COMET Phase-II

NUFACT2014, XVIth International Workshop on Neutrino Factories and Future Neutrino Facilities

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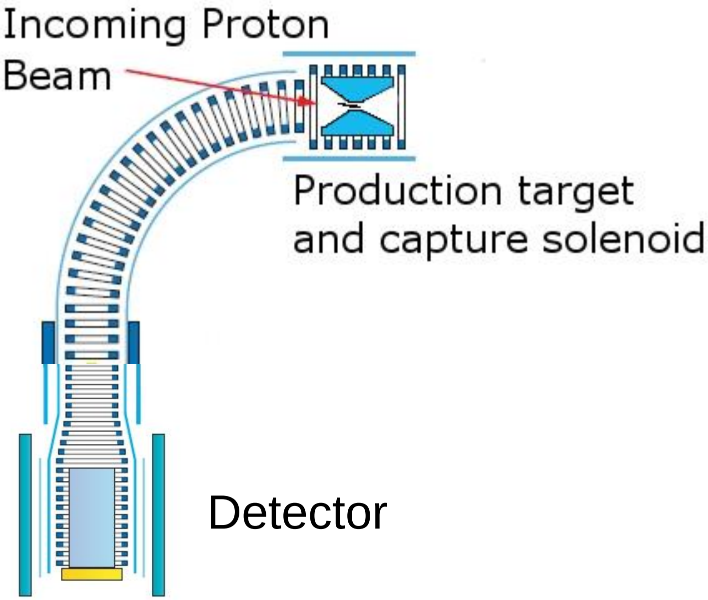
Introduction

- COMET aims to search for muon to electron conversion with a single event sensitivity 2.6×10^{-17}.
- Previous limit set by the SINDRUM-II experiment is 7×10^{-13}.
  - 4 orders of magnitude improvement!
- The experiment will be built in two stages.
  - Allows important measurements of the beam.
  - Test prototypes of the detector systems.
- Most numbers and plots for Phase-II taken from the CDR.
  - Design will change based on experience from Phase-I.
- Overview of the experimental setup of Phase-II.

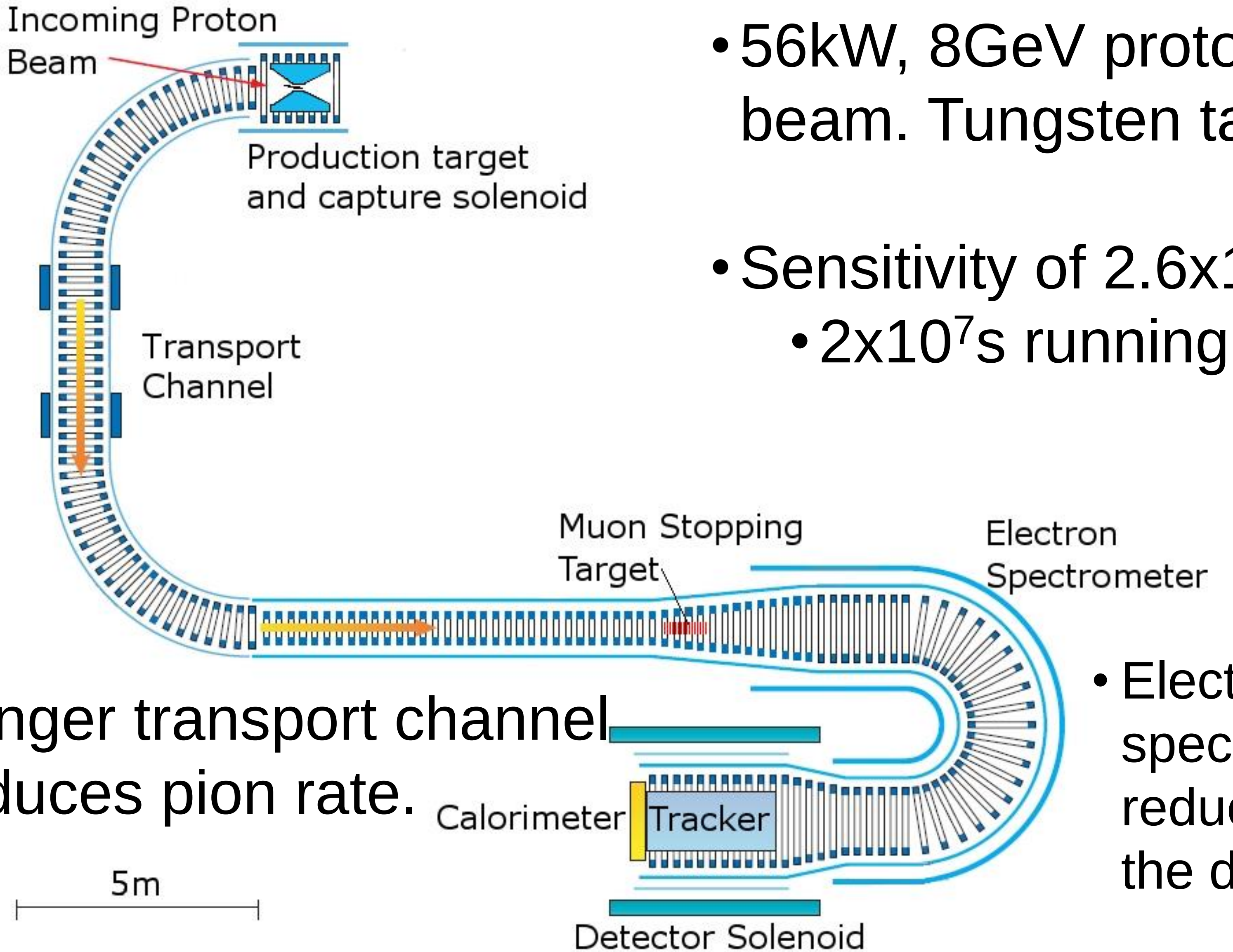
COMET Phase-I



- 3kW, 8GeV proton beam. Graphite target.
- Sensitivity of $3x10^{-15}$
    - 90 days running.

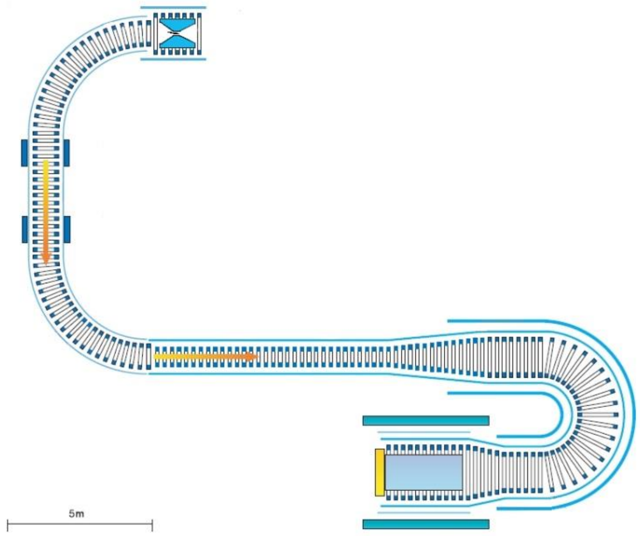
Construction of COMET experimental hall.

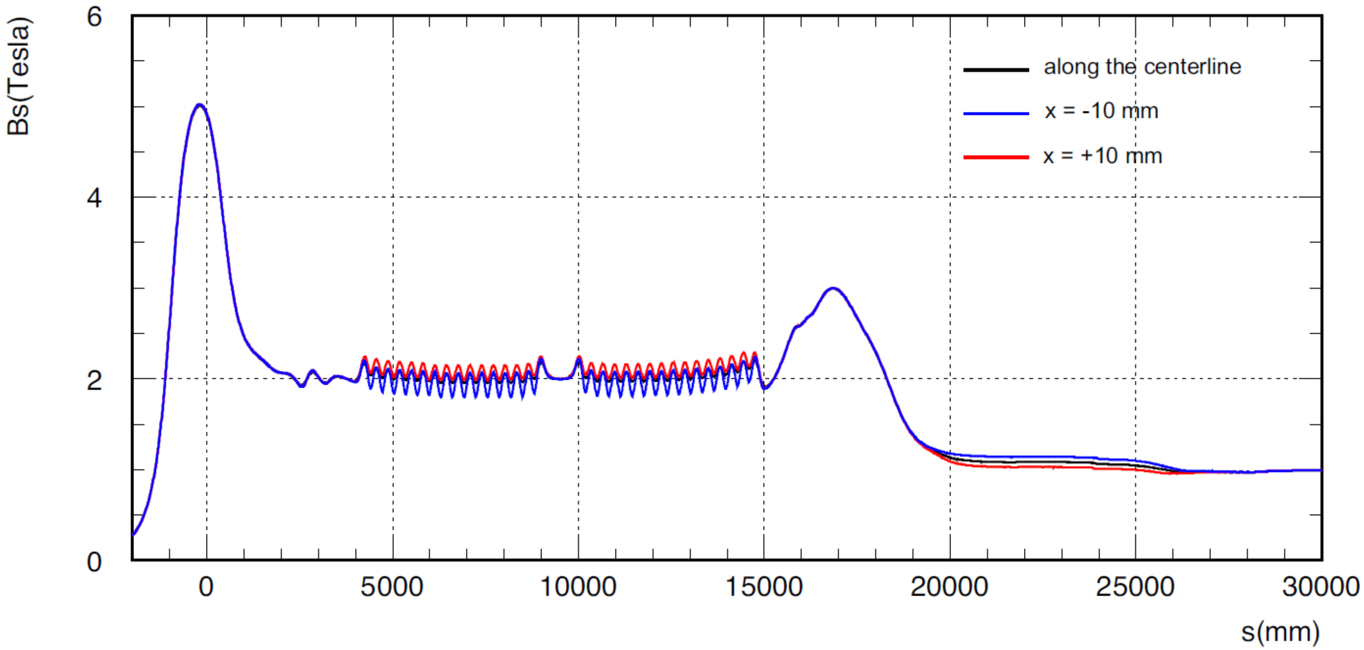
COMET Phase-II



- 56kW, 8GeV proton beam. Tungsten target.
- Sensitivity of 2.6×10^{-17}
  - 2×10^{7}s running.
- Electron spectrometer reduces rate in the detectors.
- Longer transport channel reduces pion rate.

COMET Phase-II

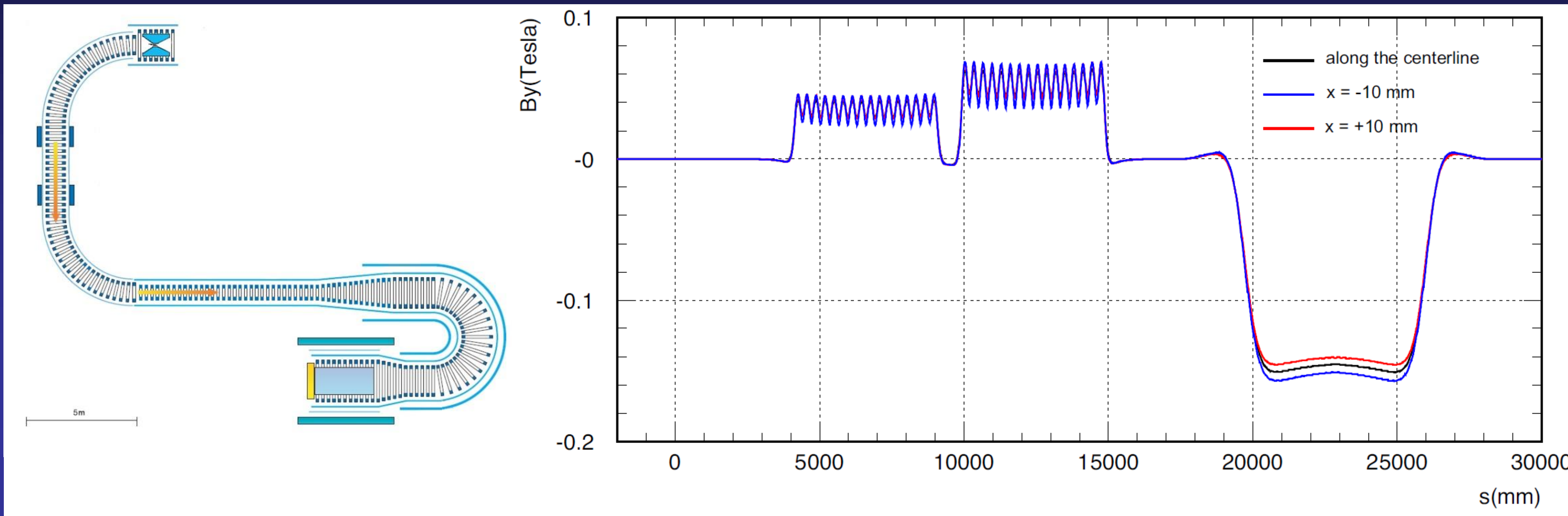




- Continuous superconducting solenoid channel from 5T to 1T.
- Bent solenoid allows selection of charge and momentum.

$$drift = \frac{1}{qB}\left(\frac{s}{R}\right)\frac{P_L^2 + \frac{1}{2}P_T^2}{P_L}$$

COMET Phase-II

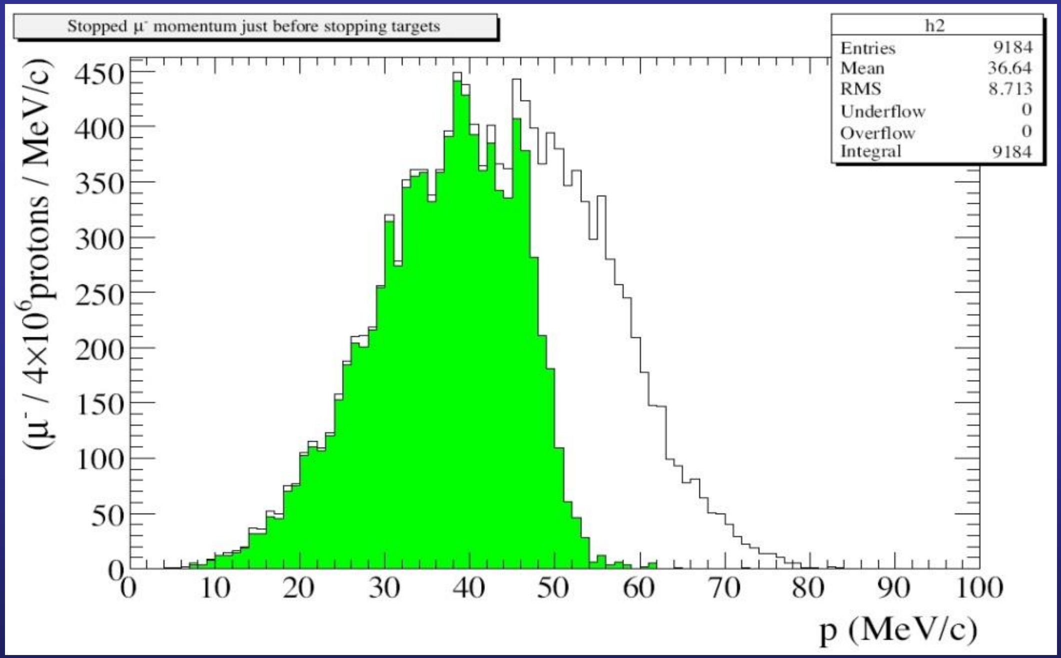


- Use a vertical dipole field to keep P=40MeV/c muons on axis.

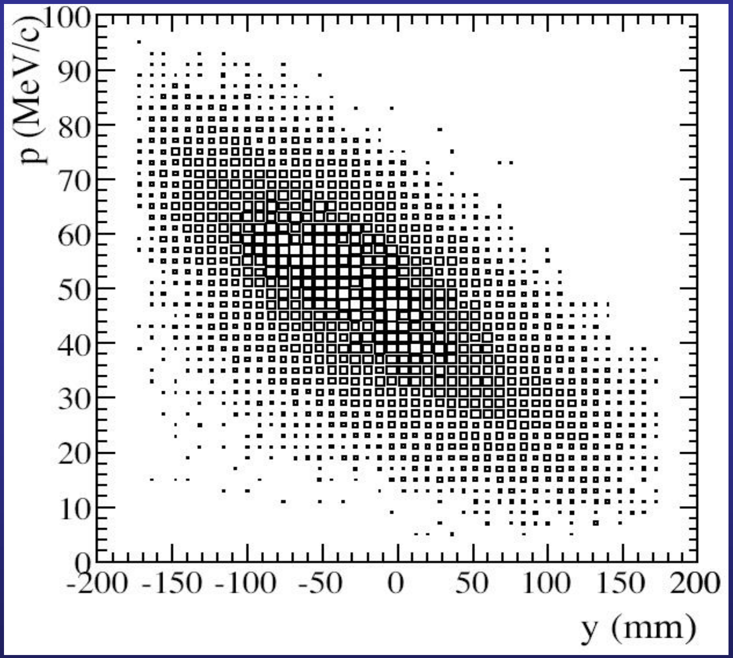
$$B_{comp} = \frac{1}{qR}\frac{P_L^2 + \frac{1}{2}P_T^2}{P_L}$$

Transport Channel

- Phase-II has a longer beam line and an additional 90° bend in the transport line before the muon stopping target.
  - Reduces pion contamination. Expect $<10^{-4}$ electrons from pion decay in signal region.
  - Increased dispersion removes more high momentum particles.

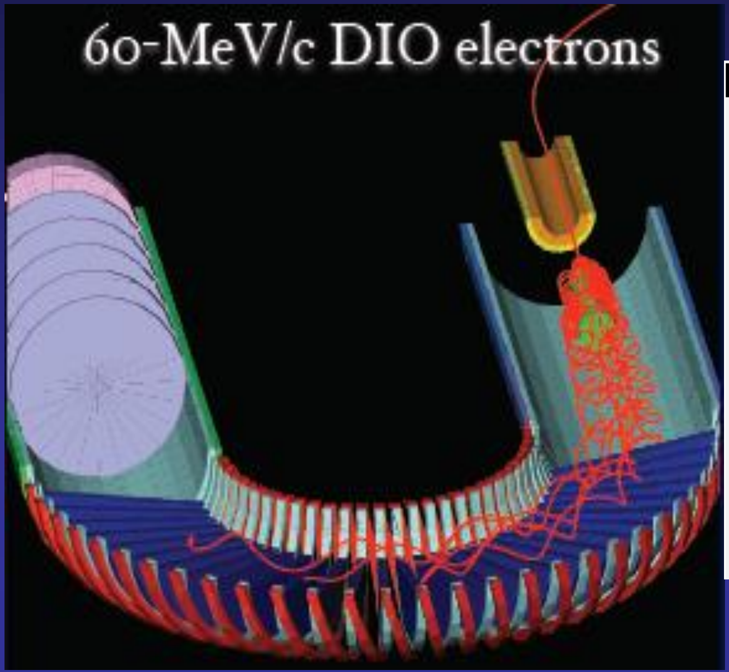


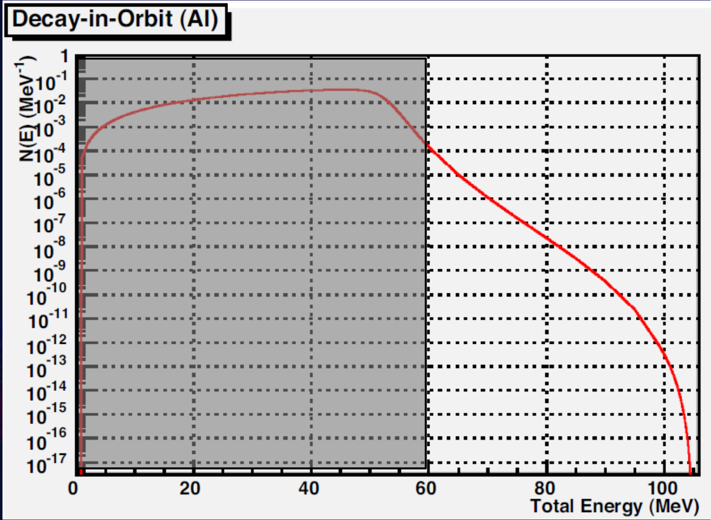
Muon momentum distribution at the stopping target with those that are stopped in green.

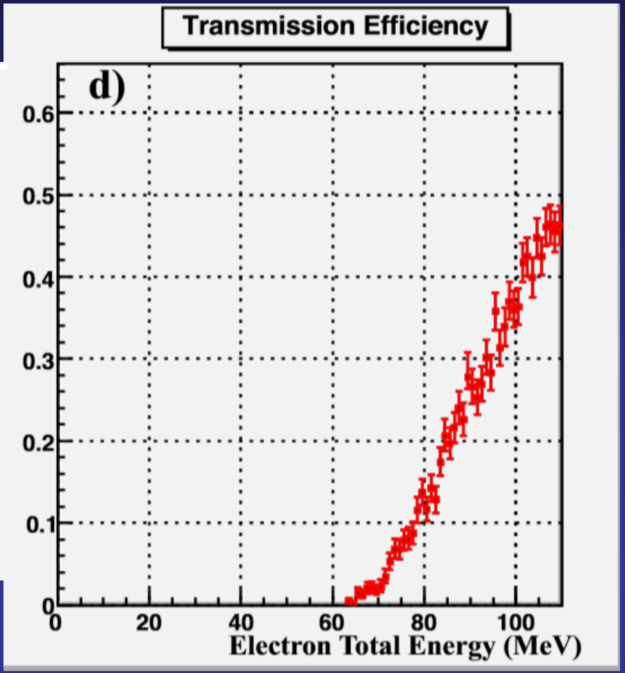


Dispersion at the end of the muon transport channel.

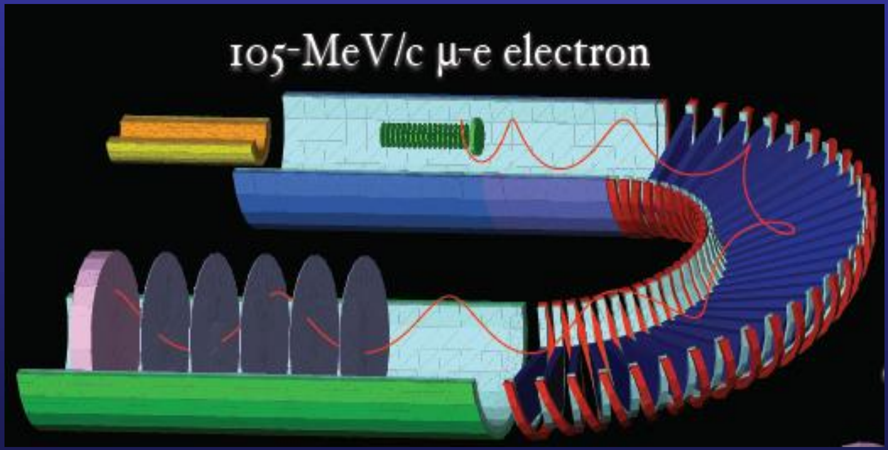
Electron Spectrometer



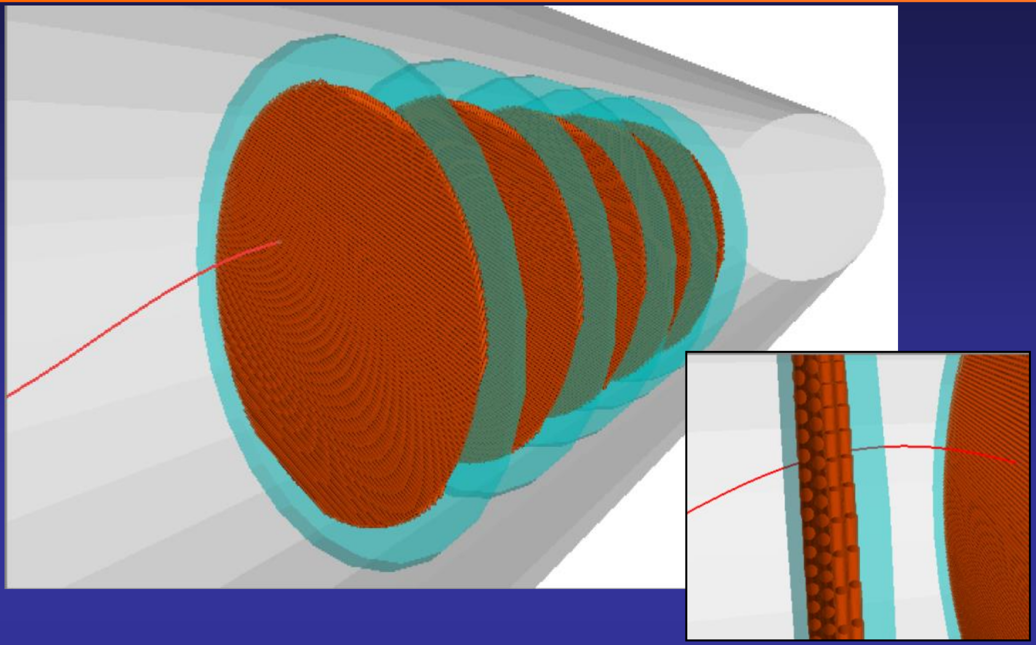


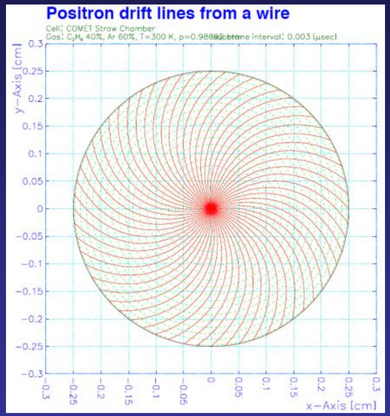


- 180° bent 1T solenoid with a 0.17T dipole field.
- Vertical dispersion of toroidal field allows electrons with P<60MeV/c to removed.
  - reduces trigger rate to ~1kHz.

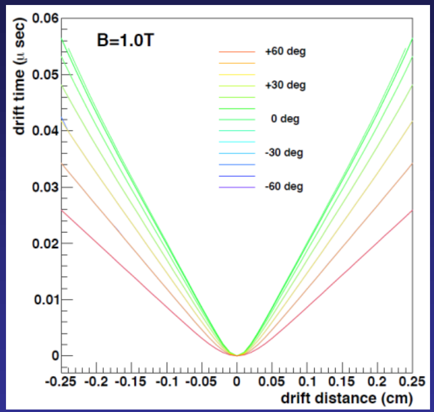


Straw Tracker





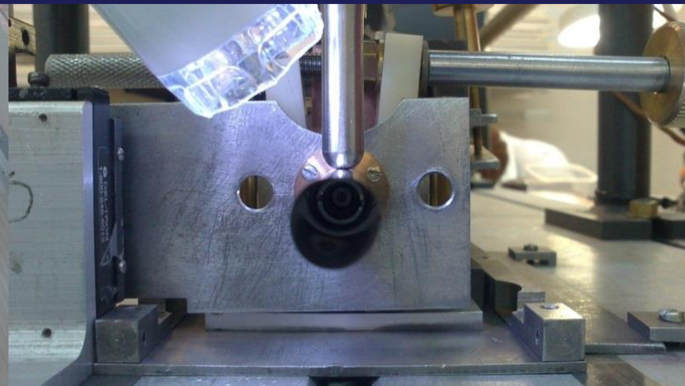
GARFIELD simulation of the drift lines and isochrones of a straw tube.

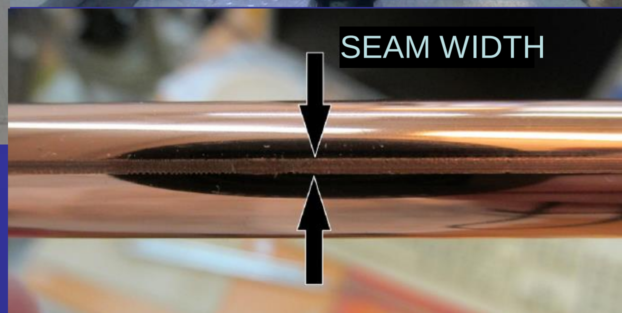


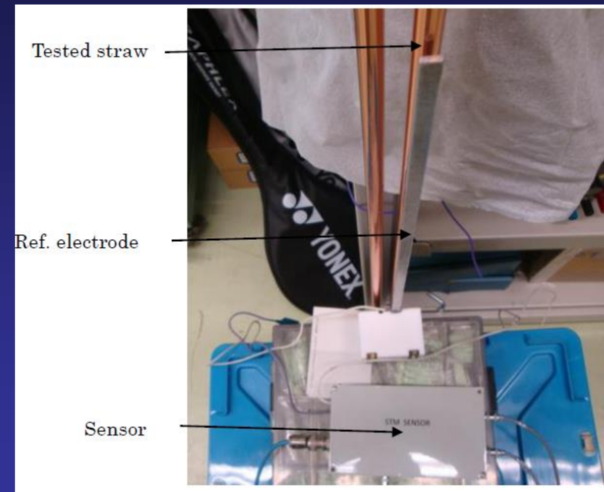
Drift time as a function of distance from the anode wire for different incident angles. From GARFIELD simulations.

- Requirements
  - operate in a 1T solenoid field.
  - operate in vacuum (to reduce multiple scattering of electrons).
  - 800kHz charged particle rate and 8MHz gamma rates.
  - 0.4% momentum and 700μm spatial resolution.
- 5 planes 48cm apart with 2 views (x and y) per plane and 2 layers per view (staggered by one straw radius).
- 9.75mm diameter gas filled straw tubes made from 12μm thick metalised polyimide with a gold coated tungsten anode wire.

Straw Tracker Prototyping and Testing

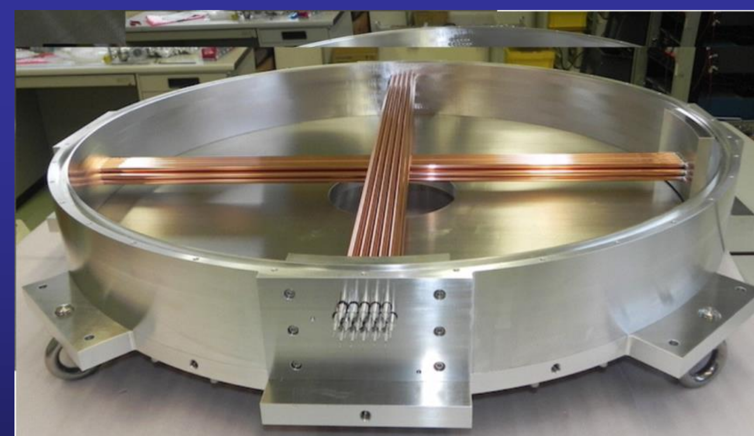






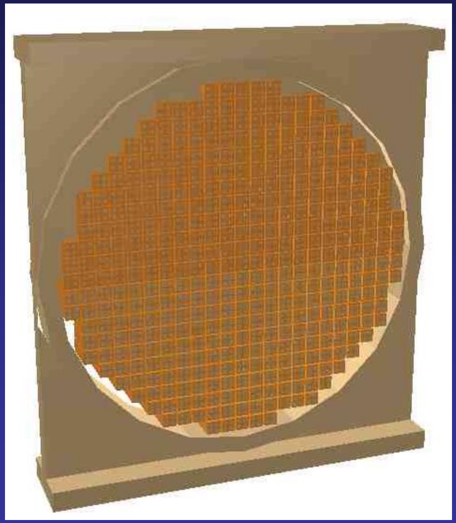
Straw tube tensioning tests

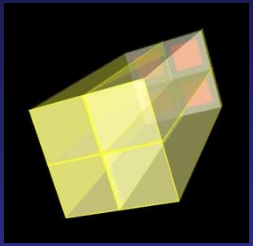
20-100 cm straw tubes produced by ultra-sonic welding at JINR. Seam width is 0.6 – 0.9mm, which will not deteriorate the electric field. Investigating thicknesses 12-36μm and Cu+Au and Al+mylar coatings.



Prototype construction at KEK

Calorimeter





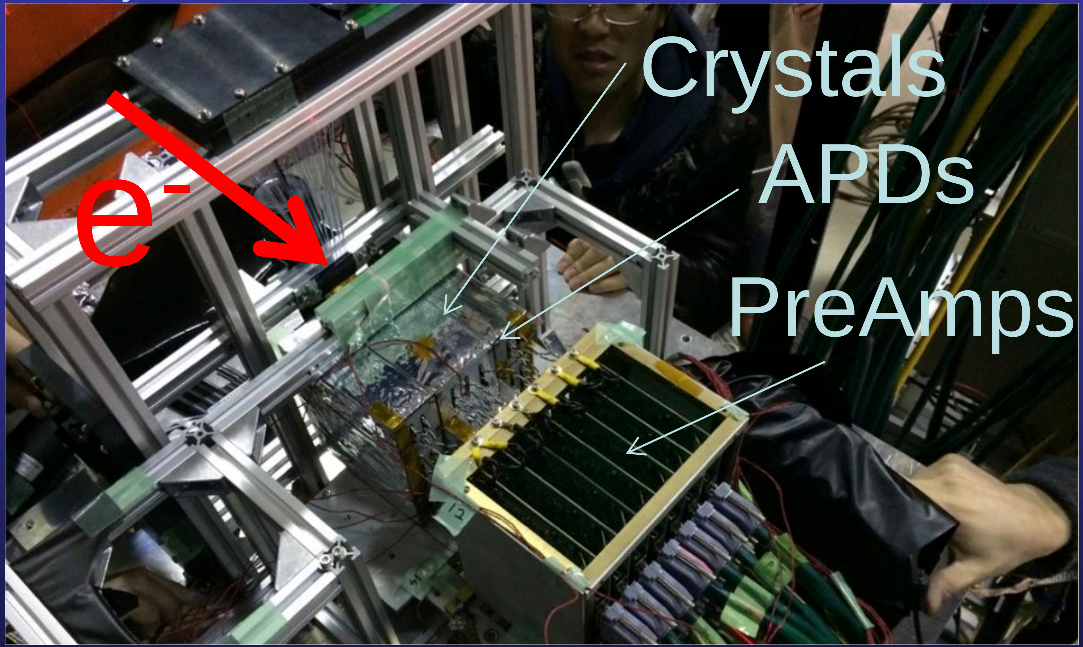
2x2 crystal module

Prototype 2x2 crystal module wrapped with teflon and Al-mylar and 4 APDs.

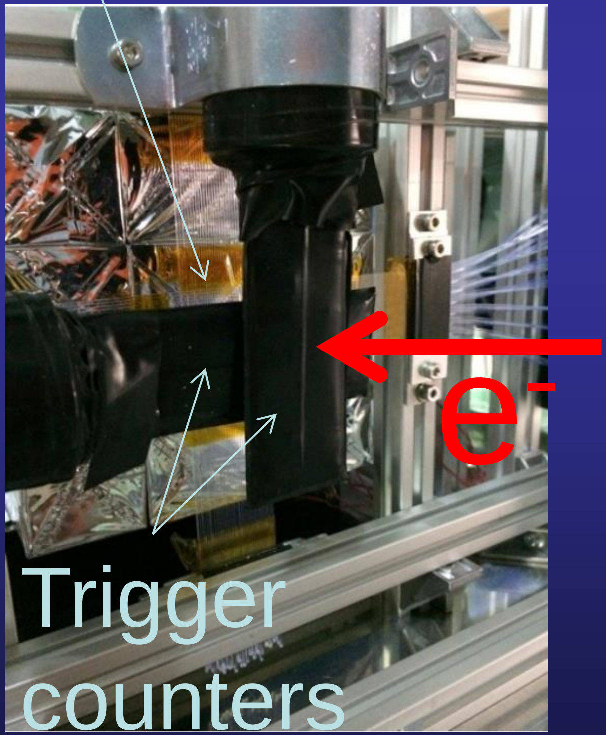
- Requirements
  - Measure energy, PID and give additional position information. Can be used to make a trigger decision.
  - 5% energy and 1cm spatial resolution at 100MeV.
    - High segmentation (2x2 cm^2 cross-section).
  - Operation in 1T magnetic field.
- Candidate inorganic scintillator materials are Cerium-doped Lutetium Yttrium Orthosilicate (LYSO) or Cerium-doped Gd_2SiO_5 (GSO).
- APD photo detector with a custom pre-amp.

Crystal Choice and Beam Tests

- Crystal choice: GSO or LYSO
  - Size: GSO 20x20x150mm^3, LYSO 20x20x120mm^3
  - Radiation length: GSO 10.9 X_0, LYSO 10.5 X_0
  - Light yield: GSO ~ $^1/_3$ × LYSO
  - Cost: GSO ~ $^1/_2$ × LYSO
- Need to test both meets <5% resolution requirement.
- Beam tests in Tohoku March 2014.
  - Preliminary results are promising.
  - Final analysis results will be available soon.



Fibres to measure beam size and position

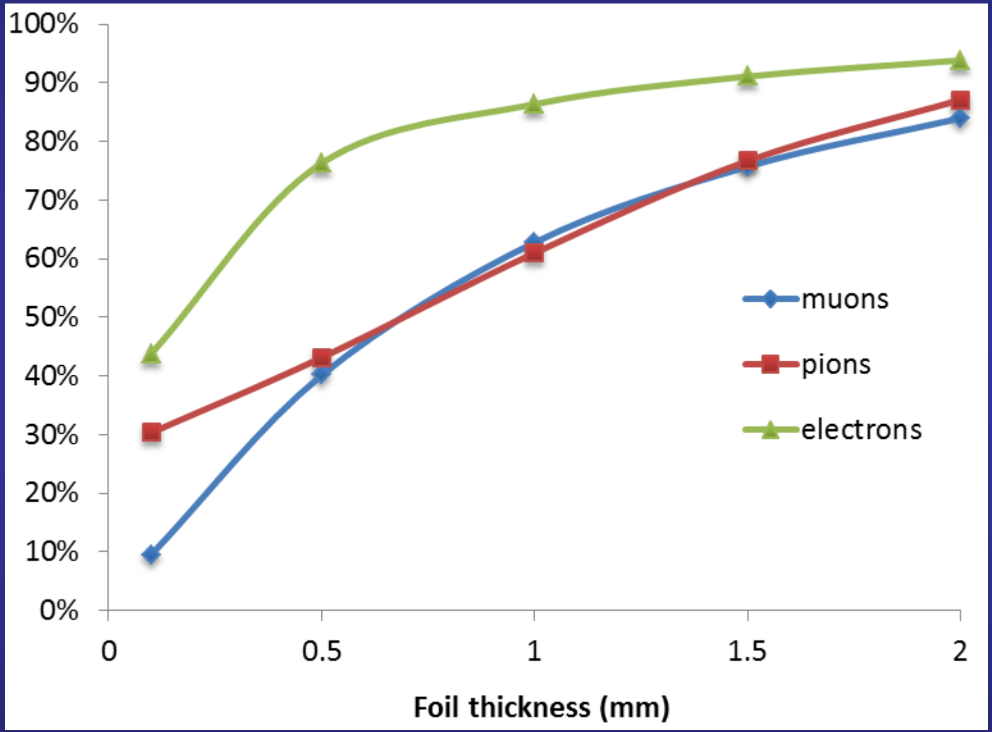


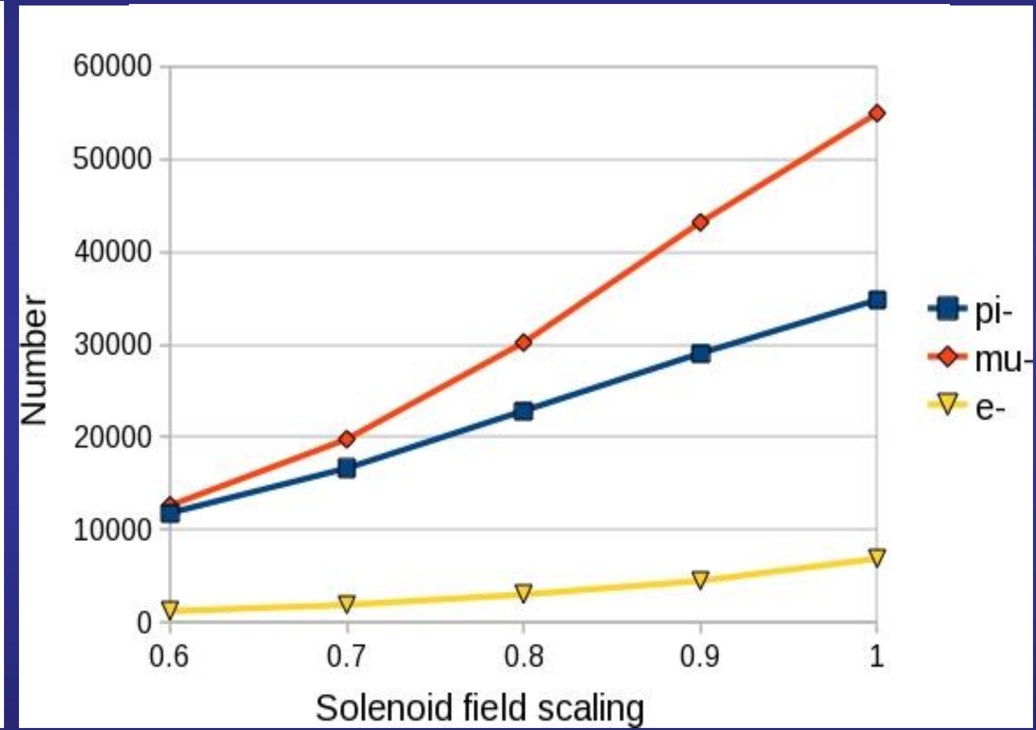
Measurements with Phase-I

- Beam characterisation.
  - Phase-II has a long continuous solenoid channel with little space for beam diagnostic devices.
    - Beam emittance.
    - Particle composition is very important for understanding backgrounds.
  - Potential field bumps can lead to late arriving particles.
    - Look at arrival time distribution.
- Simulation validation.
  - Large variations of the pion and muon yield depending on hadron production model.
  - Field map tracking.
    - Compare tracking field maps with measurements
      - Effect of adjusting fields on beam composition.

Measurements with Phase-I

- Look at ways of affecting the beam and using a simple detector to measure the beam.





Different tungsten absorber foil thicknesses.

Varying the solenoid field.

Sensitivity

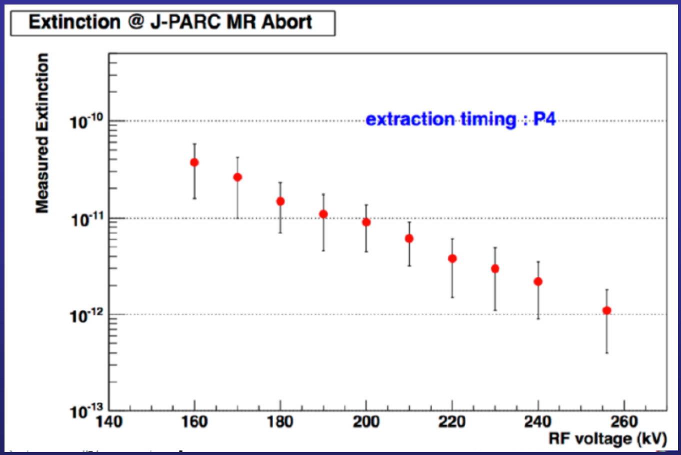
- The single event sensitivity for $2x10^7$s running is

$$B(\mu^- + Al \rightarrow e^- + Al) \sim \frac{1}{N_p\ \varepsilon_{ST} f_{CAP} A_e} = \frac{1}{8.5 \times 10^{20} \cdot 0.0023 \cdot 0.61 \cdot 0.031}$$
$$= 2.6 \times 10^{-17}$$
$$= 6 \times 10^{-17}\ \text{(90\% C.L.)}$$
$$= 3.8\ \text{events if}\ BR = 1 \times 10^{-16}$$

where N_p is the total number of protons produced, ε_{ST} is the number of stopped muons per proton, f_{CAP} is the fraction of muons captured and A_e is the detector acceptance.

Radiative Pion Capture	0.05
Beam Electrons	$< 0.1^{\ddagger}$
Muon Decay in Flight	< 0.0002
Pion Decay in Flight	< 0.0001
Neutron Induced	0.024
Delayed-Pion Radiative Capture	0.002
Anti-proton Induced	0.007
Muon Decay in Orbit	0.15
Radiative Muon Capture	< 0.001
μ^- Capt. w/ n Emission	< 0.001
μ^- Capt. w/ Charged Part. Emission	< 0.001
Cosmic Ray Muons	0.002
Electrons from Cosmic Ray Muons	0.002
Total	0.34

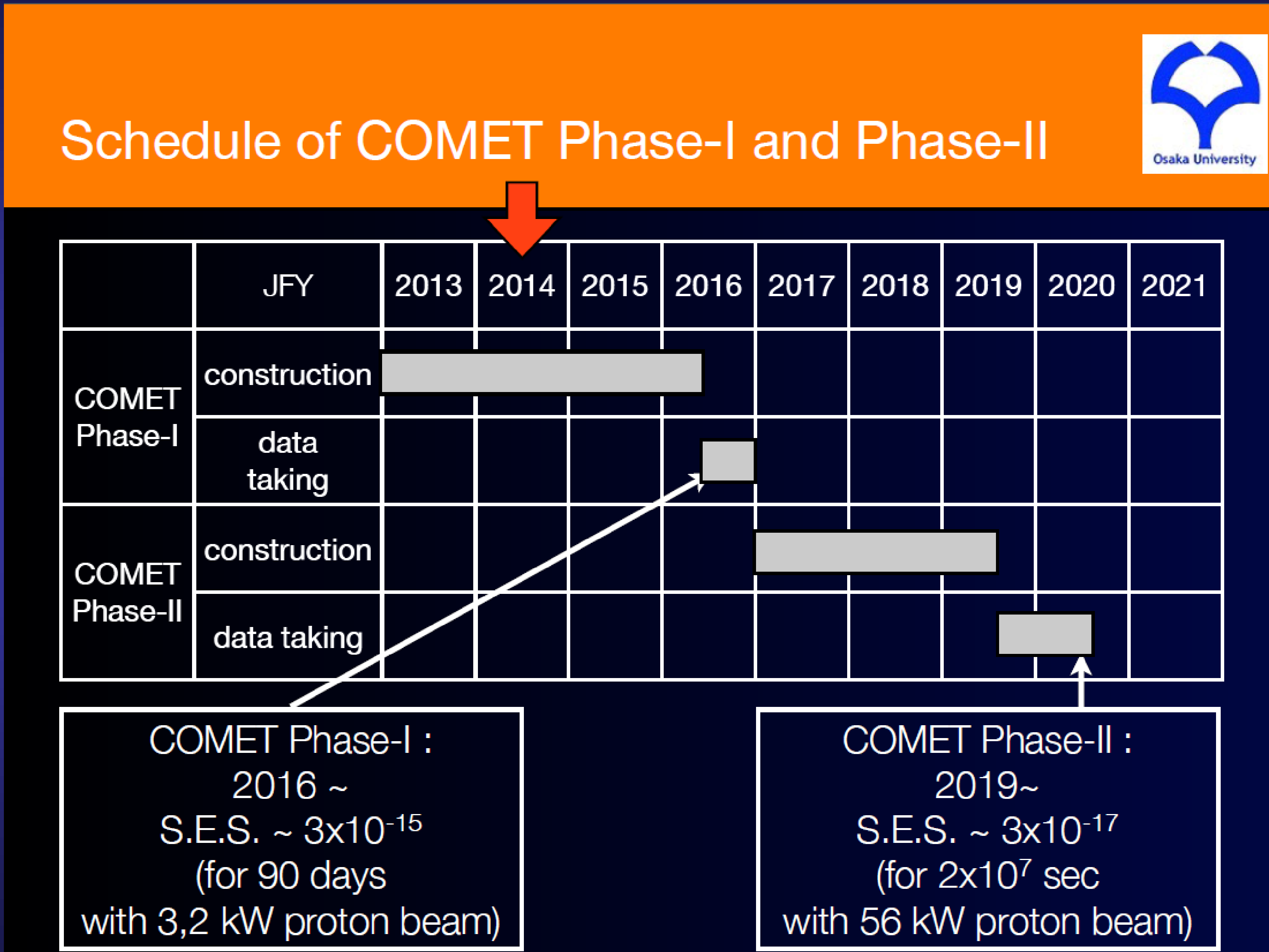
Estimated backgrounds from the CDR.



Beam extinction measured in May 2014. 8GeV beam without the slow extraction.

- Improved extinction will reduce beam related backgrounds.

Schedule


Schedule of COMET Phase-I and Phase-II
Osaka University
JFY
2013
2014
2015
2016
2017
2018
2019
2020
2021
COMET Phase-I
construction
data taking
COMET Phase-II
construction
data taking
COMET Phase-I :
2016 ~
S.E.S. ~ 3x10-15
(for 90 days
with 3,2 kW proton beam)
COMET Phase-II :
2019~
S.E.S. ~ 3x10-17
(for 2x107 sec
with 56 kW proton beam)

Summary and plans

- Staging COMET will lead to an improved design of the experiment.
  - Several important measurements can be made with Phase-I.
  - Lead to improved simulations, sensitivity estimate and optimisation of Phase-II.
- Phase-II detector technologies are being prototyped and can be tested with Phase-I.
- Phase-I construction has started, data taking will start in 2016.
- Phase-II construction will start in 2017 and data taking in 2019.