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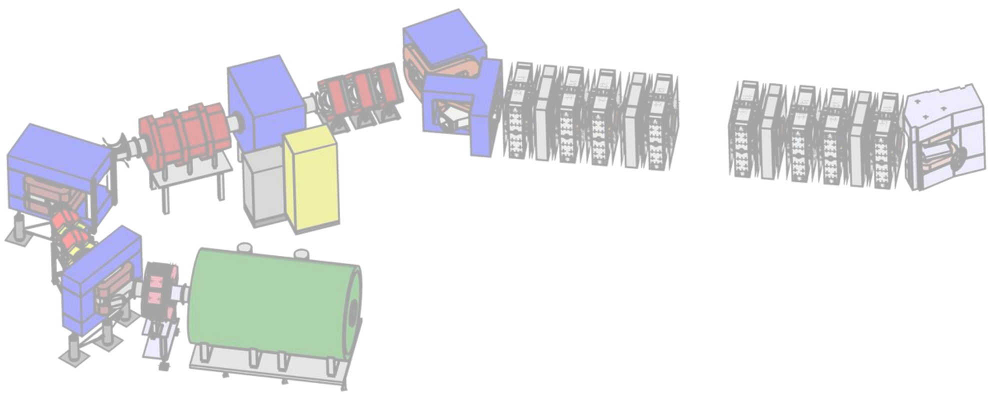


The Compact Muon Beam Line

Felix Anton Berg

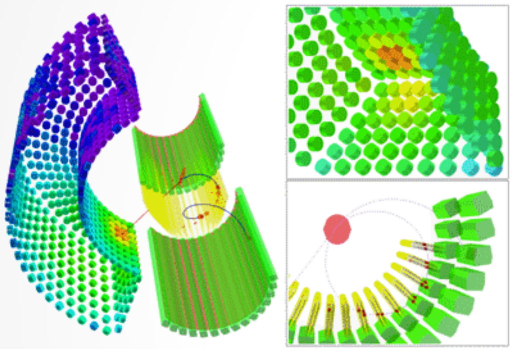
PhD Seminar

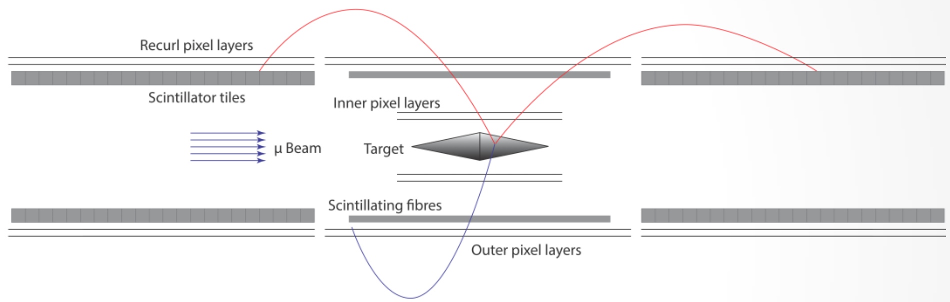
27.8.2015 PSI

Two intensity frontier experiments at PSI

MEG : $\mu^+ \rightarrow e^+ + \gamma$

Mu3e : $\mu^+ \rightarrow e^+ + e^+ + e^-$





MEG II and Phase I of Mu3e will share the πE5 surface muon channel.

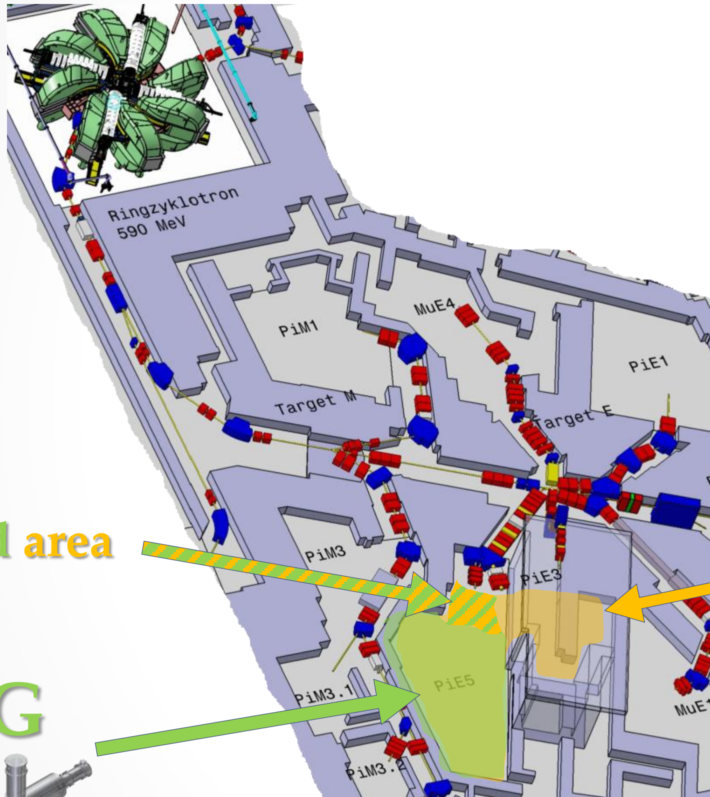
πE5 is one of the highest flux muon sources worldwide.

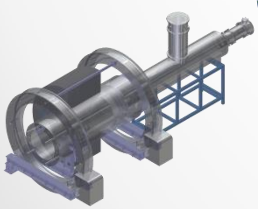
For a later phase II of Mu3e possibilities for a new high intensity muon beam line are under investigation in the HiMB project at PSI → talk by Zachary Hodge

Overview floormap

Shared area

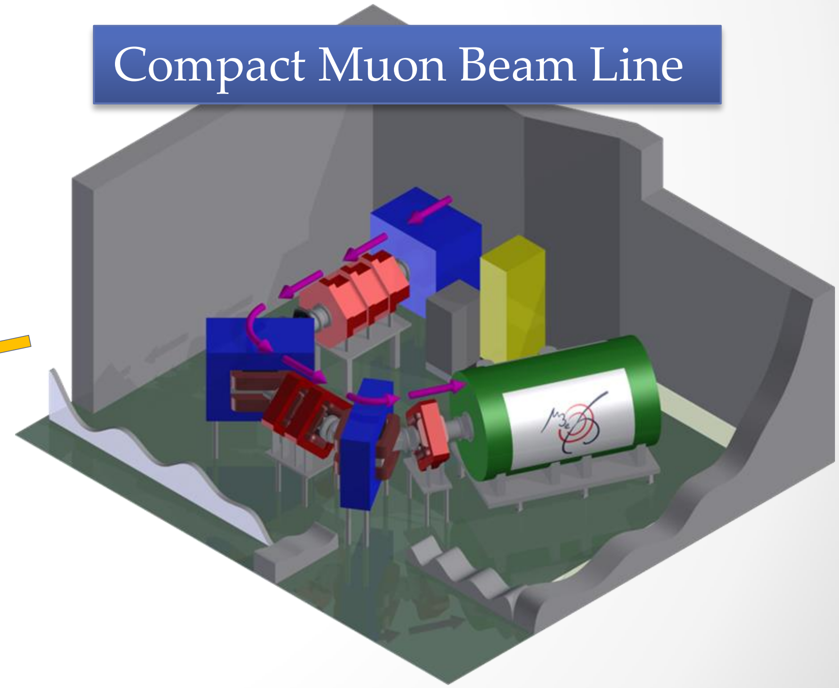
MEG





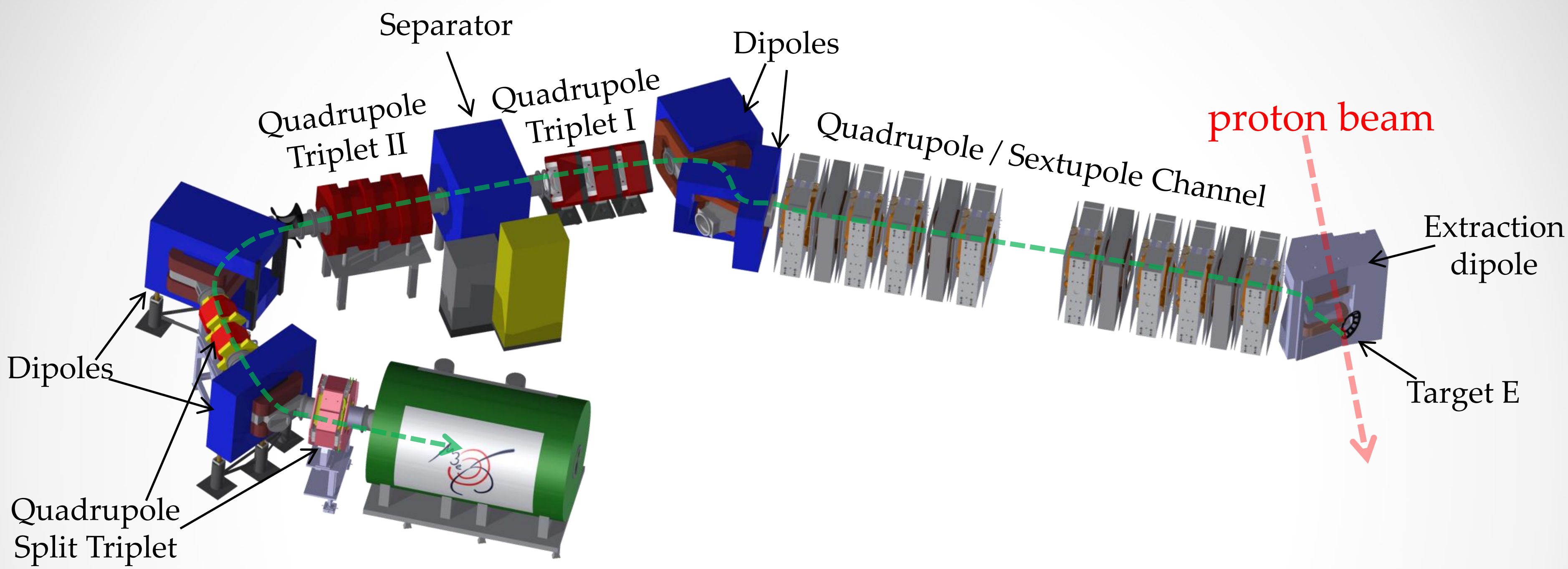
Mu3e

Compact Muon Beam Line



Strict spatial constraints!

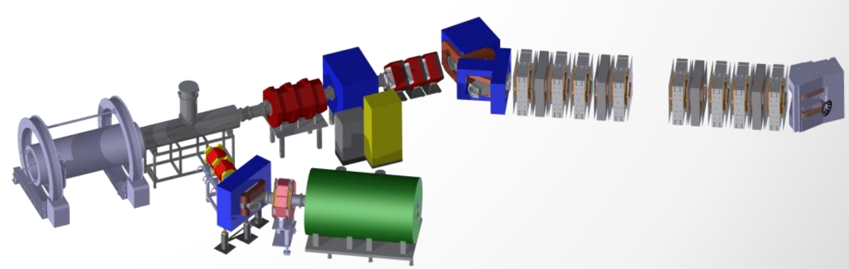
Requirements on Compact Muon Beam Line



Beam requirements:

- Surface μ^+ 28 Mev/c (~kinematic edge)
- high transmission optics
- Small achromatic beam spot on target
- Small momentum byte ($\frac{\delta p}{p_0} = 7\ \%\ FWHM$)
- Minimization of background (e^+ & π^+)

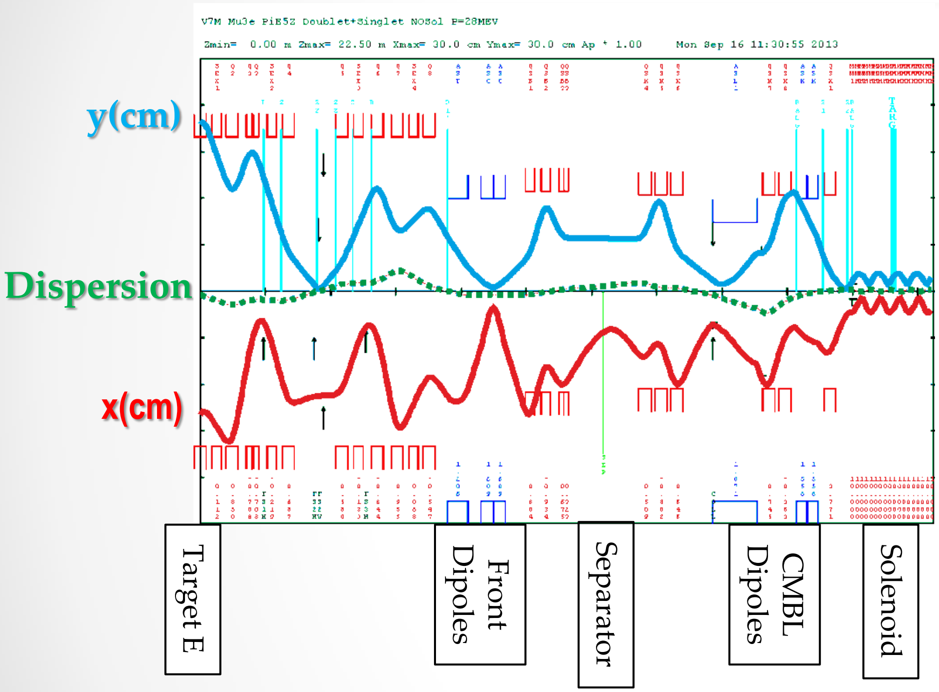
Change setup to MEG



Initial Simulation

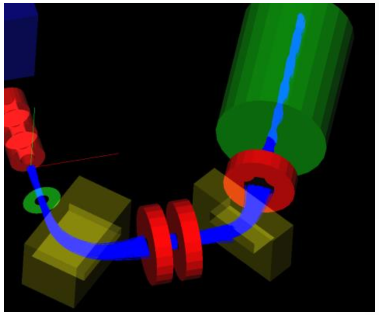
Optical Design

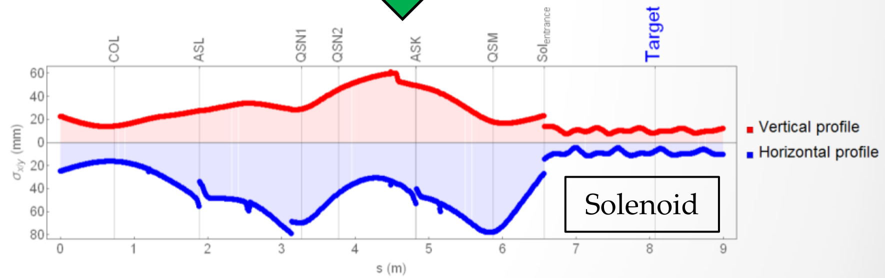
1st order TRANSPORT Fit

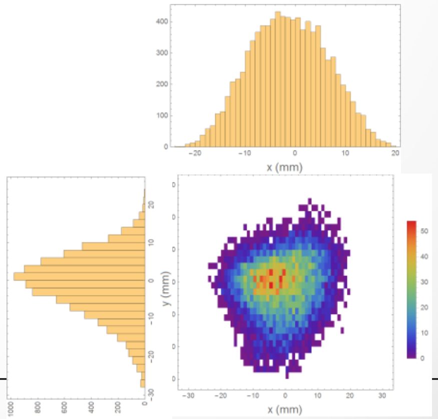


Simulation

G4Beamline from intermediate position







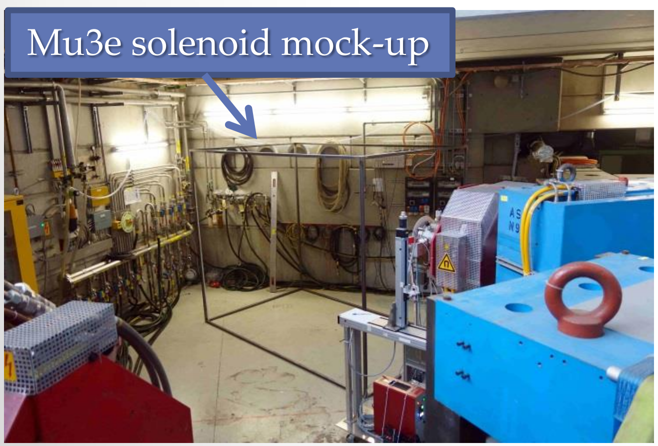
G4Beamline predictions:
Transmission to Solenoid injection: ~90%
Spot-size @ solenoid injection: σ_x =27 mm σ_y =23 mm
Spot-size @ solenoid center: σ_x =8 mm σ_y =8 mm

CMBL Testbeam setup

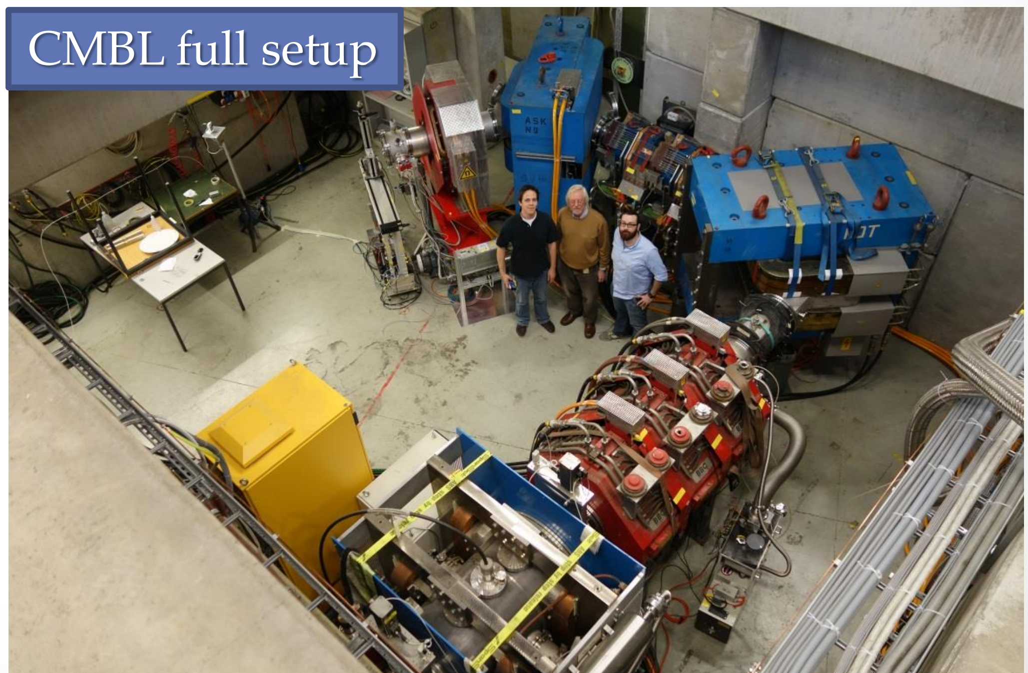
Staged setup with available elements (not all optimal)

Beam time:
end of 2014 & may 2015

Mu3e solenoid mock-up



CMBL full setup

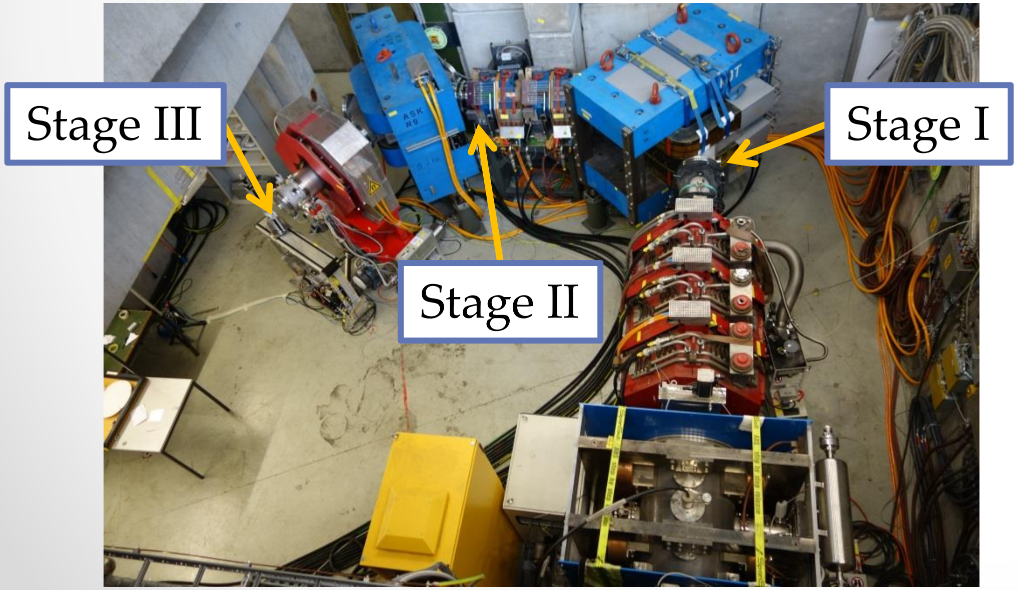


CMBL measurements

Staged setup

Goals:
- Optimize on transmission
- Profile measurements
- Phase space measurements
- Determine e^+ contamination and separation quality

Staged approach:

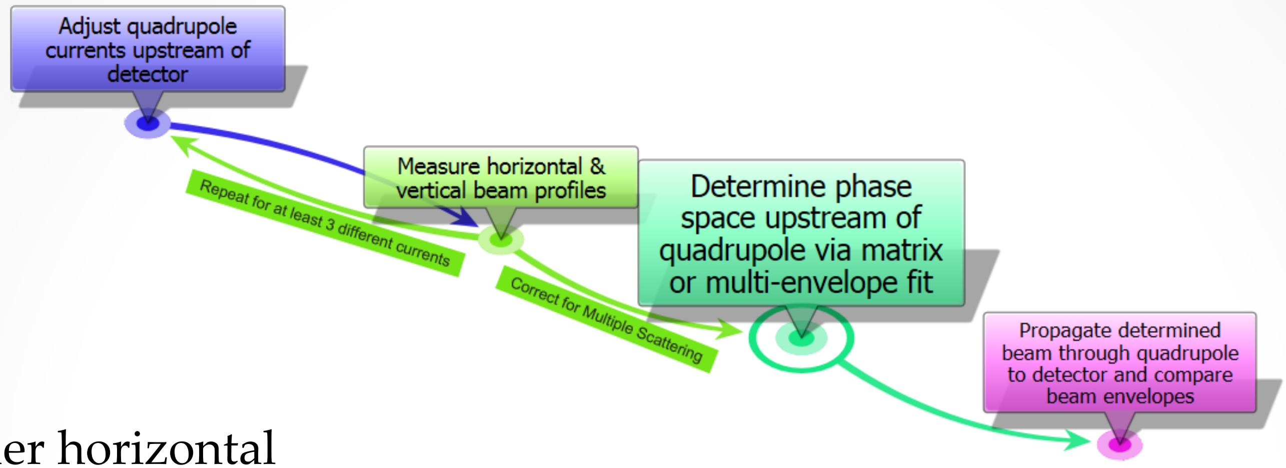


Measurement principle

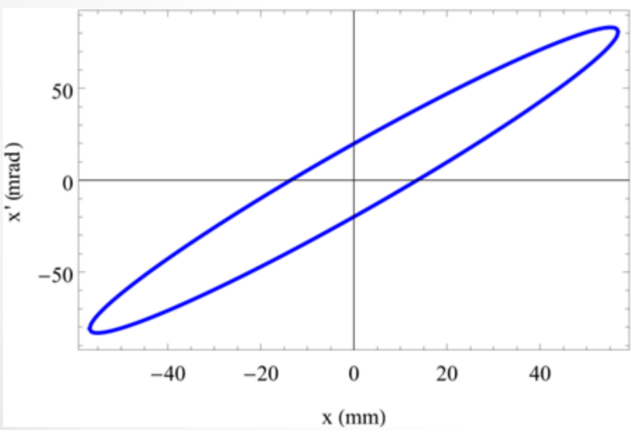
XY - Scanner (Stage II position):

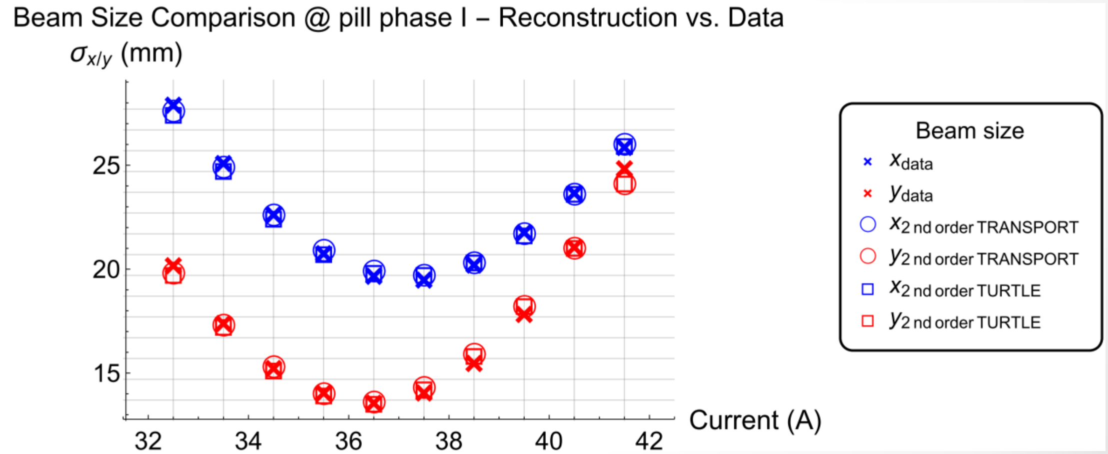
Pill Scintillator → PMT → Discriminator → Digitizer

Phase Space Reconstruction



First order horizontal Phase space from fit:

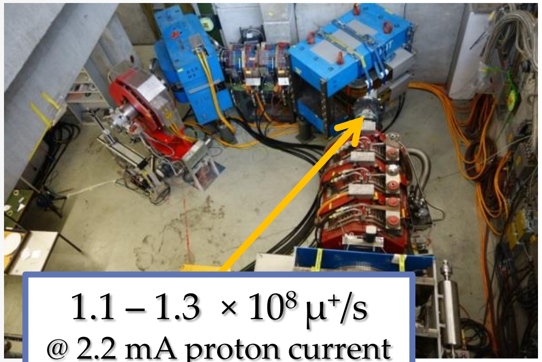




→Very good agreement between reconstruction and data.

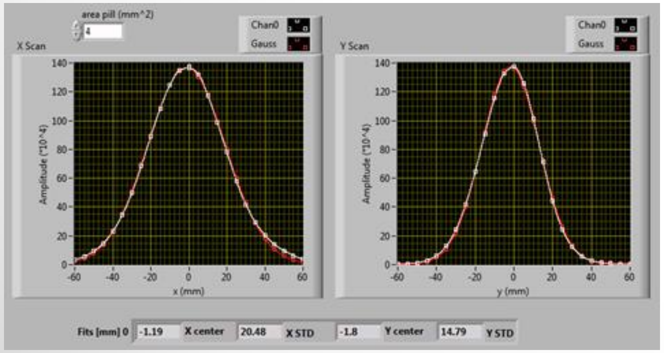
Rate @ stage I and Separation

Rate stage I
(depends on proton beam centering)

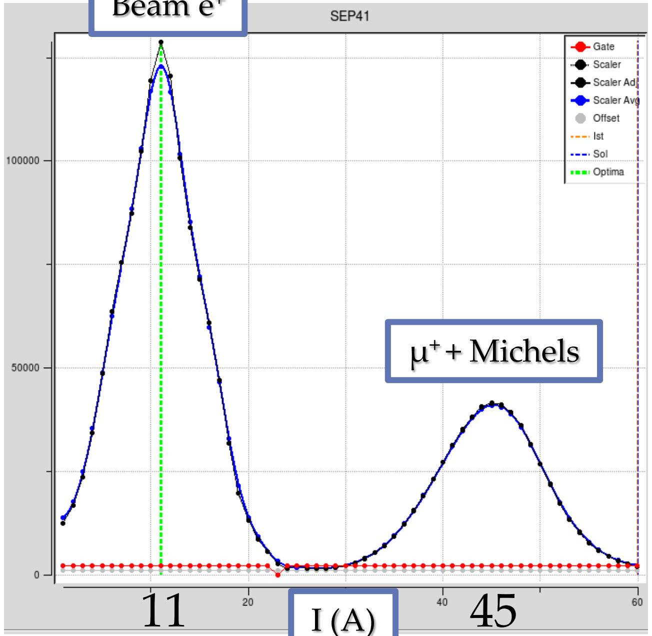


$1.1 - 1.3 \times 10^8\ \mu^+/s$
@ 2.2 mA proton current

Scan with GaussFit



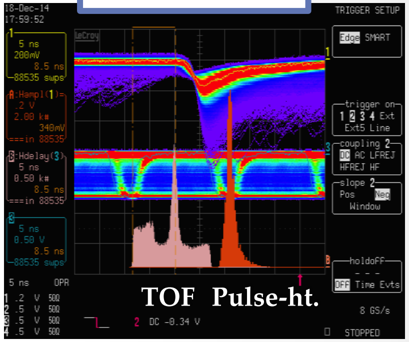
Separator Scan



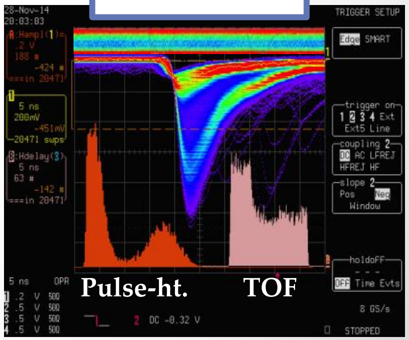
Separation power 2.5 mm/A
→ 85 mm separation ≈ 5.7 σ_μ

Detector Signal

e+-selected Wien-filter

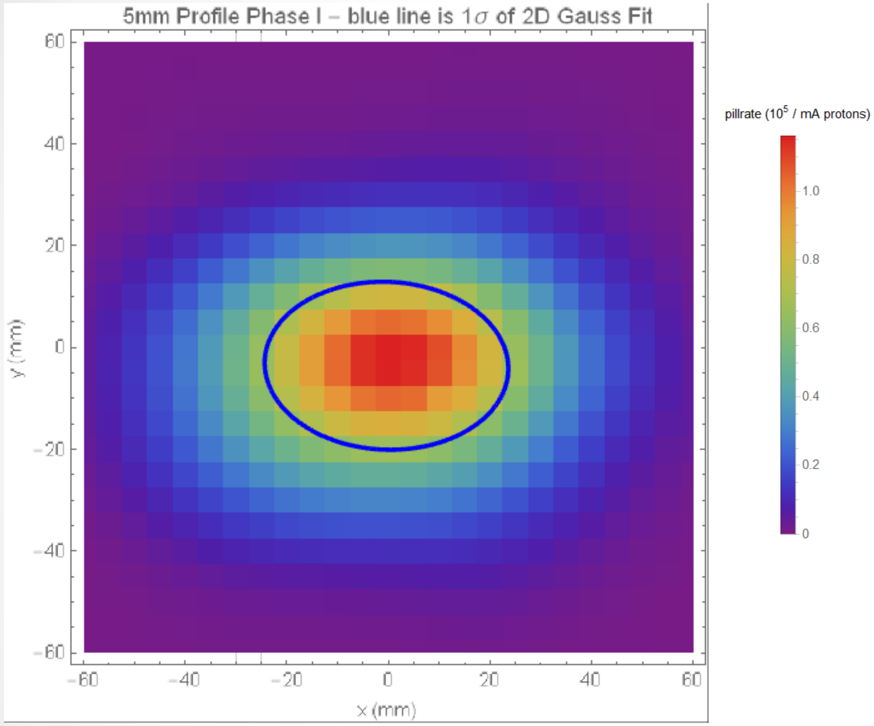


μ+-selected Wien-filter



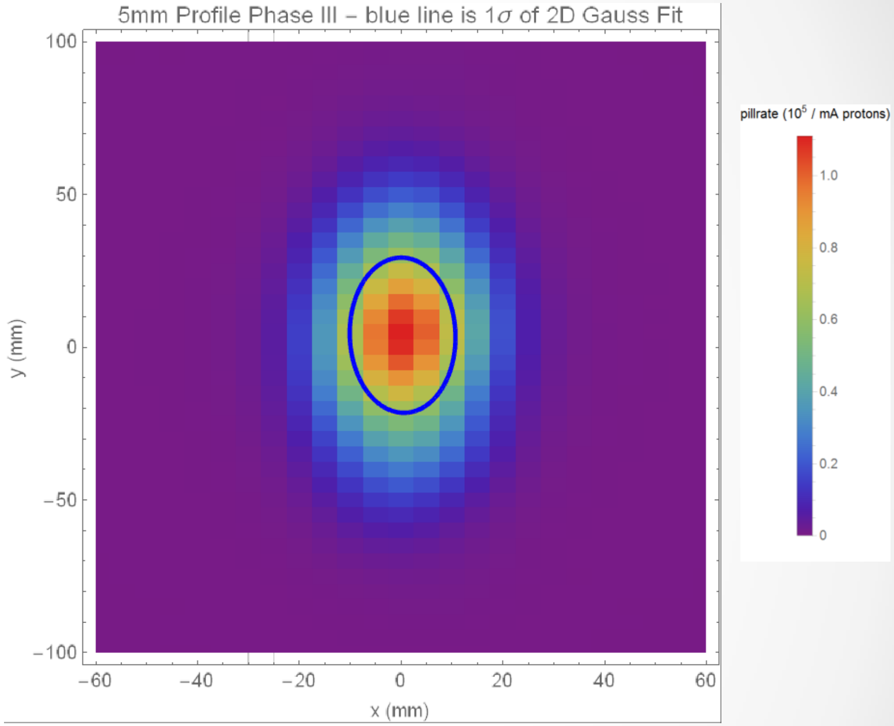
Profiles

Stage I



$\sigma_x = 24.0mm \quad \sigma_y = 16.5\ mm \quad \varrho_{xy} = 0.03$

Stage III – final focus



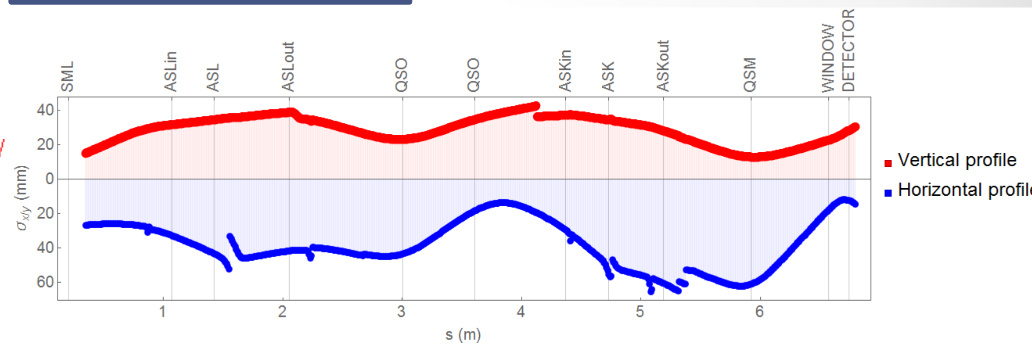
$\sigma_x = 10.4\ mm \quad \sigma_y = 25.4\ mm \quad \varrho_{xy} = 0.02$

2 D Gauss Fit 1σ border is shown as blue ellipse

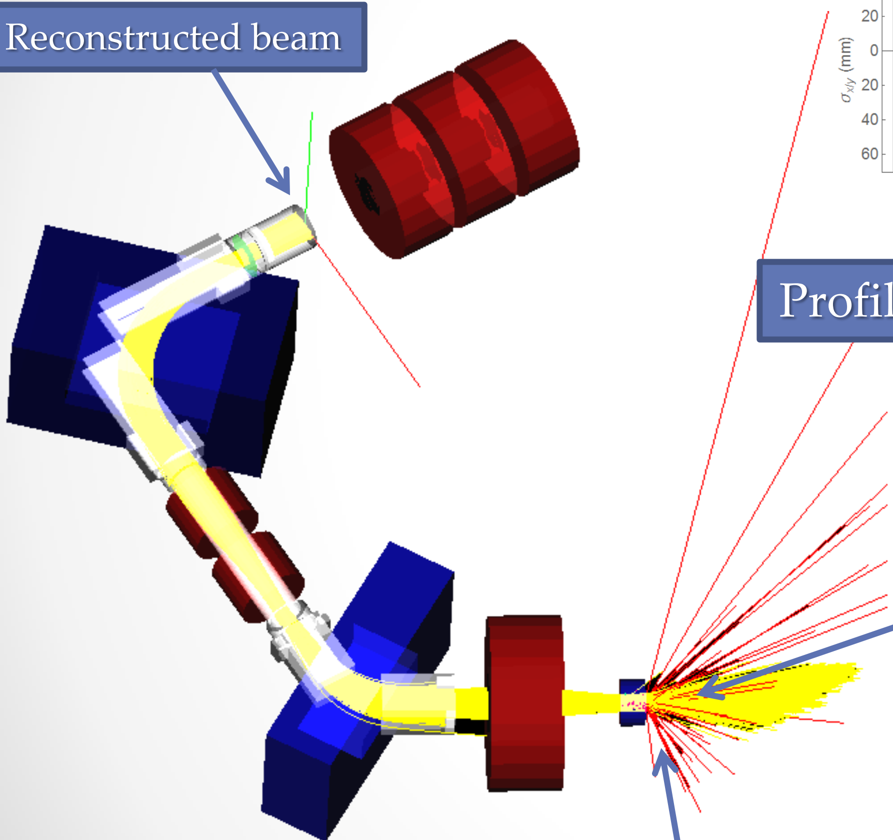
→ No XY – correlation

G4Beamline simulation from reconstructed phase space

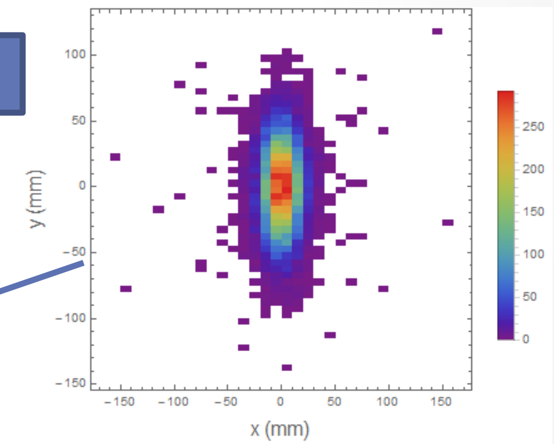
Beam envelopes:



Reconstructed beam



Profile @ final focus:



Mylar window and air

Transmission: ~68 %

σ_x =12 mm σ_y =28 mm

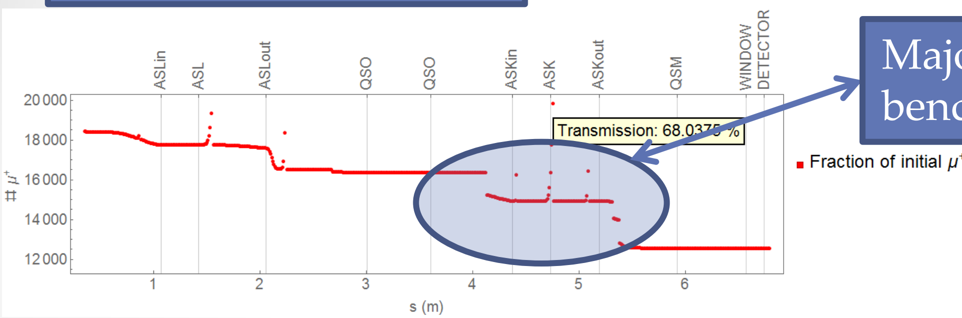
Reasonable agreement with measurement!

- *O(10^8^)* → $O(10^8)$ μ^+/s @ 2.2 mA protons
- Our goal is not yet reached.

→ optimization of test elements needed!

Optimize transmission through last part

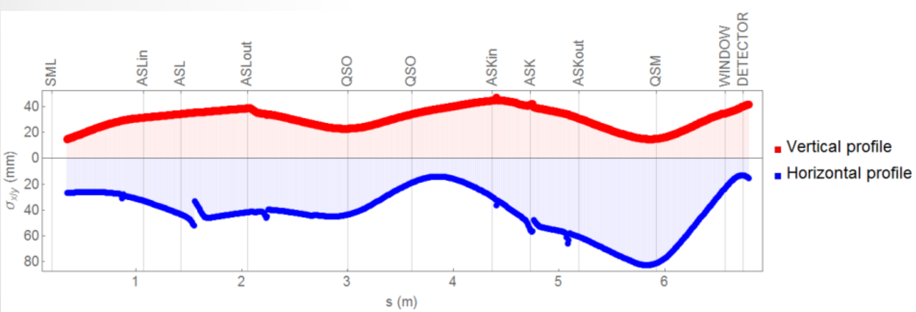
Losses along beamline:



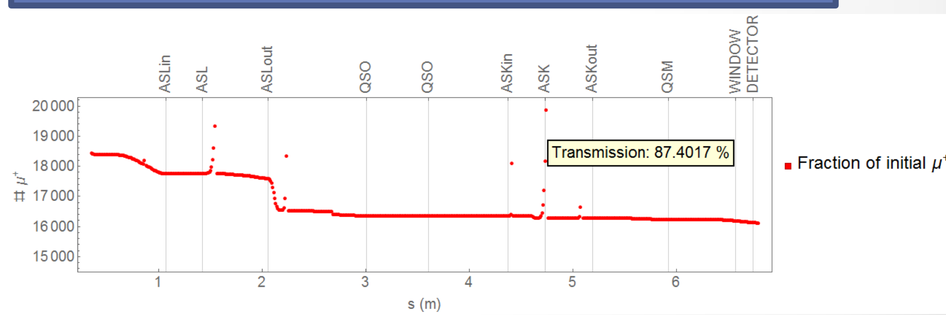
Major losses occur at the ASK (second bending magnet) vacuum chamber aperture.

→ Improve transmission by reoptimizing simulations without aperture constraints by second bending magnet

Beam envelopes without ASK aperture cuts:



Losses along beamline without ASK cuts:

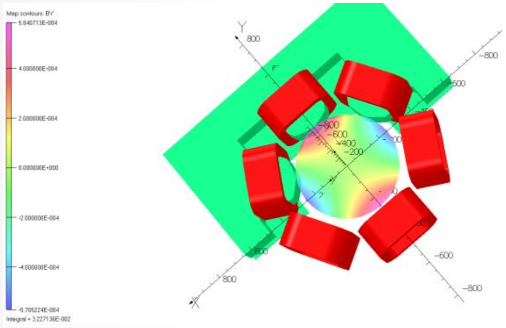


→ 87% transmission feasible for lowering ASK aperture constraints

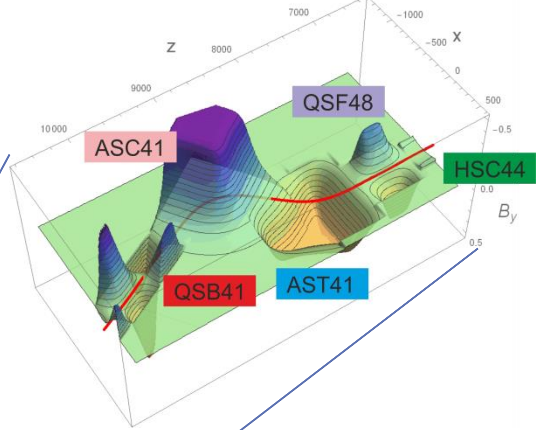
Optional - Optimize full beam line

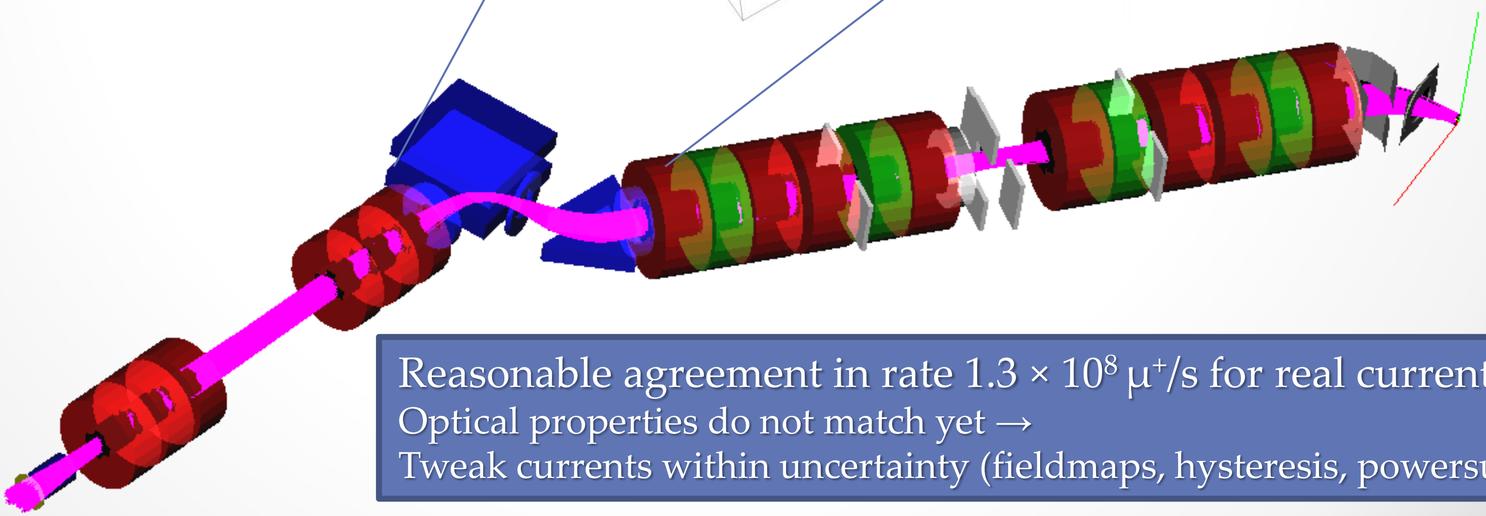
→ Improve transmission of first part by simulating full PiE5 with HiMB model beam from Z. Hodge

Fieldmaps from measurements or FEM calculations



Region of overlapping fringe fields





Reasonable agreement in rate 1.3×10^8 μ^+/s for real currents
Optical properties do not match yet →
Tweak currents within uncertainty (fieldmaps, hysteresis, powersupply)

Summary

- Design solution found for the Compact Muon Beam Line which meets the requirements (Split Triplet)
- First beam tests carried out with available elements at PSI (not optimal wrt vacuum chamber apertures)
- Full characterization of the transverse phase space at different locations along the beamline
- Optimization of beam line elements based on phase space measurements
- Complete description of πE5 beam channel is ongoing

Thank you for your attention!