Beamline Simulation and Components

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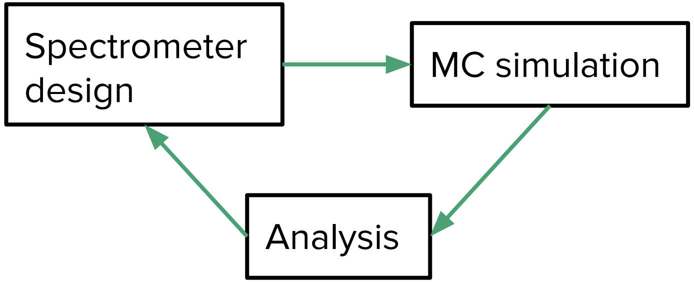
November 29, 2020

Outline

- Beamline simulation and components session (MP)
  - Introduction
  - Tertiary beamline - hardware
  - Tertiary beamline - simulation
- RPCs and threshold aerogel detectors (R. Wendell)
- ATLAS SCTs (A. Konaka)



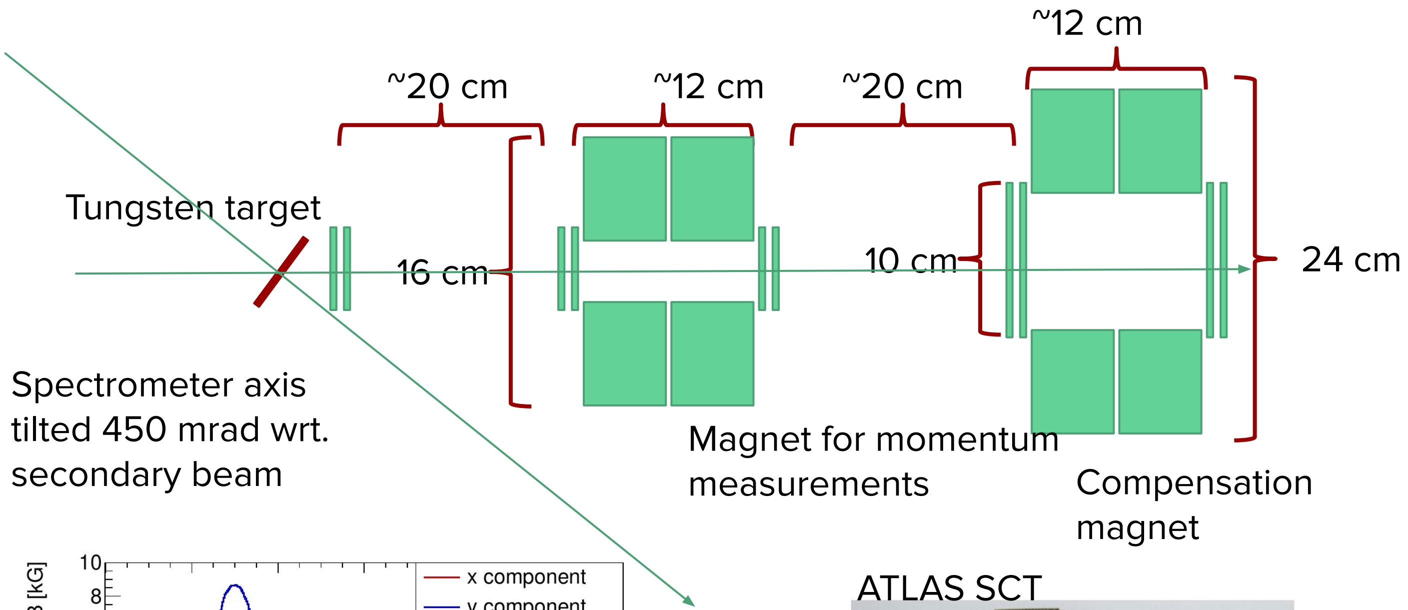
Motivation

- WCTE needs low momentum (0.2 - 1.2 GeV/c) pion, electron, muon, and proton beam
- Pions decay if the beamline is too long
- Pion and muon identification is difficult
- Solution:
  - Tertiary beam for pions and protons
  - Secondary beam for muons and electrons → Arturo Fiorentini will be working on the secondary beam simulation

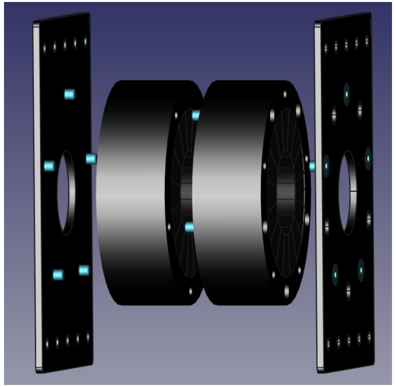
East area

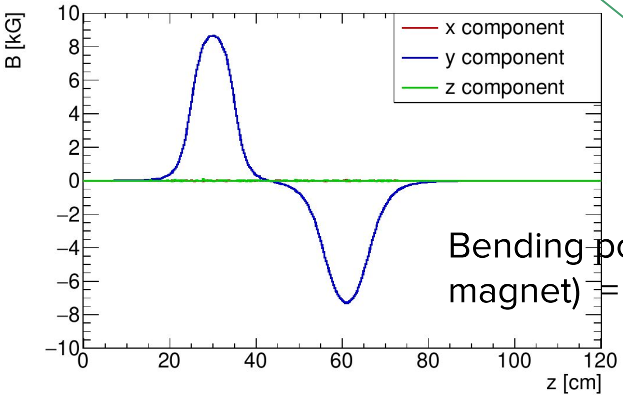
- Primary beam from PS (24 GeV/c)
- Secondary beams 0.4 - 15 GeV/c
- Max. intensity: ~$5{\cdot}10^6$ particles per 0.4s extraction, max. 3 times per 40s PS supercycle
- **T9 experimental area has enough space for WCTE**

WCTE Tertiary Beam Spectrometer



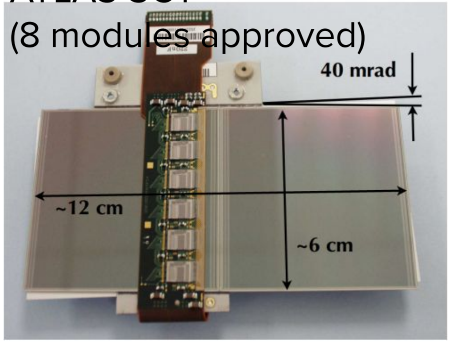
Halbach array





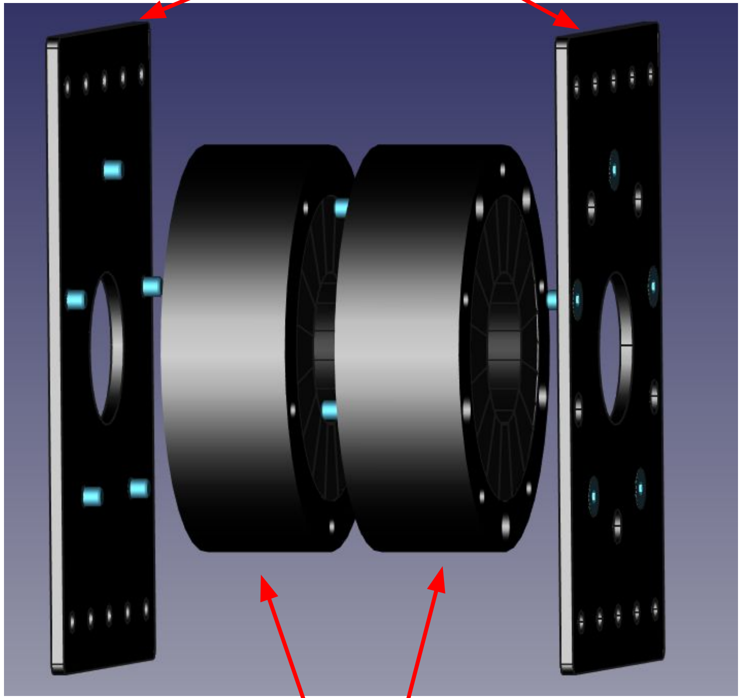
Bending power (first magnet) = 0.075 Tm

ATLAS SCT
(8 modules approved)



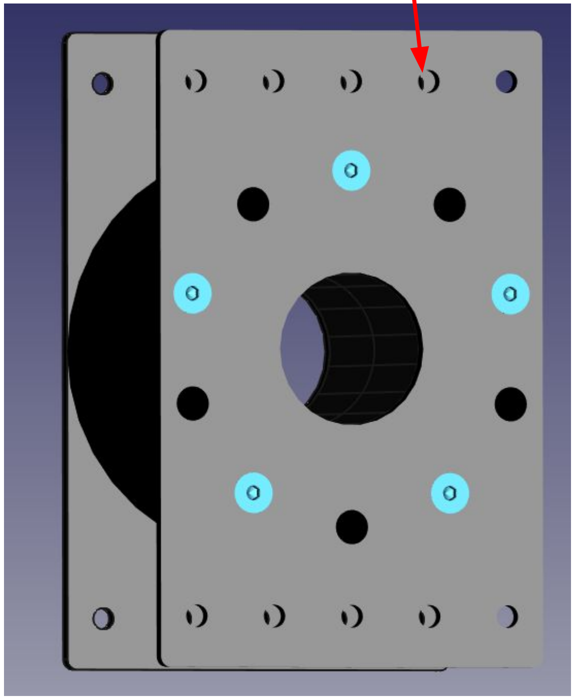
Magnet design

0.5 cm thick 304 stainless steel endplates



2x 5 cm long Halbach cylinders

Holes for M8 bolts ➜ works with 4040 aluminium extrusions

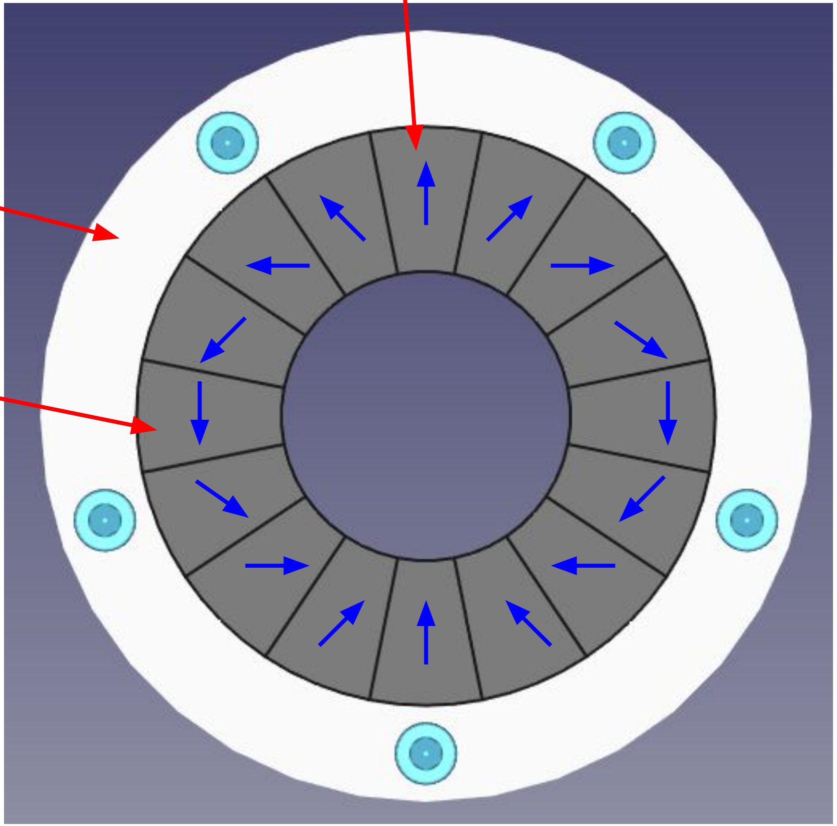


Magnet design

Magnetization directions

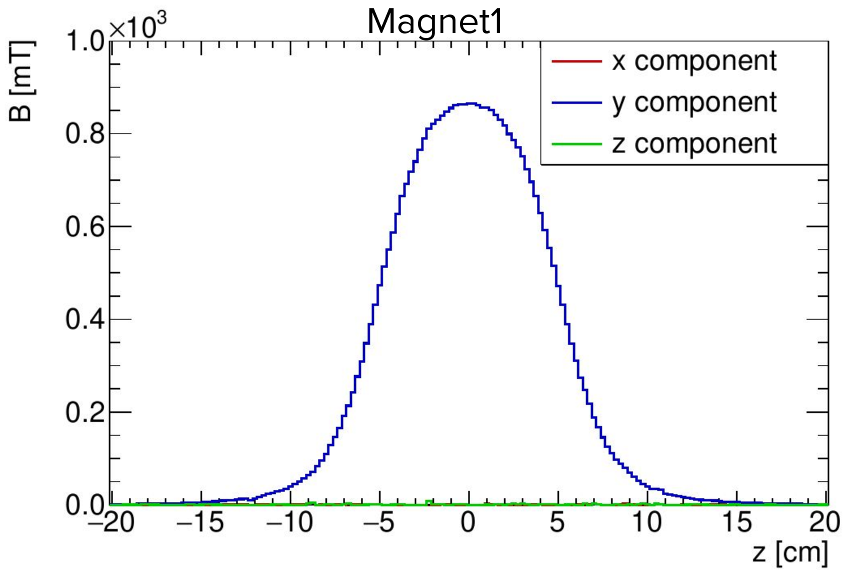
2 cm thick 304 stainless steel cylinder

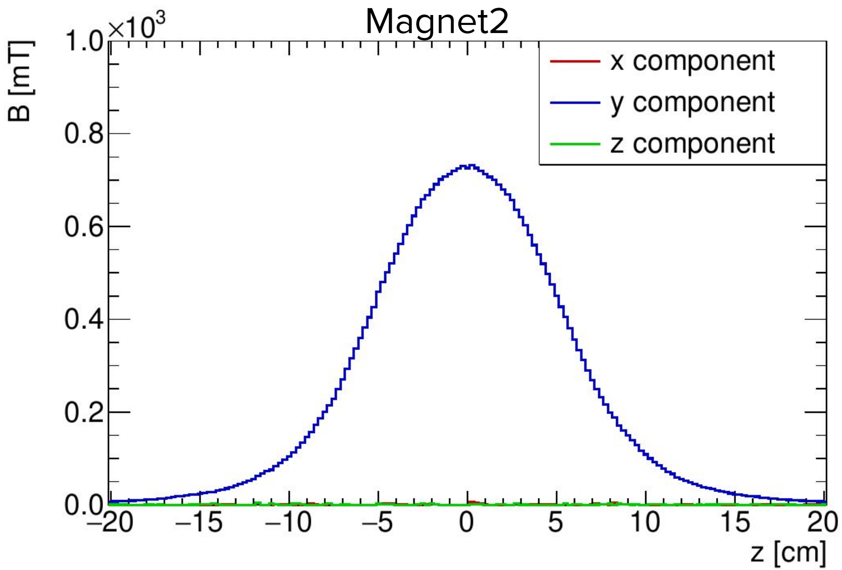
N52 neodymium segment (glued with epoxy resin)



	Magnet 1	Magnet 2
ID [cm]	6	10
OD [cm]	16	24

Field maps (x = y = 0 cm)

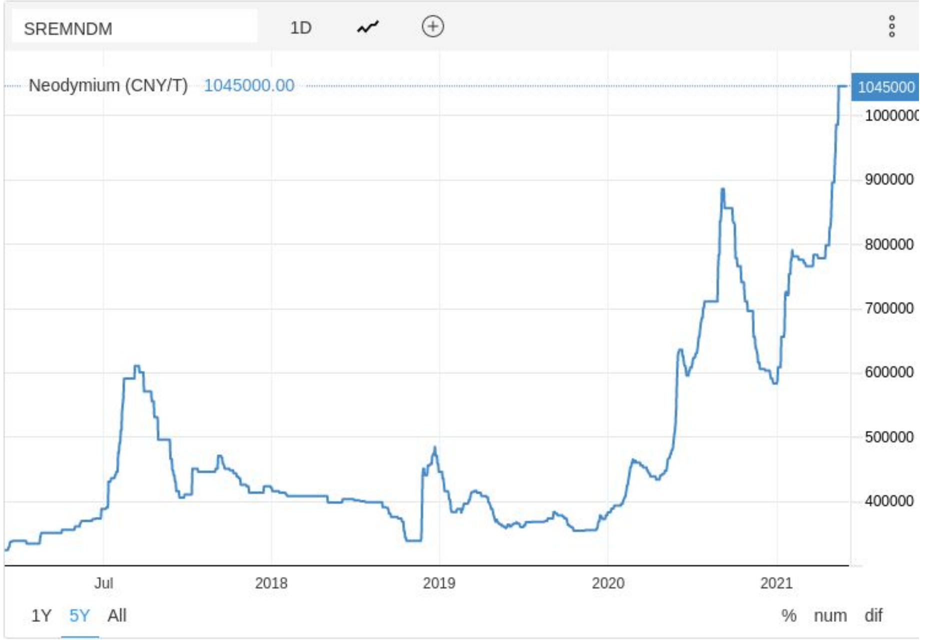




- Simulation done in Comsol 5.4
- Bending power of magnet 1 is 0.075 Tm ➔ ~5% momentum resolution achievable with silicon strips with 80 µm pitch and X/X_0 = 0.003 per detector

Magnet prices

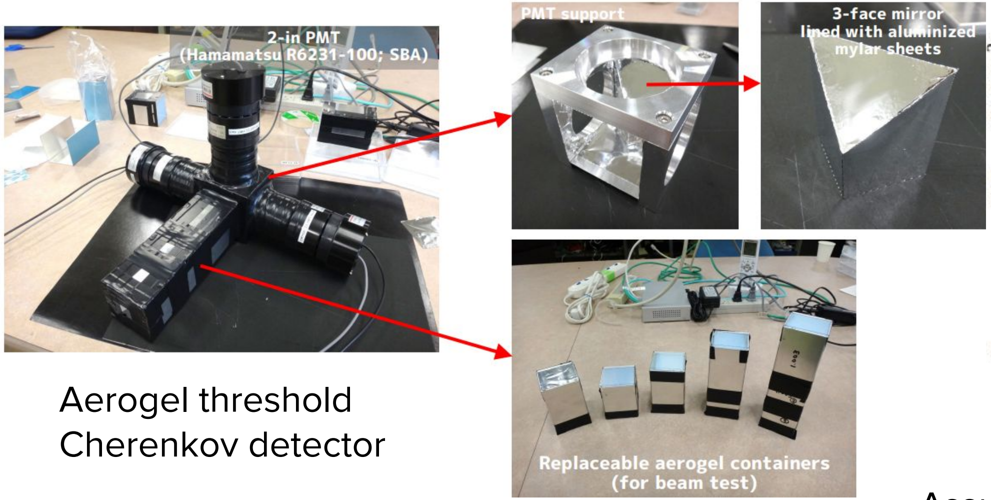
- Asked for a quote in February (China Magnets Source Material Limited)
- Magnet 1:
  - 7825 USD
  - Jig fee: 1500 USD
- Magnet 2:
  - 9984 USD
  - Jig fee: 1500 USD
- Price changes a lot based on neodymium price
- Recently asked for a second quote (still waiting)



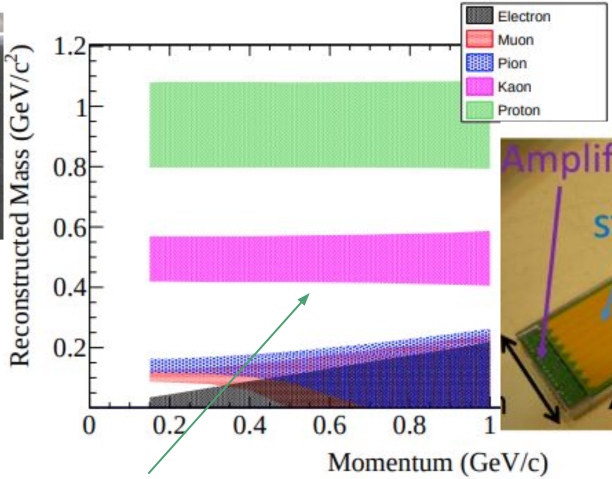
Roger Wendell

WCTE Tertiary Beam Spectrometer

- Tertiary beam particle ID will be done by measuring time-of-flight (with RPCs) and aerogel threshold Cherenkov detectors
  - Aerogel with index of refraction of 1.0026 was produced ➜ it can be used to identify electrons (p > 350 MeV/c)
- RPCs can be used to detect pion decays (kinks in trajectory)

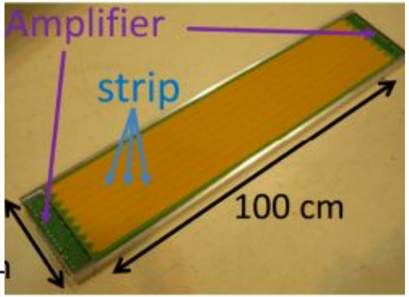


Aerogel threshold Cherenkov detector



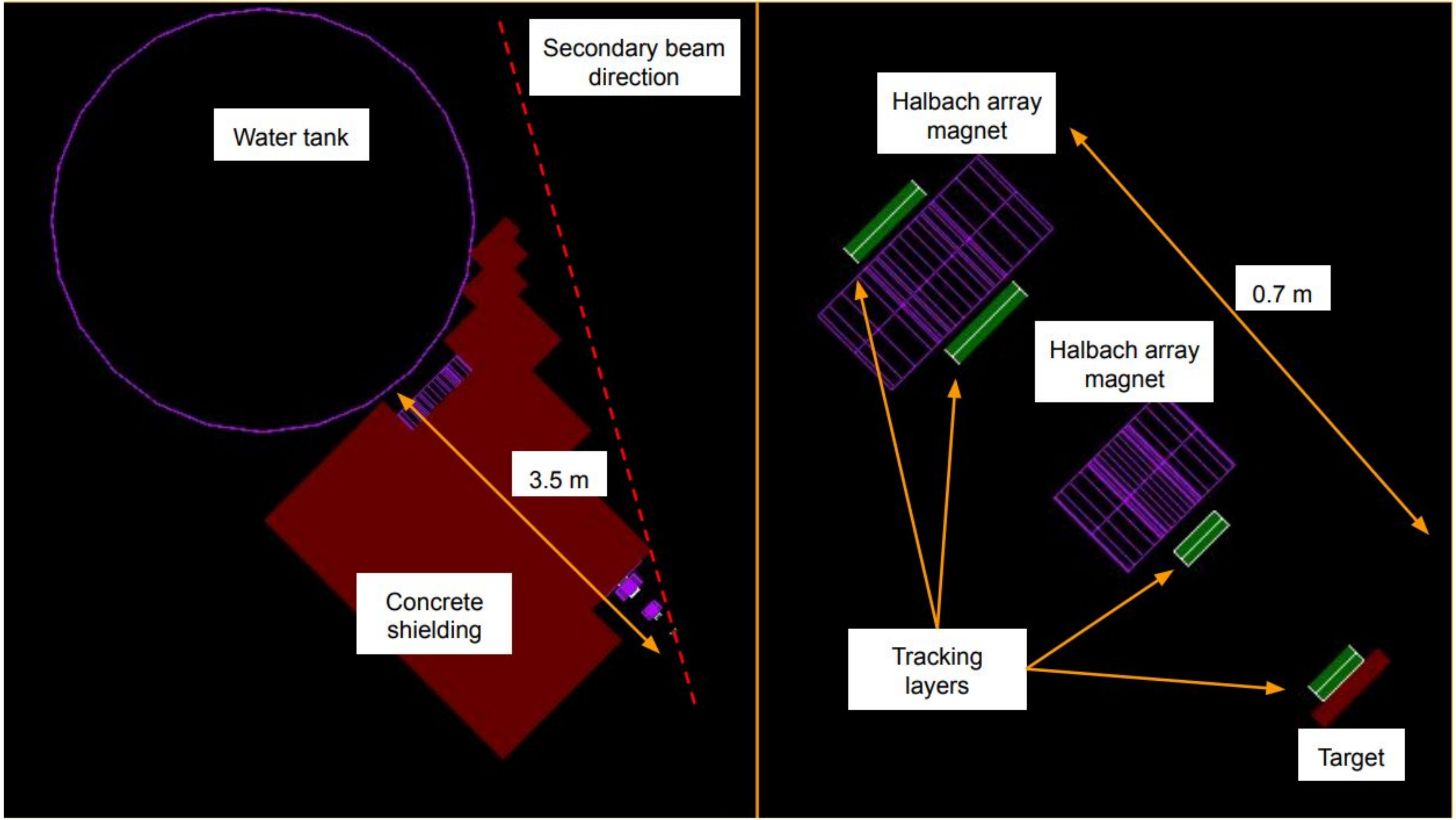
Assuming 100 ps timing resolution

RPCs



Monte Carlo simulation

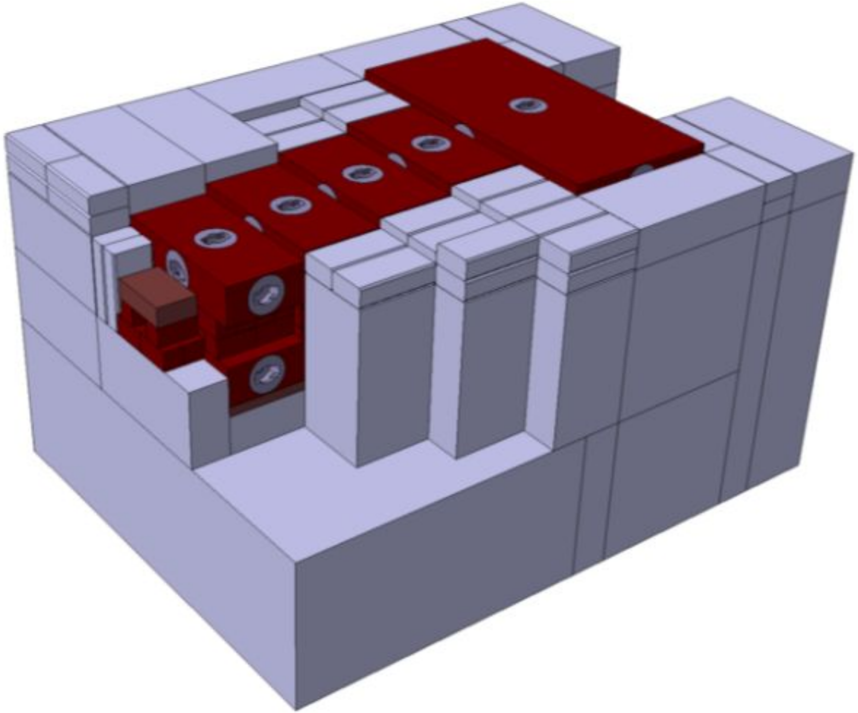
- 12 GeV/c protons
- 2 cm tungsten target
- GEANT4.10.06 FTFP_BERT
- 450 mrad tilt between the beam direction and the spectrometer ➔ **surviving secondary beam does not hit the water tank**
- Target length, material, beam momentum, production angle, magnet bending power have been optimized!


Water tank
Secondary beam direction
3.5 m
Concrete shielding
Halbach array magnet
0.7 m
Halbach array magnet
Tracking layers
Target

Shielding and collimator

Damien Brethoux
Dipanwita Banerjee

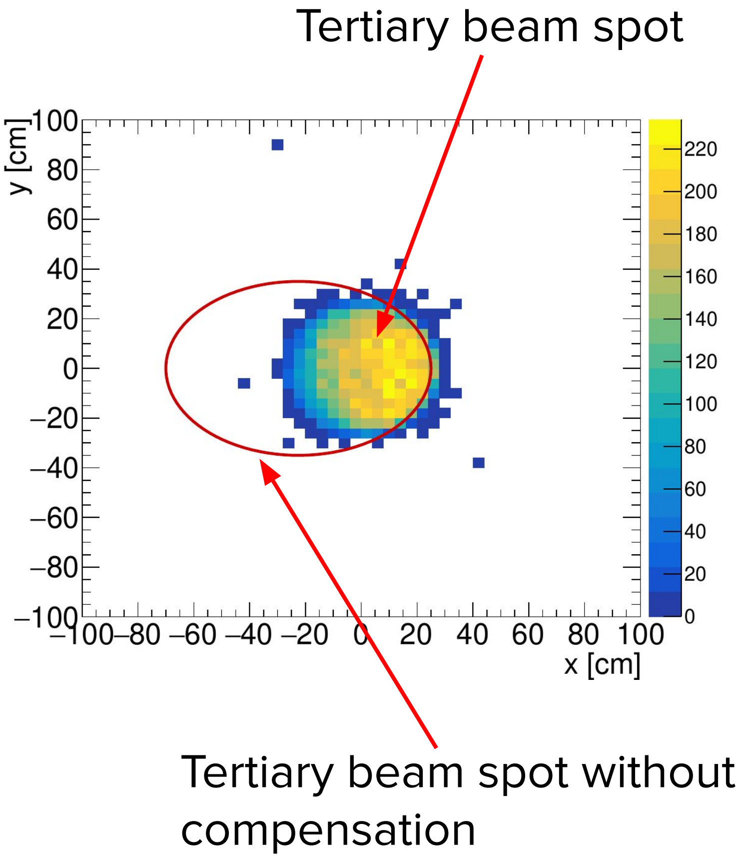
- Initial design work done for collimator and shielding based on the existing blocks

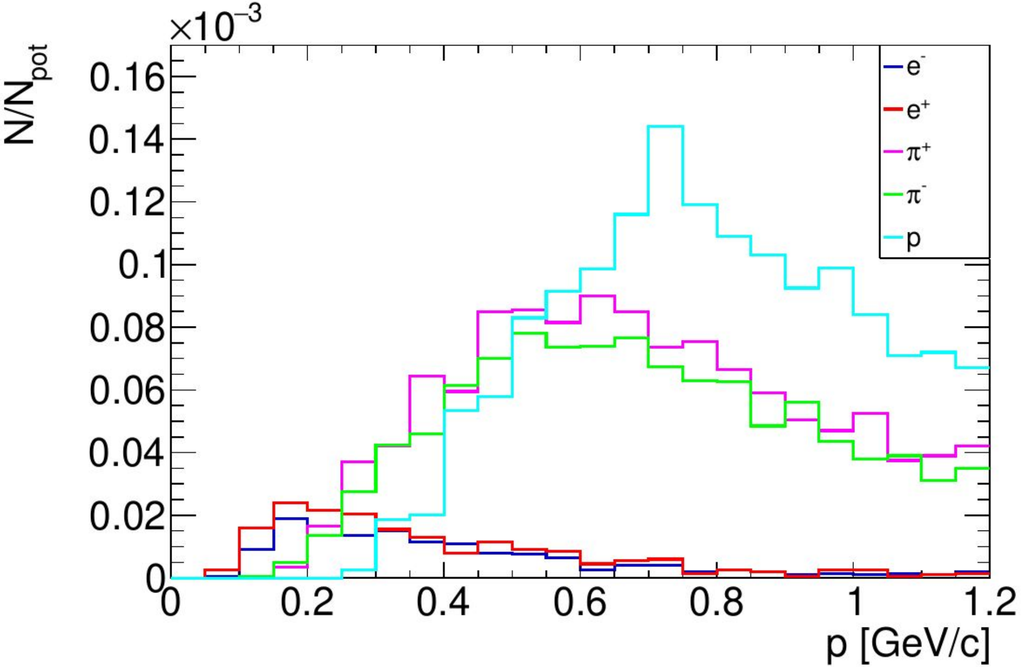


WCTE Tertiary Beam

Integrated tertiary particle flux per secondary beam spill (10^6 particles)

e^-	e^+	π^+	π^-	p
143	181	1193	1053	1502



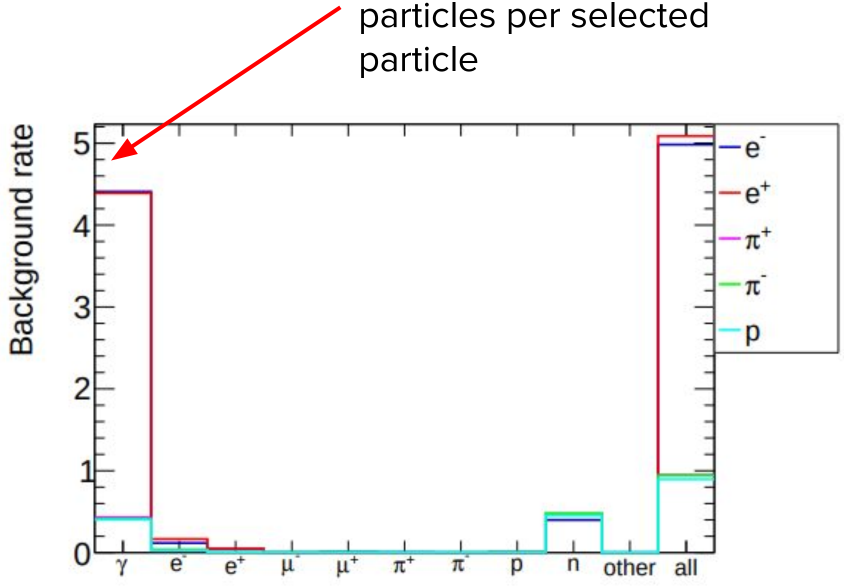


Backgrounds

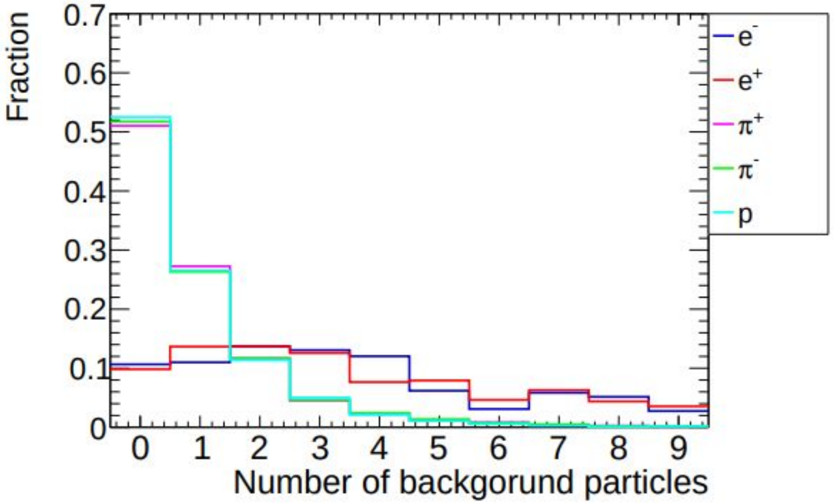
1. Neutral and charged particles created in the target, magnet, collimator and shielding alongside selected particle
2. Muons (pion decays before hitting the tank)
3. Interactions in the tank structure (beam window) ➜ negligible ➜ <<1% interaction length

Background (type 1)

Number of background particles per selected particle

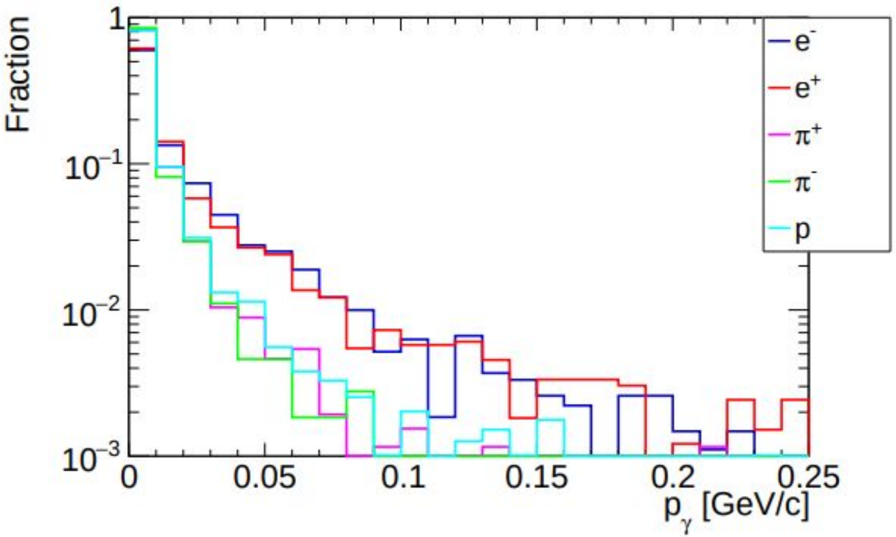


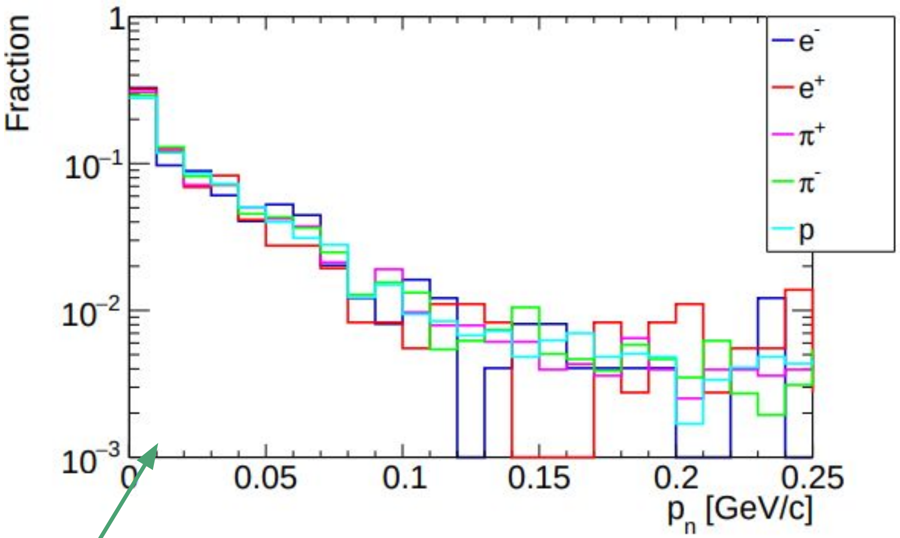
>50% of selected pions and protons have 0 background particles accompanying them



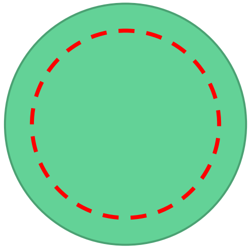
Background (type 1)

γ and neutron background momentum distributions for selected tertiary beam particles



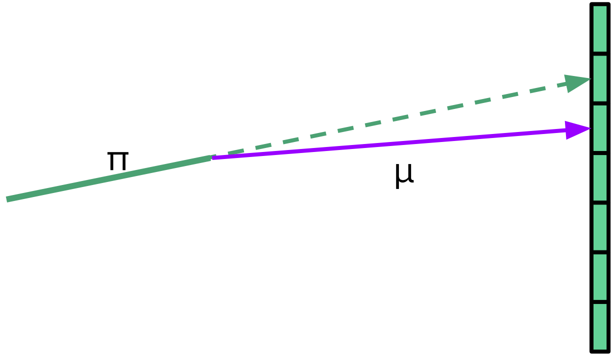


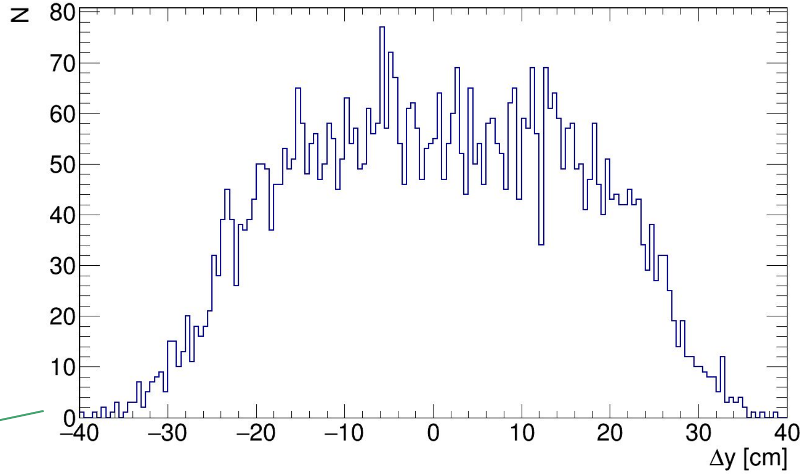
We can remove most of the low momentum backgrounds by using fiducial volume cut



Background (type 2)

- Particle ID is done by tof (RPCs)
  - 20x50 cm^2
- Segmented TOF detector is needed to identify pion decays ➔ kinks in the pion trajectory
- RPC channels ~2 cm in size will be sufficient





Difference between predicted pion position and muon position at 350 cm

Conclusions

- WCTE will use secondary beam for muons/electrons and tertiary beam for pions/protons
- According to the simulation sufficiently high rates of tertiary pions and protons with low background rates
- Tertiary beam spectrometer will use silicon strip detectors for tracking and RPCs for particle ID
- Permanent magnets for momentum measurement and beam profile compensation