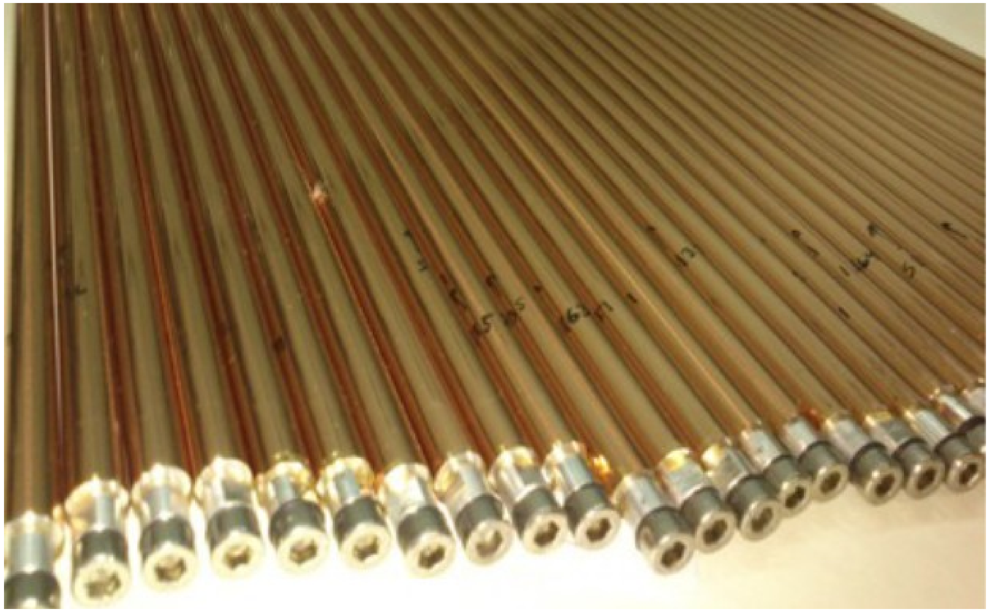
- The final Phase-II detector will consist of a straw tube tracker and an electromagnetic calorimeter
- Phase-I will develop prototypes of these for background measurements



Phase-I Detector

Straw Tube Tracker

- Proposing to use the same straws developed at JINR for NA62 with some modifications
- The COMET straws will probably be thinner to improve resolution

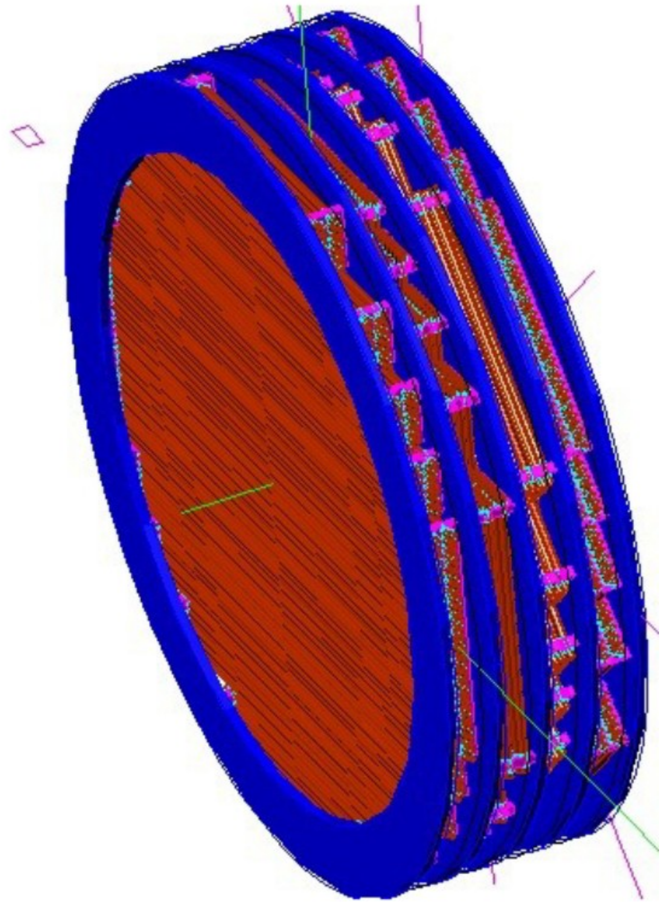


Straw Tube Tracker

- KEK-JINR collaboration set up to develop the COMET straw tube tracker
- Prototype will be built with NA62 straws for detector R&D
- Prototype under construction with R&D in the second half of this year

Straw Tube Tracker

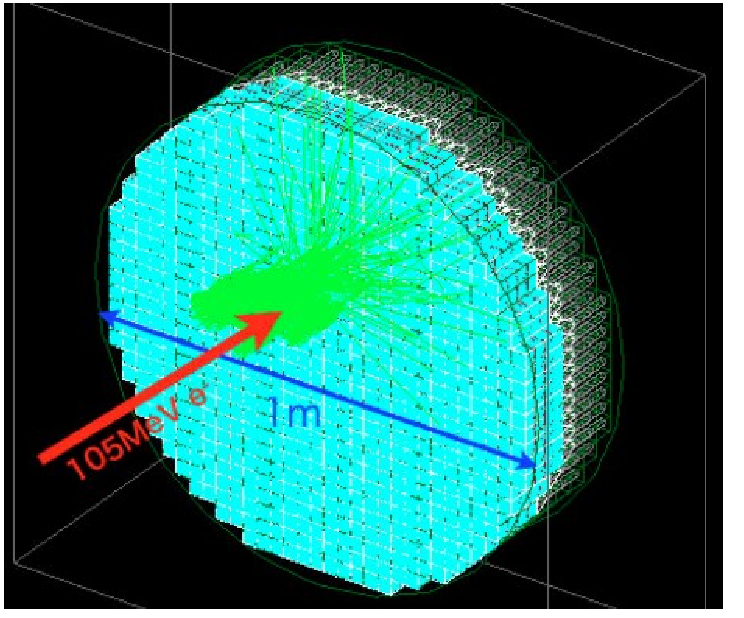
- Current design is to have 5 super-layers each with 4 layers of straws
- Many things to think about
  - Support structure
  - Feed through

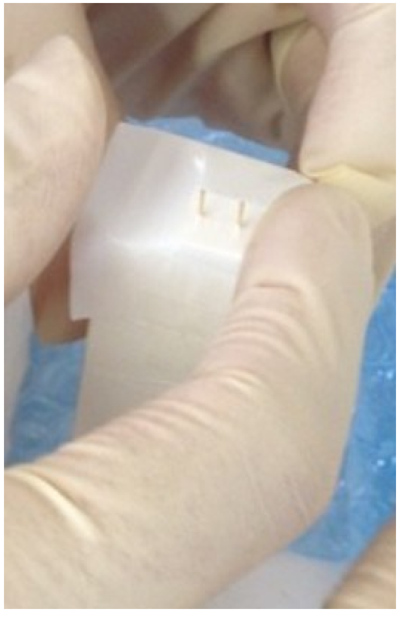


Tentative design of one super-layer

Electromagnetic Calorimeter

- Requirements
  - Resolution: <5% at 105 MeV/c
  - Trigger Rate: <5 kHz
  - Spatial resolution: <1.5 cm
  - Response: <100 ns
- Two candidate crystals
  - GSO and LYSO



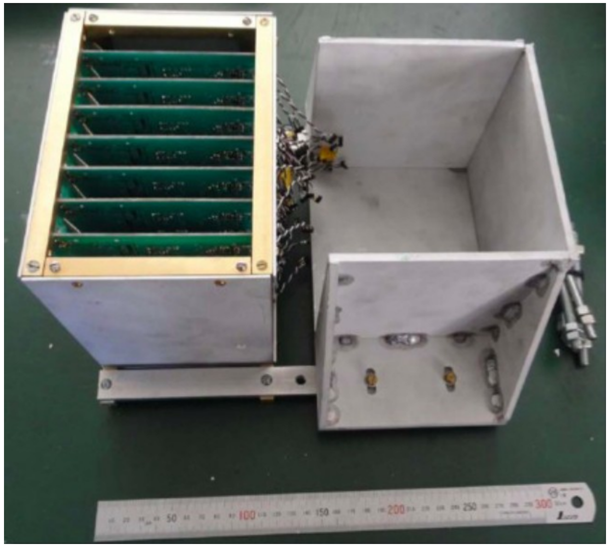


One Crystal

Electromagnetic Calorimeter

- Beam test at KEK (28th Apr - 2nd May)
  - Used both GSO and LYSO crystals
  - 7x7 crystal array
  - Measured the resolution at 80, 90, 105, 120, 180 and 250 MeV/c
- Planning future beam tests (KEK and BINP)

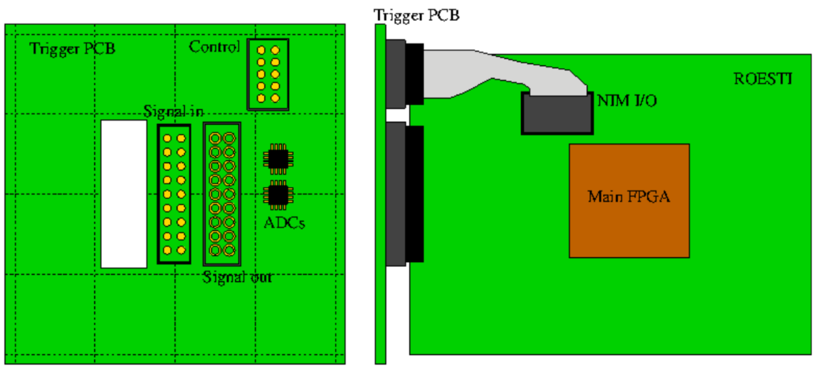
2x2 Crystal Array



Prototype Frame

DAQ & Trigger

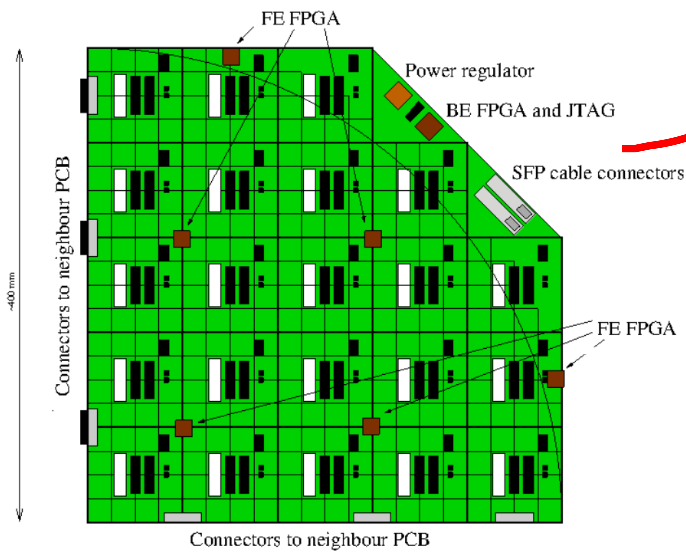
- The basic unit will be a 4x4 crystal array with a single trigger board which can scale up to the full ECAL

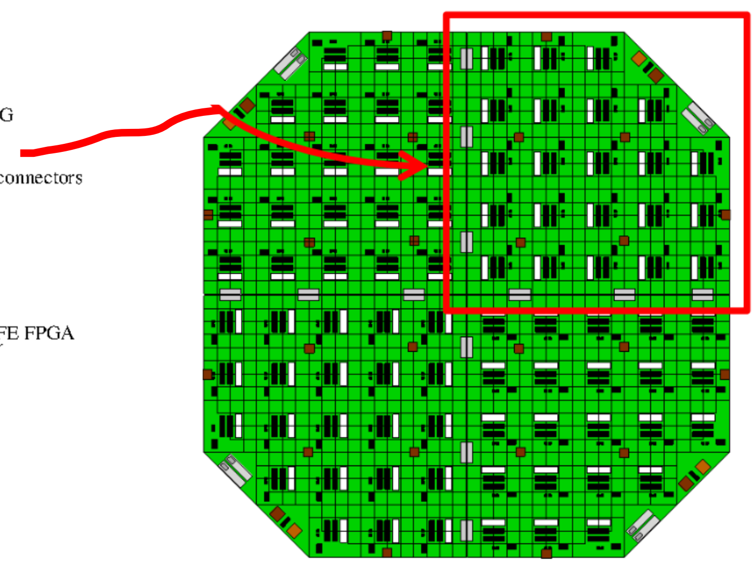


Left: Basic Unit

Below: Full scale with modular quadrants

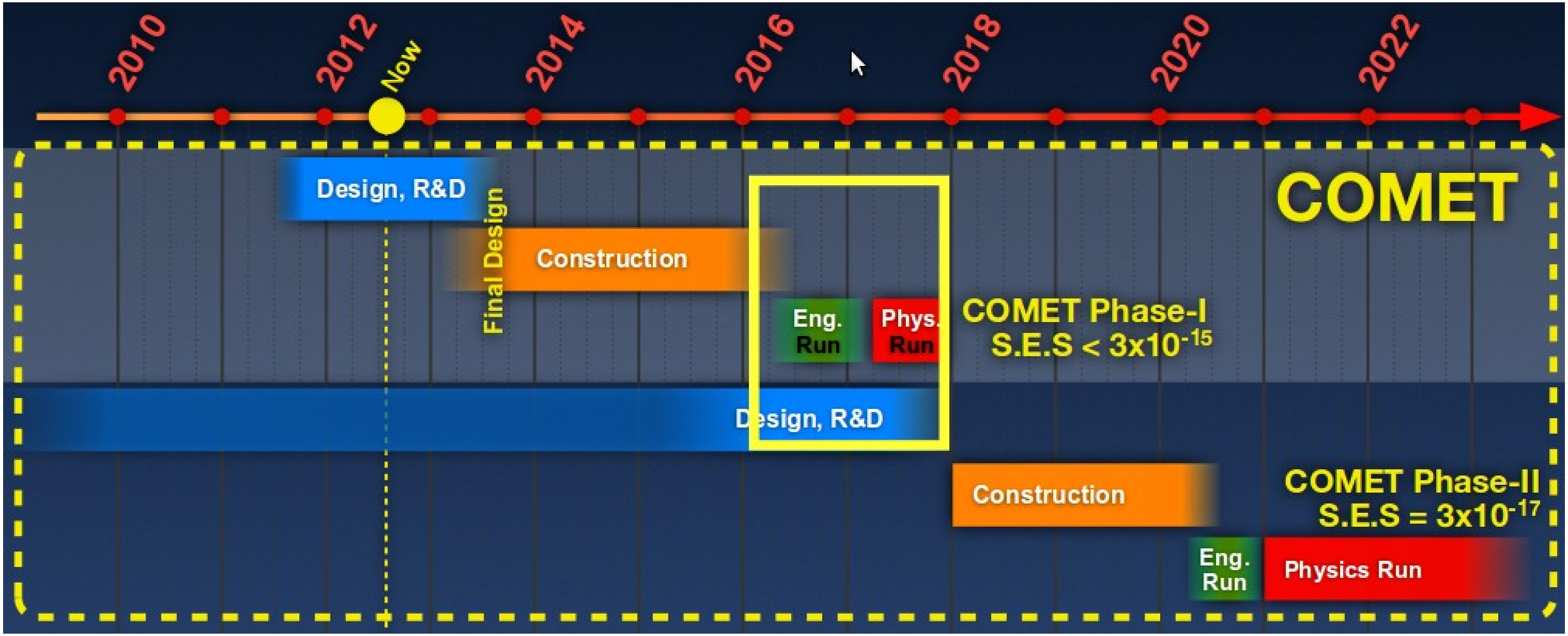
For 1316 crystals





Timeline

- Current time scales



Conclusion

- COMET is going to take a staged approach
  - Starting in 2016: Phase-I – S.E.S: 3×10^{-15}
  - Starting in 2020: Phase-II – S.E.S: 3×10^{-17}
- Design and R&D is well underway
- Funding secured and construction started for COMET Phase-I

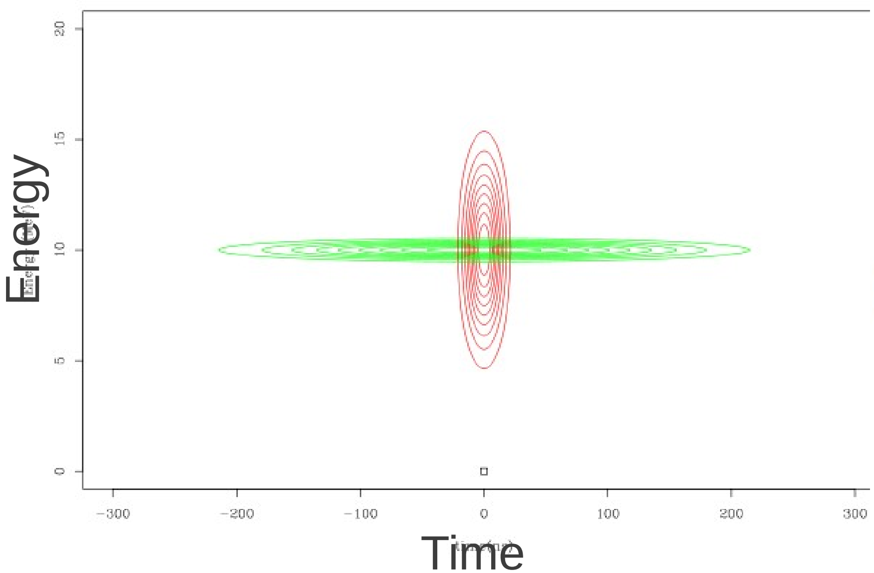
Thanks for Listening

Any Questions?

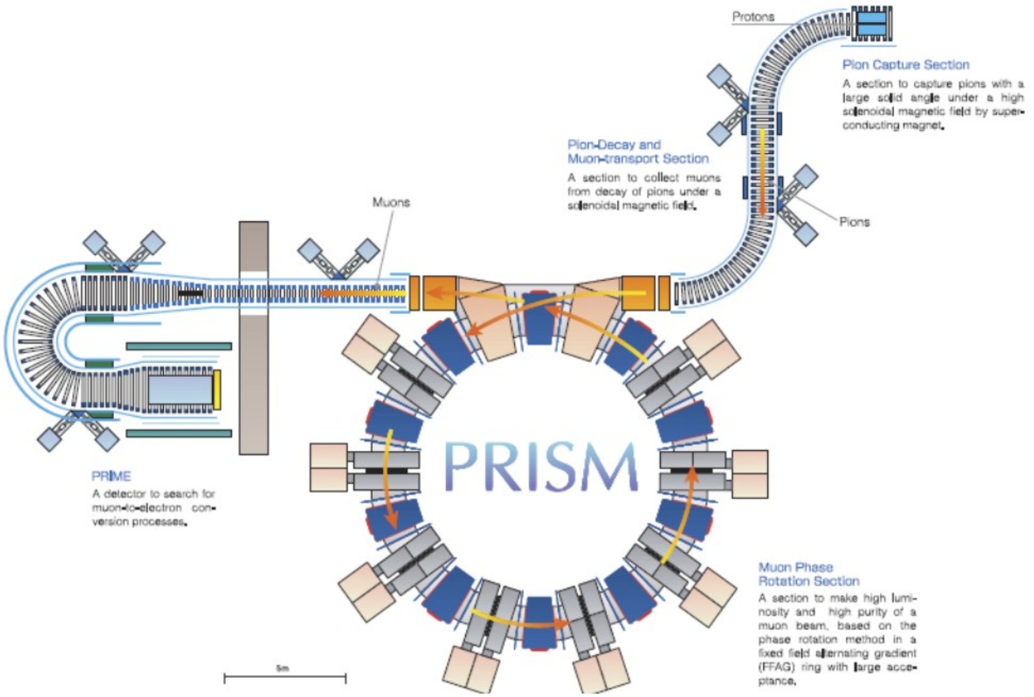
Back Up

PRISM/PRIME

- To get down to 10^{-18} and beyond PRISM/PRIME propose to use an FFAG ring
- This gives the muon beam a small momentum width which allows the use of one target disk



Before phase rotation (red)
After phase rotation (green)



Background Estimation

- Here are the estimates for our backgrounds for Phase-I
  - Two main backgrounds are DIO and RPC

Background	estimated events
Muon decay in orbit	0.01
Radiative muon capture	< 0.001
Neutron emission after muon capture	< 0.001
Charged particle emission after muon capture	< 0.001
Radiative pion capture	0.0096^*
Beam electrons Muon decay in flight Pion decay in flight	$< 0.00048^*$
Neutron induced background	$\sim 0^*$
Delayed radiative pion capture	0.002
Anti-proton induced backgrounds	0.007
Electrons from cosmic ray muons	< 0.0002
Total	0.03