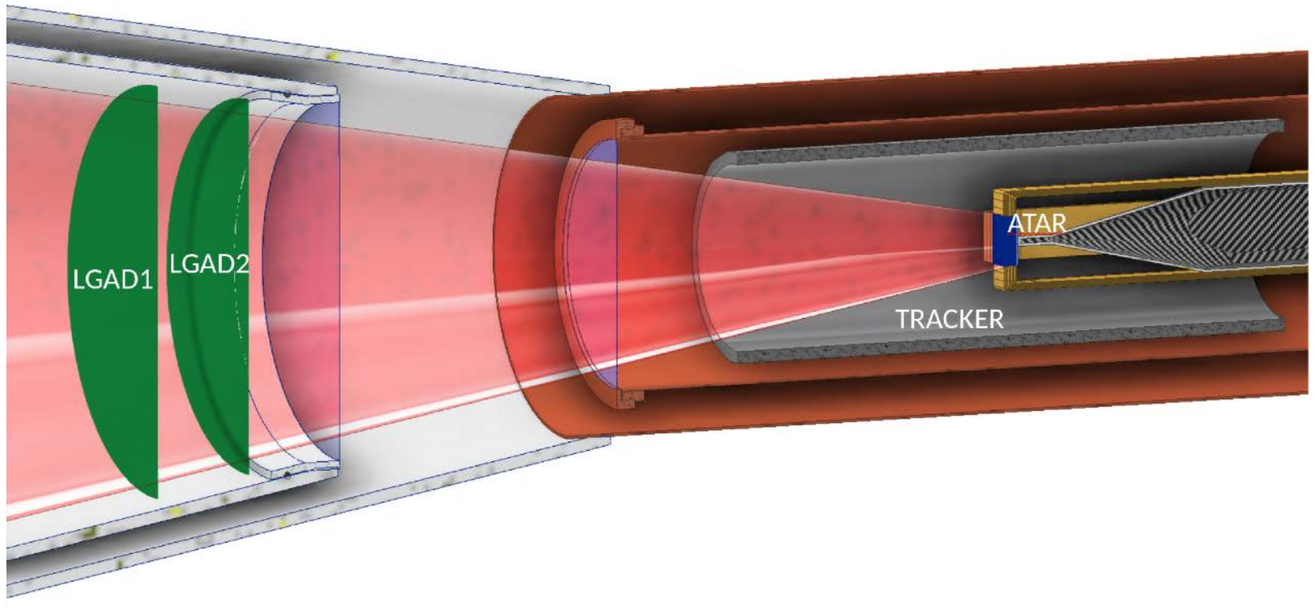
# PIONEER
# Beam ‘22 @ PSI

Anna Soter for PIONEER

Thanks for slide contributions form the beamtime crew!
& Andreas Knecht @ PSI

# Beam requirements of PIONEER (the short version)




Continuous wave beam (cw) for event-by-event analysis

Phase I

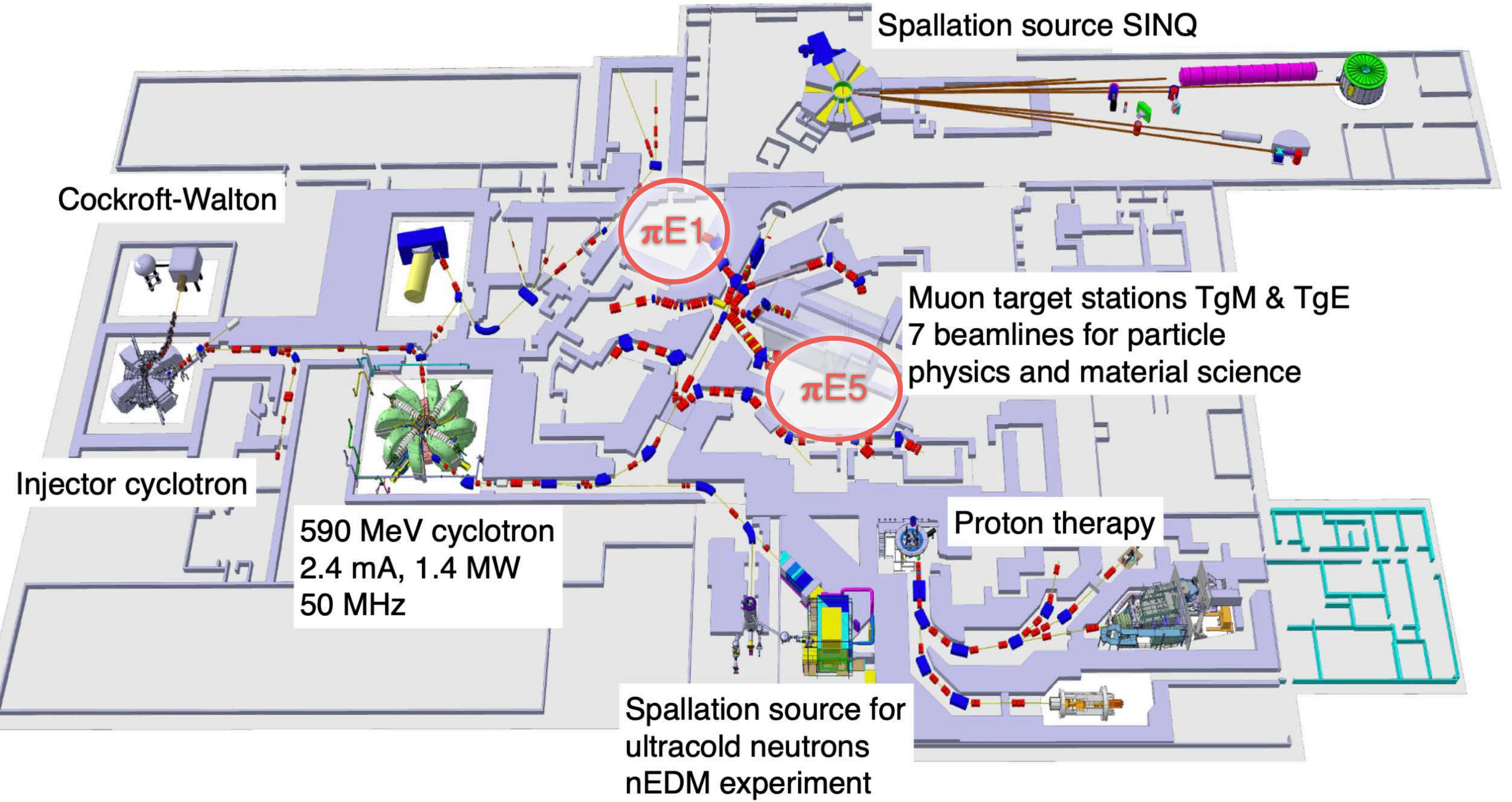
- Rate in ATAR : 300 kHz
- Spot in focus: 20mm x 20mm
- Momentum bite: $\Delta p/p < 2\%$
- Contamination: $(\mu+e)/\pi < 10\%$

- Clean beam, moderate rates

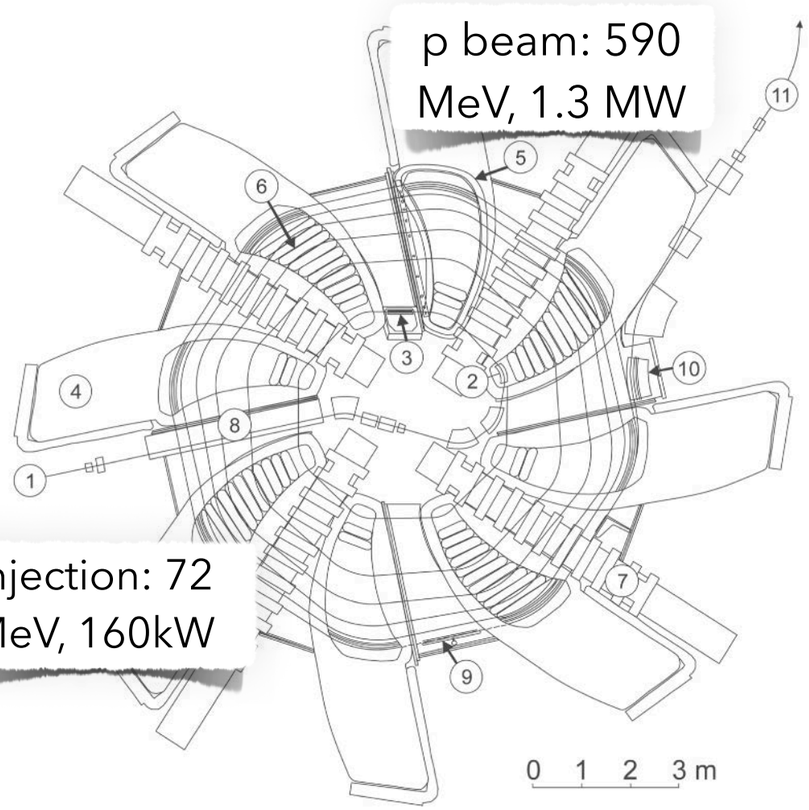
Preferred: possibly **low momentum** (~55-56 MeV/c) for ATAR stop

Disadvantage: decay losses, low π rates, decay in flight high $(\mu+e)/\pi$

# The PSI accelerator and beamlines

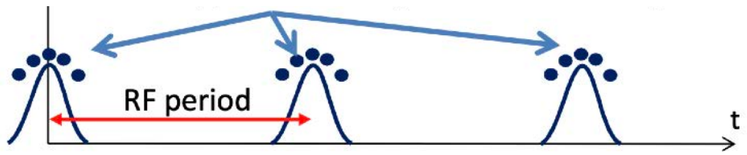


# PSI cyclotron - highest intensity cw muons and pions

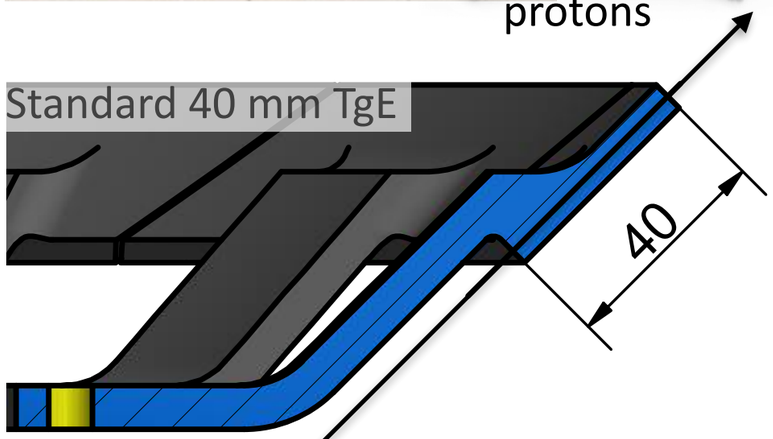



**Separated sector isochronous cyclotron**

- 8 magnets, 4 cavities
  850kV @ 50.6 MHZ

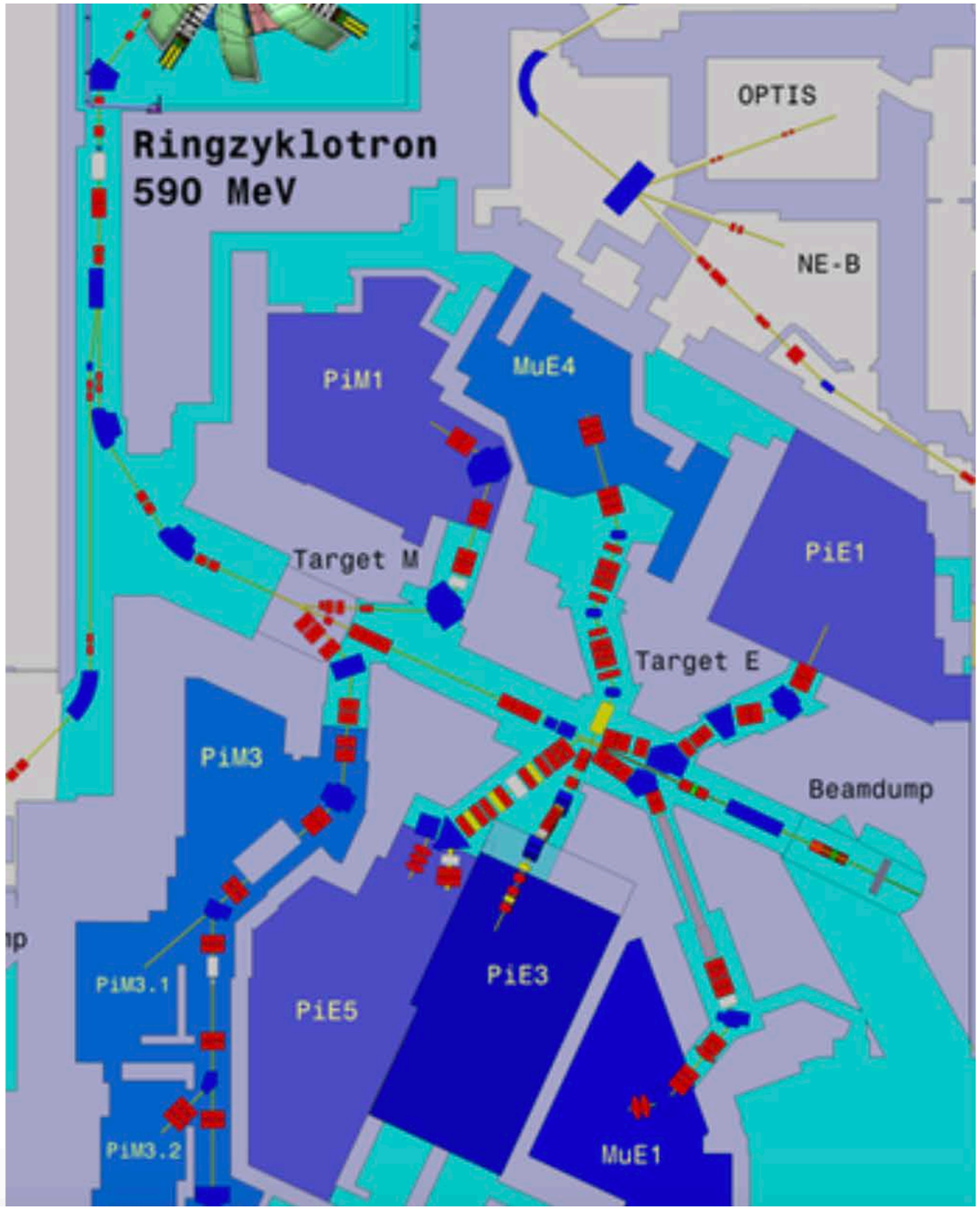



- Results in micro bunches spaced by ~20 ns
- 590 MeV protons, ~2 mA beam current
- two production targets: thick (target M) and thin (target E)

# PSI Accelerators and Beamlines

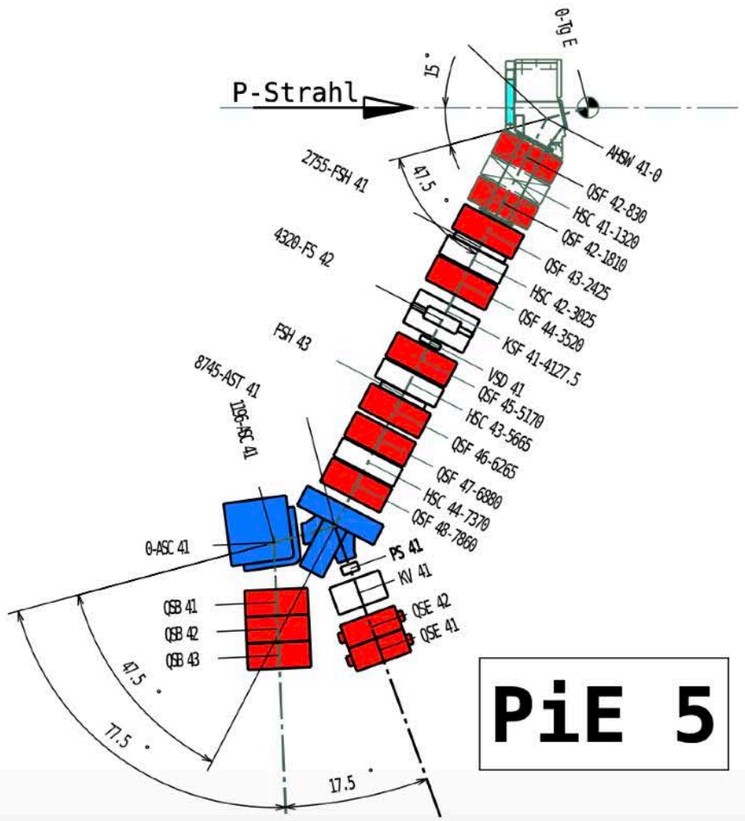
- PiE5:
  - Highest-rate beamline available to particle physics
  - Home of MEG, Mu3e, Lamb Shift, piHe, …
- PiE1:
  - Shared with muSR
  - Home of MuSun, PIBETA, PEN, …



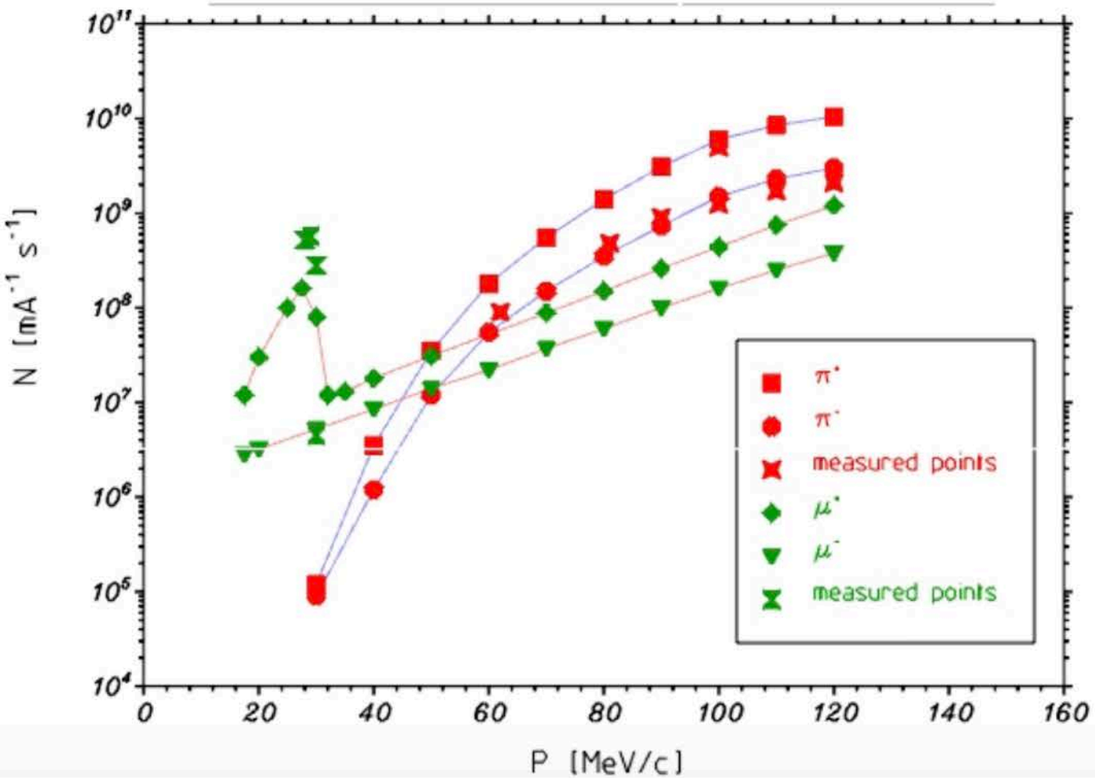
# PiE5 Area

- Low-momentum, low-resolution, high-acceptance beamline

- Particle rates given in the plot typically too high:
  However, a few $10^8$ pi+/s at 85 MeV/c and full momentum acceptance possible

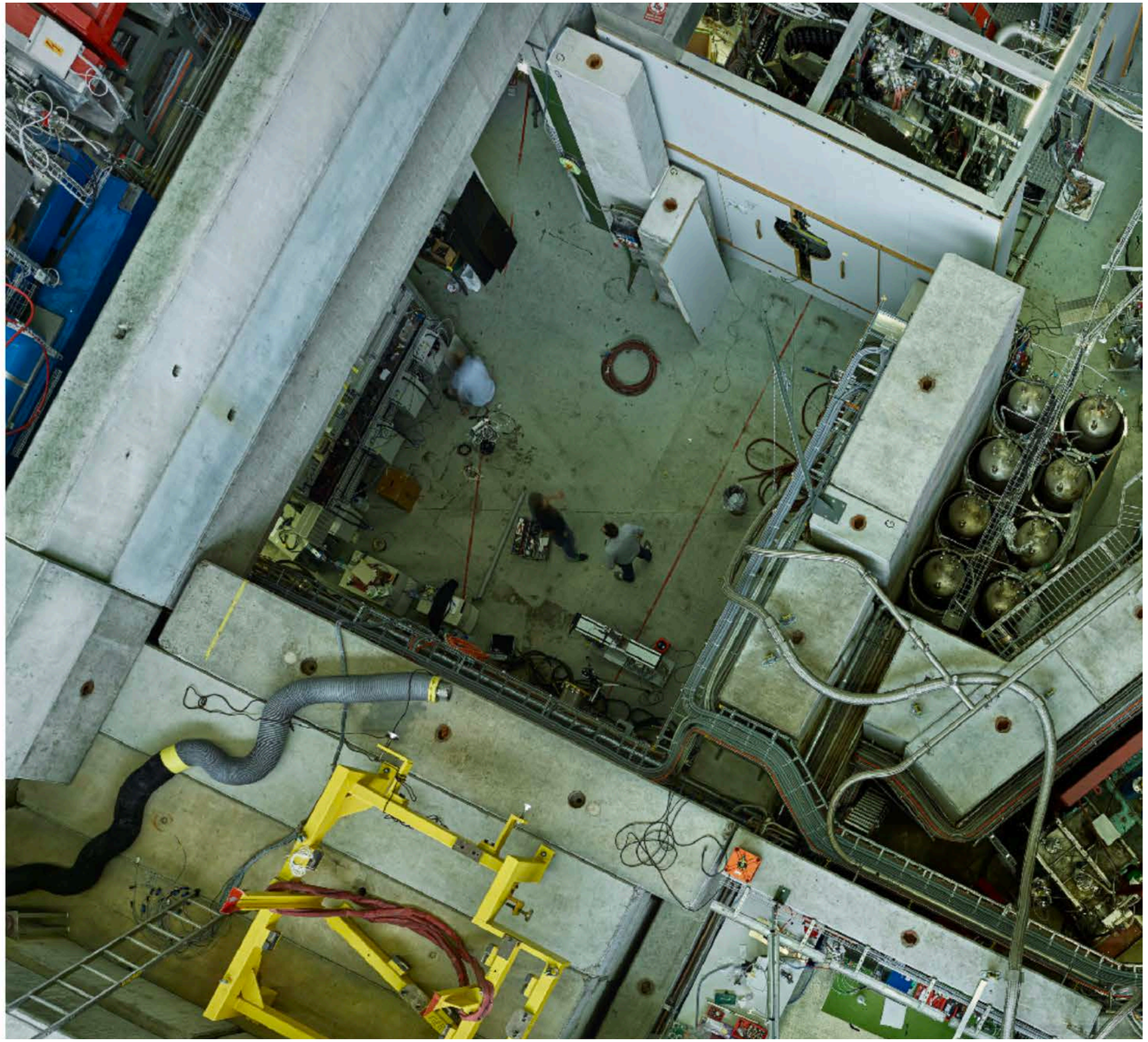



| | |
|---|---|
| Length | 10.4 m |
| Solide angle | 150 msr |
| Momentum acceptance (FWHM) | 10 % |
| Momentum resolution (FWHM) | 2 % |
| Spot size (FWHM) | 15 mm horizontal |
| | 20 mm vertical |
| Angular divergence (FWHM) | 450 mrad horizontal |
| | 120 mrad vertical |



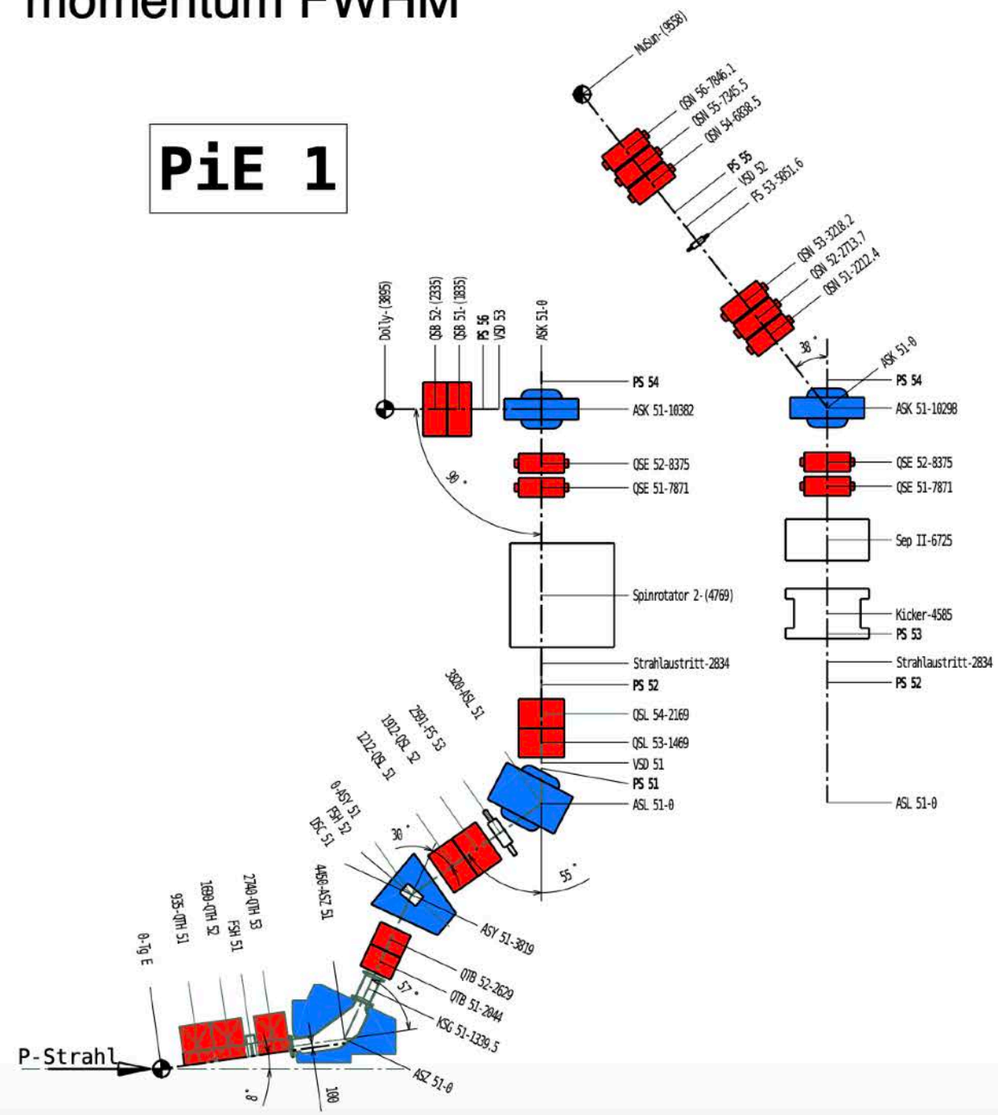
# PiE5 Area

- piE5 front area with MEG behind

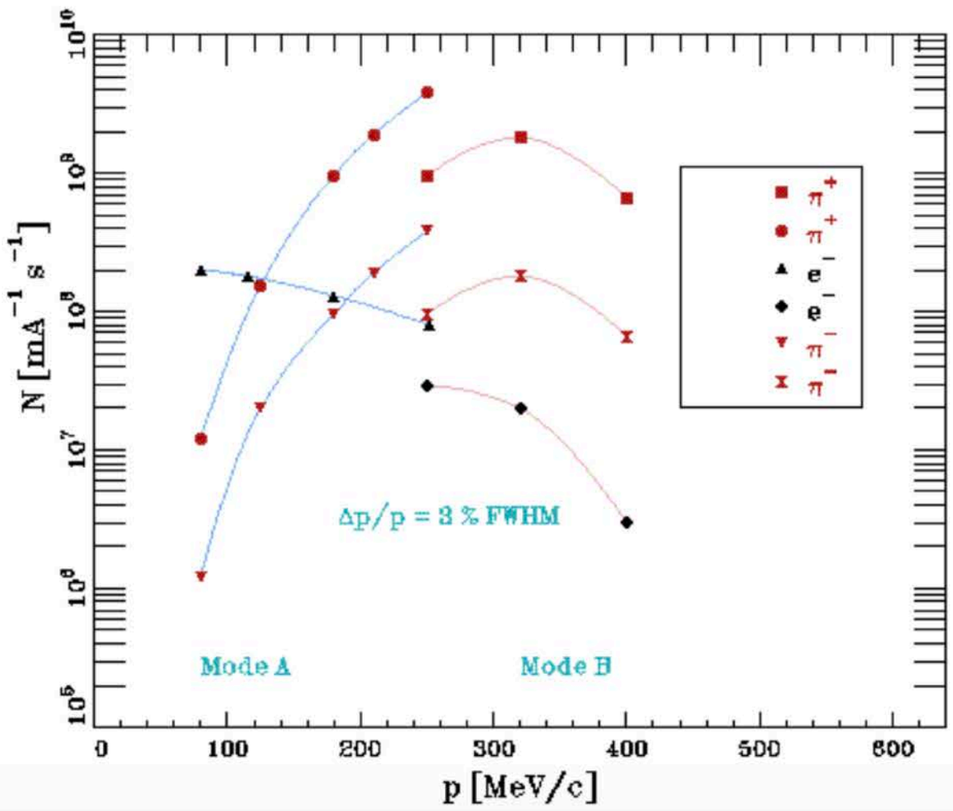


# PiE1 area

- High-momentum, high-resolution, low-acceptance beamline
- ~$10^7$ pi+/s at 85 MeV/c and 3% momentum FWHM



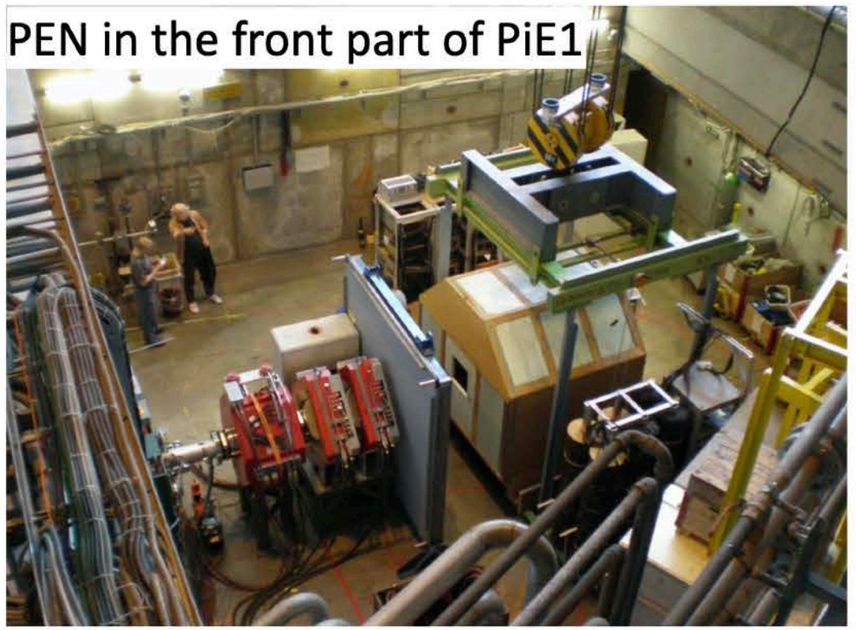

| Mode | A | B |
|---|---|---|
| Length [m] | 16 | 16 |
| Max. momentum [MeV/c] | 280 | 500 |
| Solide angle [msr] | 32 | 13 |
| Momentum acceptance (FWHM) | 7.8 % | 8.0 % |
| Momentum resolution (FWHM) | 0.8 % | 0.26 % |

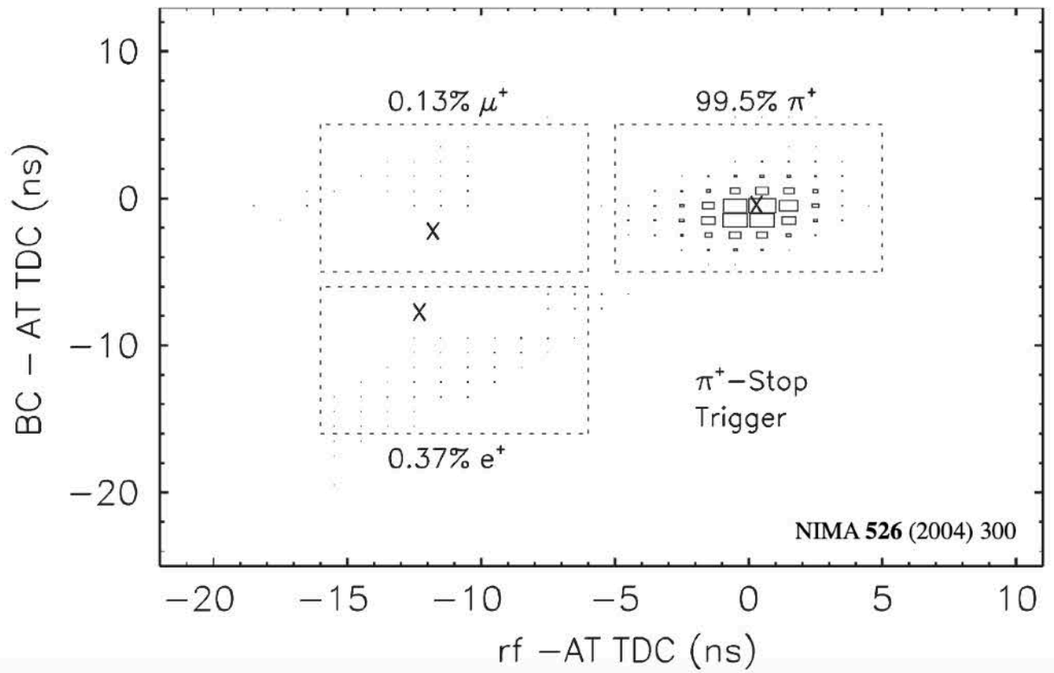


# Pion beams for PIBETA and PEN at PiE1

- PIBETA:
  - ~$10^6$ pi+/s at 113 MeV/c (1% momentum bite, 1.7 mA proton current, 60 mm TgE)
  - Positrons separated through differential energy loss in 4 mm thick carbon degrader mounted upstream
  - PID at active target through TOF
- PEN: few $10^4$ pi+/s at 70-85 MeV/c

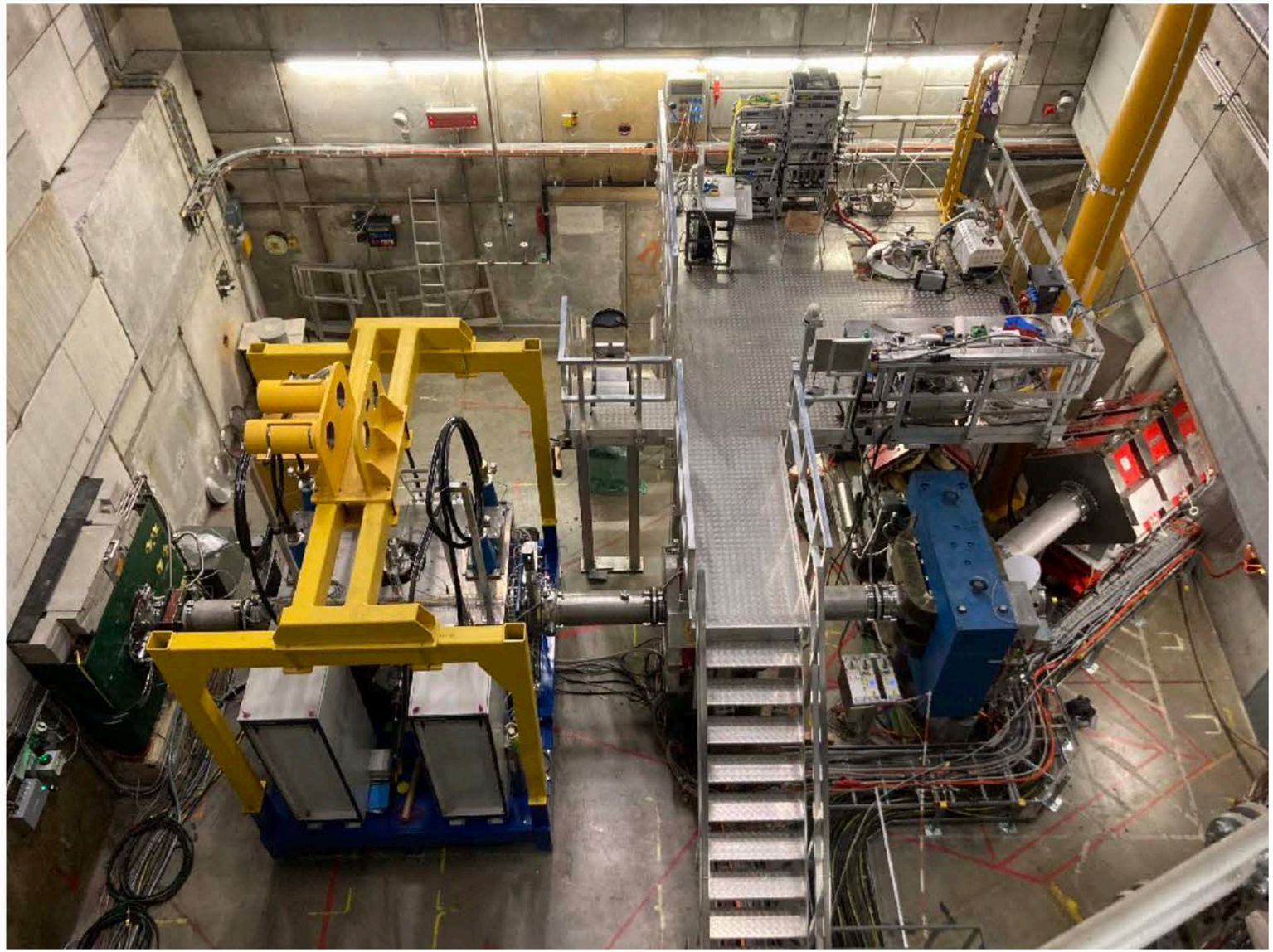
PEN in the front part of PiE1





# This is how the area normally looks like

- piE1 front area with installed spin rotator and muSR instrument DOLLY



# Choice between areas

## piE1

- Rate is (just) sufficient for p > 75 MeV/c for PIONEER Phase I
- More clean beam: narrow momentum bite, +/- 300 kV spin rotator
- Beam is only available for 1/2 beamtime (MuSR is the other half)
- Degrader in the beamline (2/4/6 mm glassy carbon)

## piE5

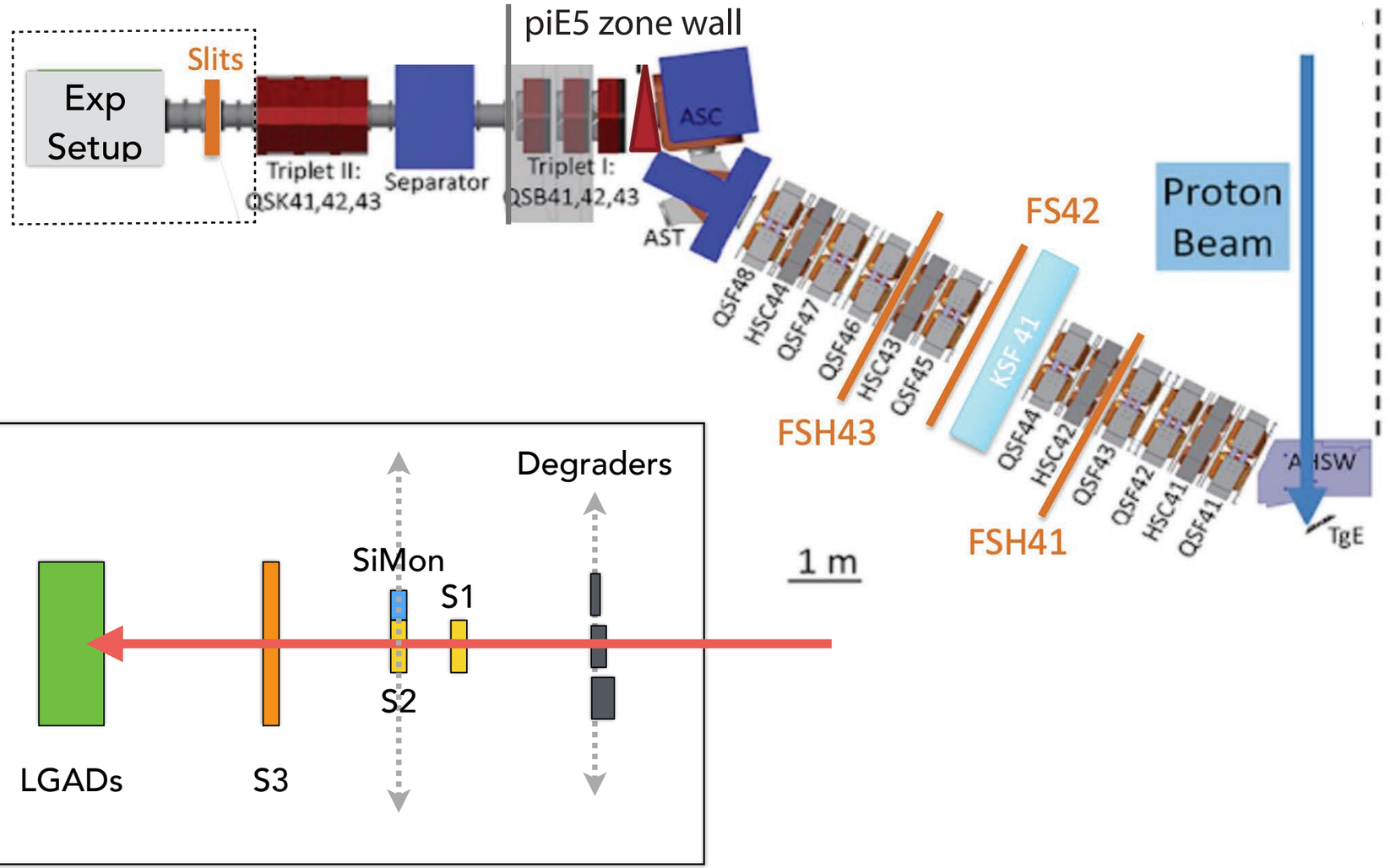
- Provides pions at lower momentum (55 MeV/c) in the necessary flux (300 kHz)
- The only possible beamline with hig enough rate for Phase II
- Two large users, MEGII and Mu3e

## HIMB?

- Construction from 2027, M target update
- Target area for Mu3e future program
- 10 x more in surface muon rates, large phasespace (30-50 mm beamspot)

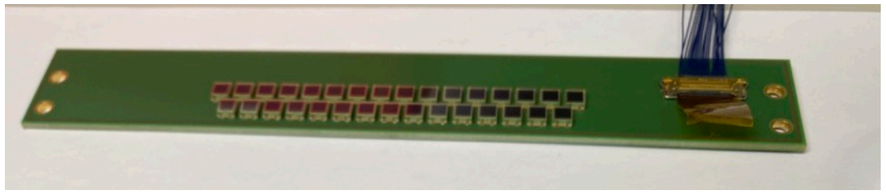
# 2022 June: PIONEER testbeam at PSI

- Goal: pi rate and spotsize low momentum (55-75 MeV/c)
- pion rate to beam muons and electrons
- $\Delta p/p$ measurements
- ATAR test



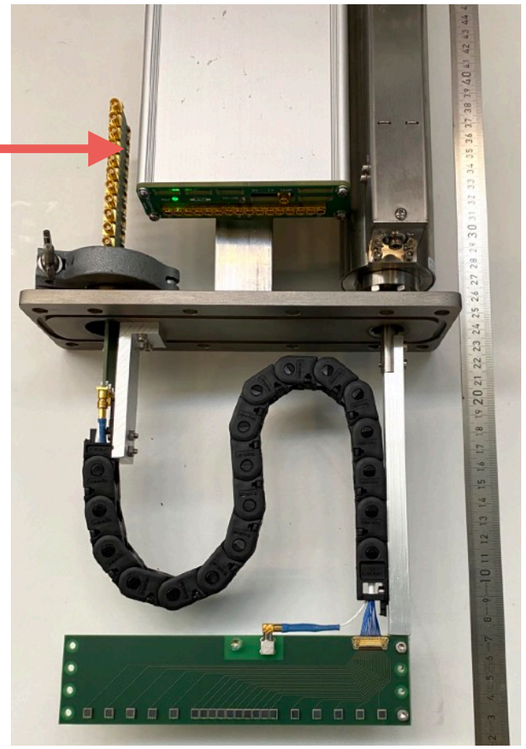

- Beam instrumentation: scanning pill detectors with 2.5 mm resolution (SiMon)
- ATAR sized scintillators
- LGAD prototype

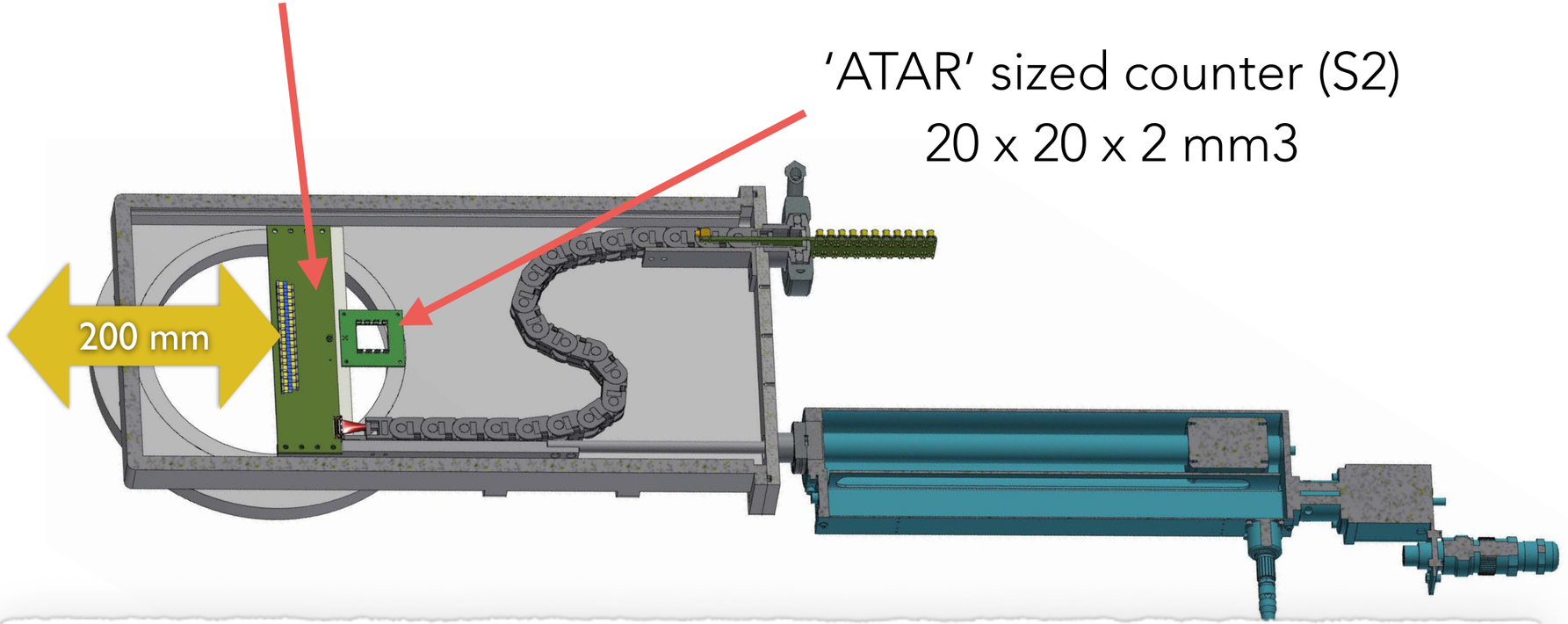
# SiMon detector (SiPM based beam Monitor)



SiMon: 31 pc of 2.5 x 2.5 x 2 mm3

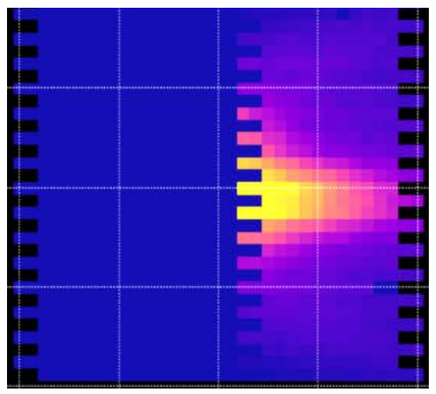
WaveDream
Readout





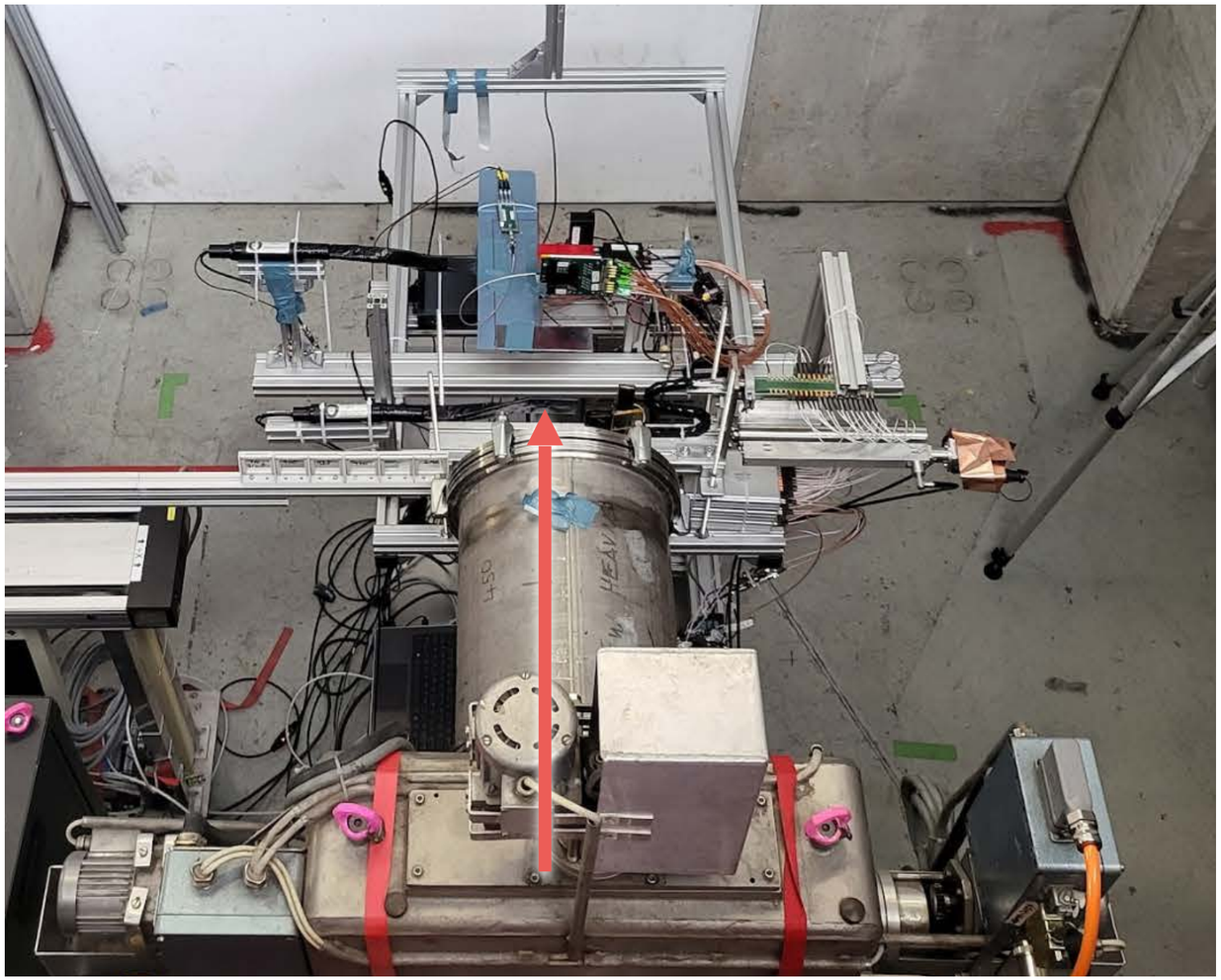

'ATAR' sized counter (S2)
20 x 20 x 2 mm3

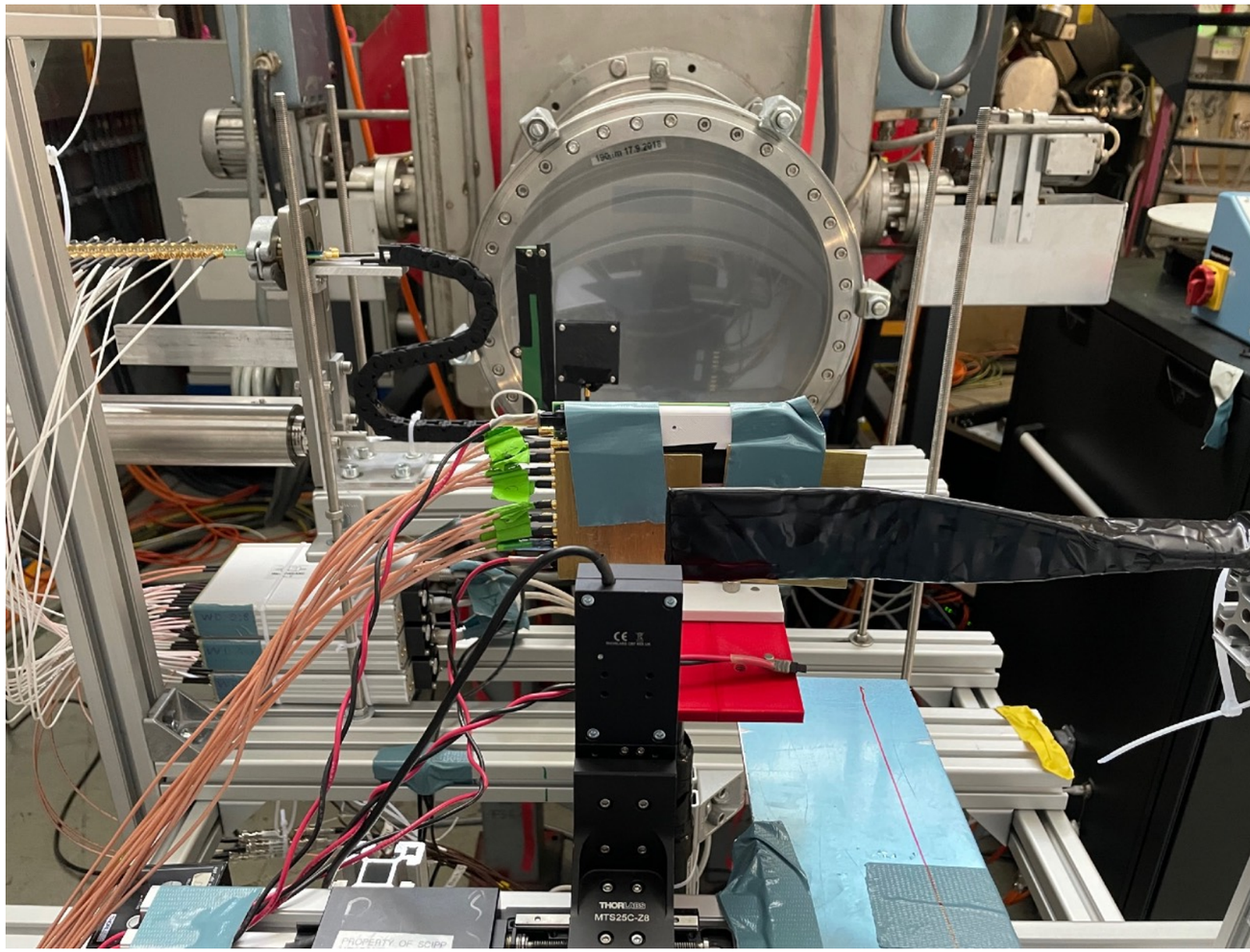
Layout
- 200 mm horizontal motion
- 77 mm vertical span
- zigzag layout of 31 pills, 2.5 mm granularity
- usual scan:



WaveDream
- 16 DRS4 channels
- 1 to 5 GS/s
- 700 MHz analogue bandwidth
- Input gains: 0.25-100
- Adjustable pole-zero cancellation
- SiPM HV power supply
- Standalone Ethernet or backplane operation
- Inter-channel jitter ~25ps

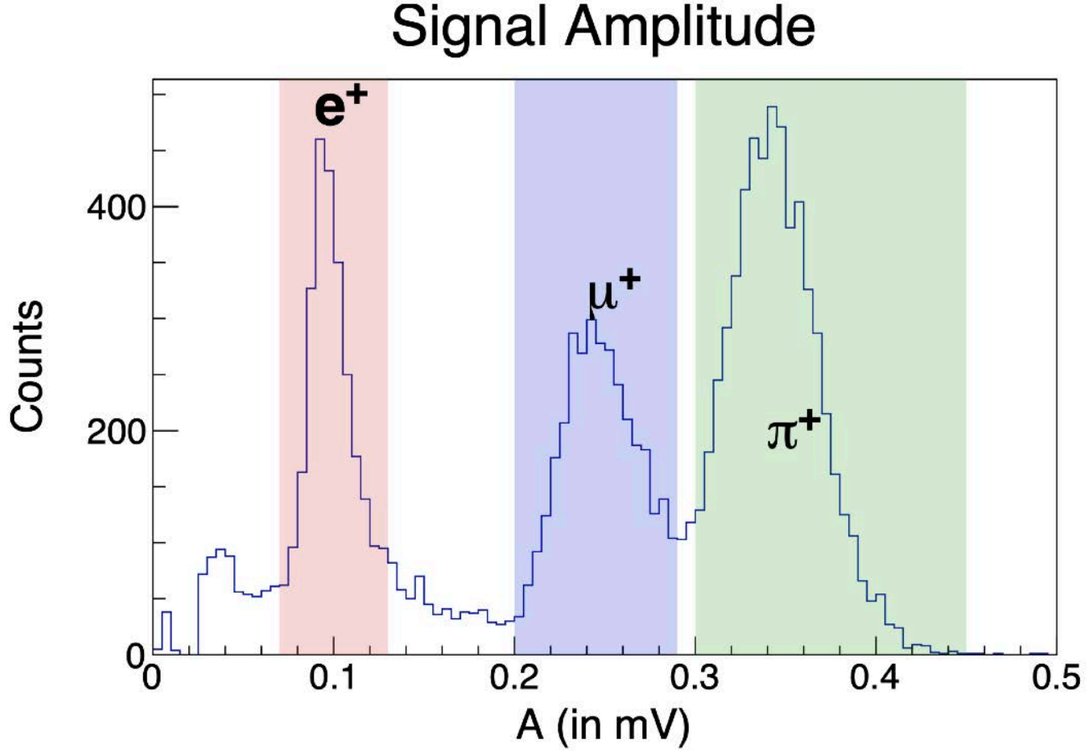
# Setup at PSI, piE5

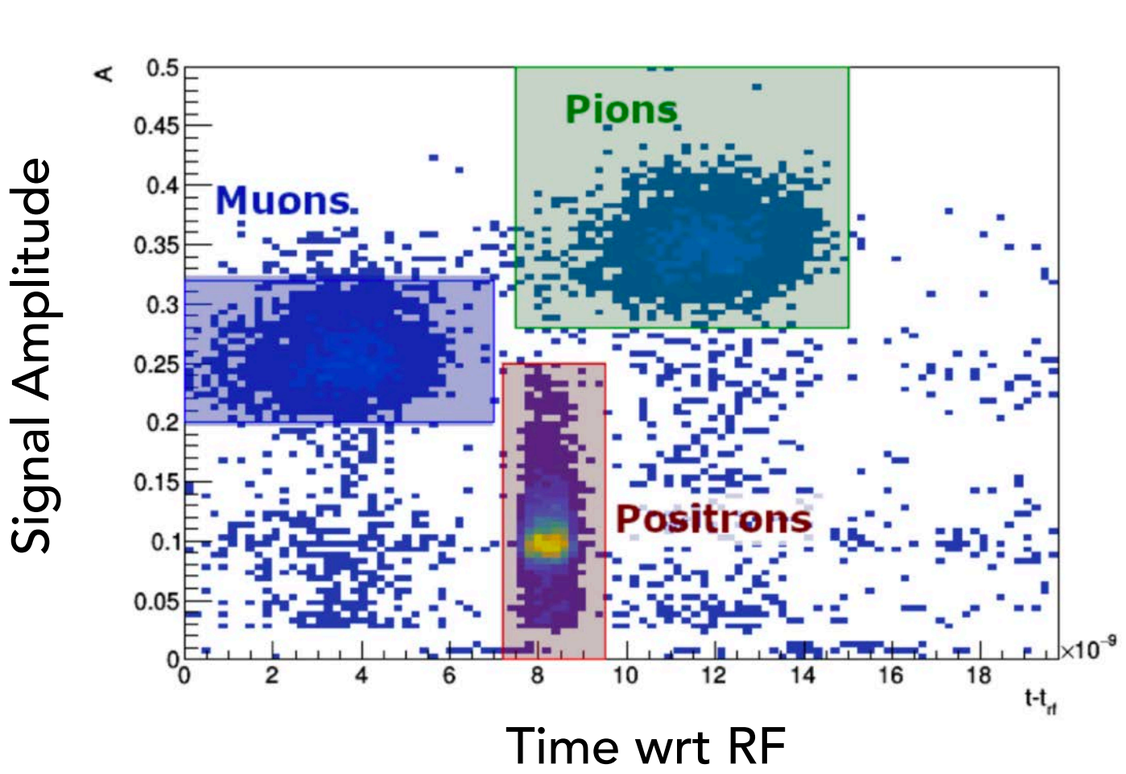




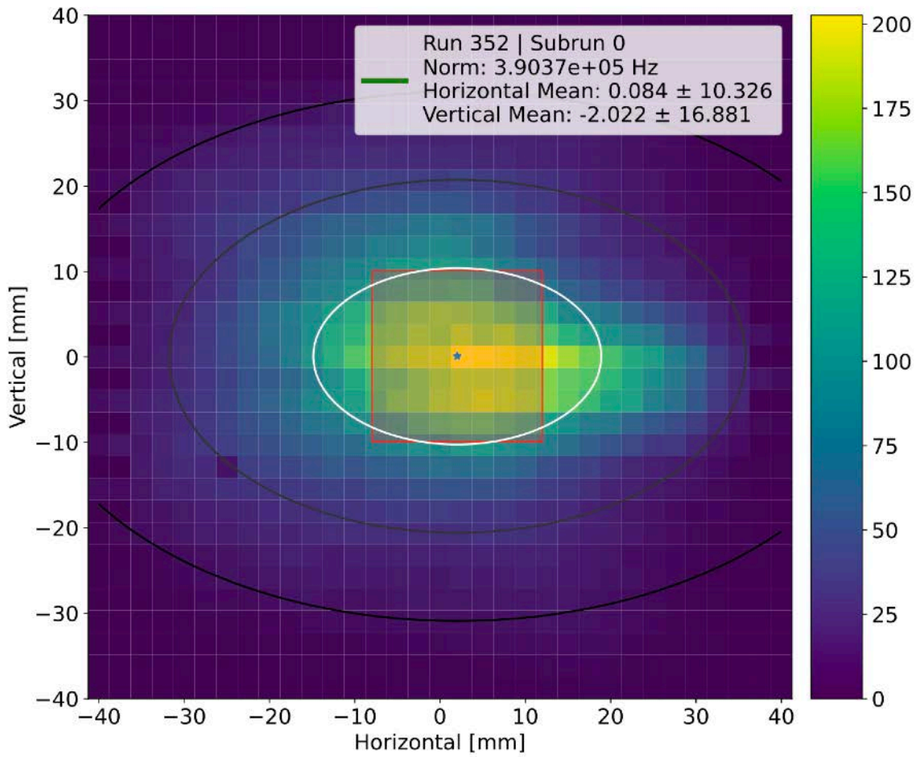
# Data provided by the SiMon detectors

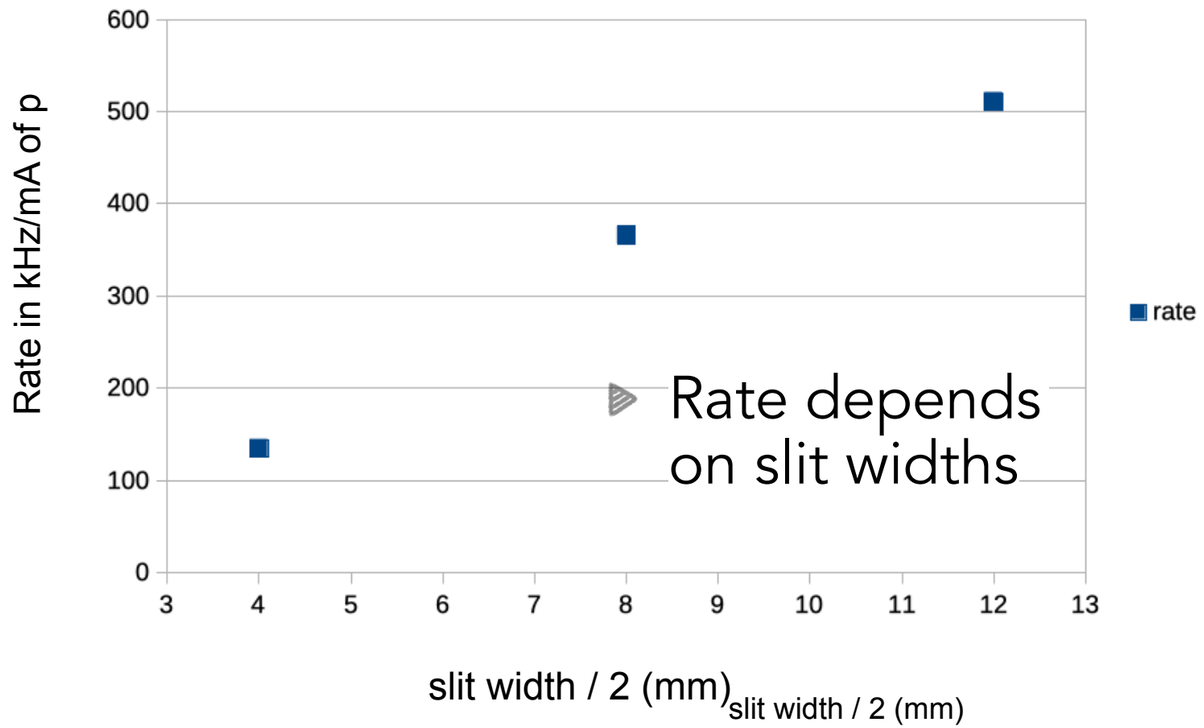
- Counting mode: channel specific threshold, recording trigger rate only
- Full waveform digitization: amplitude and time data
- Precise time provided by continuous recording of the beam RF



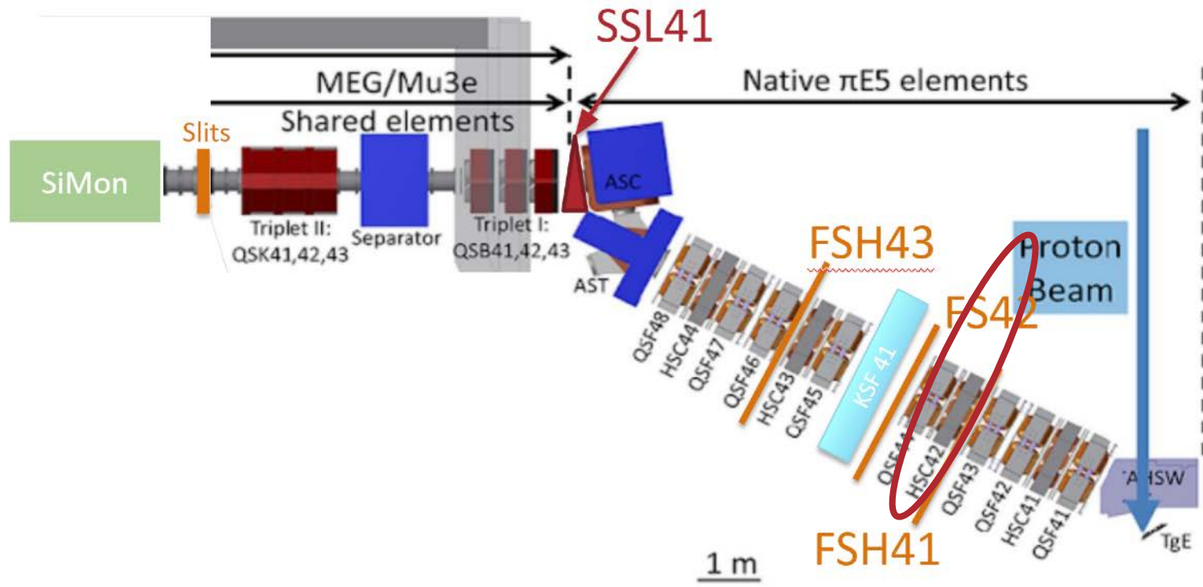



# Pion rates

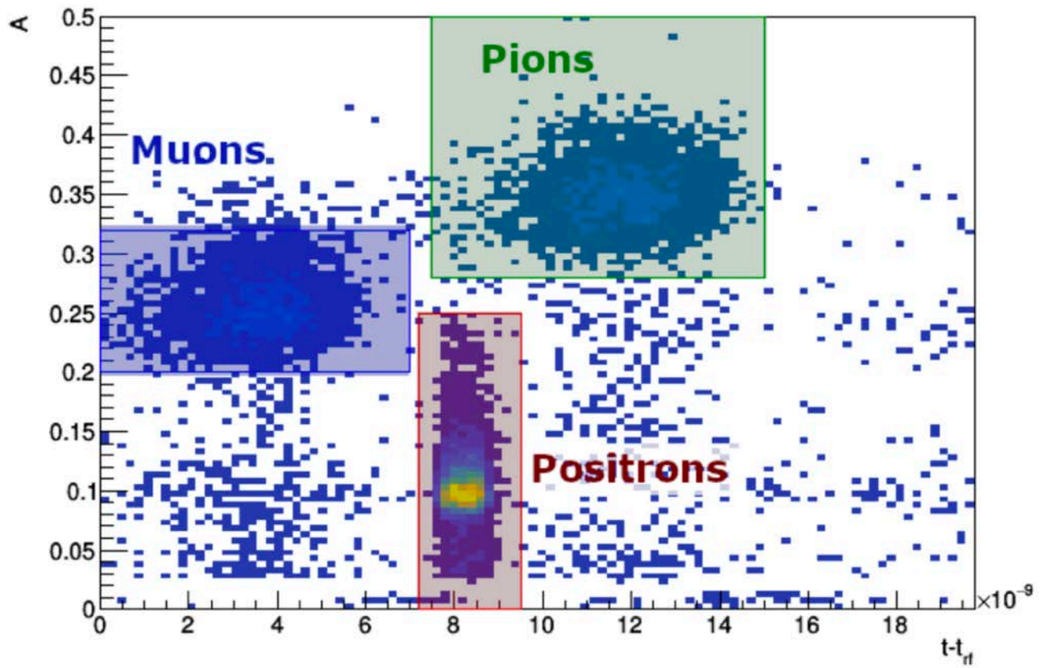


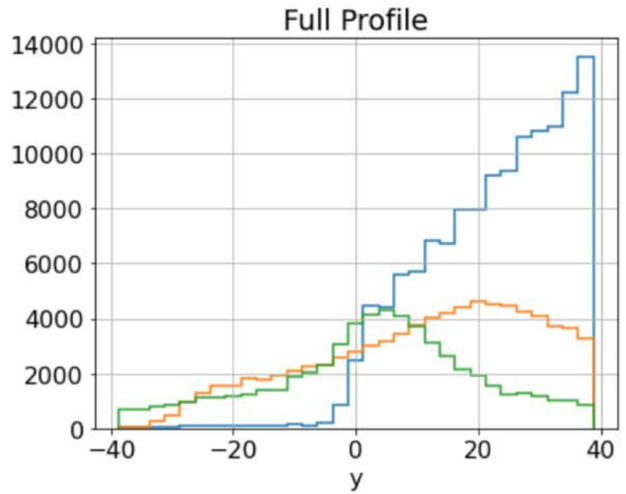



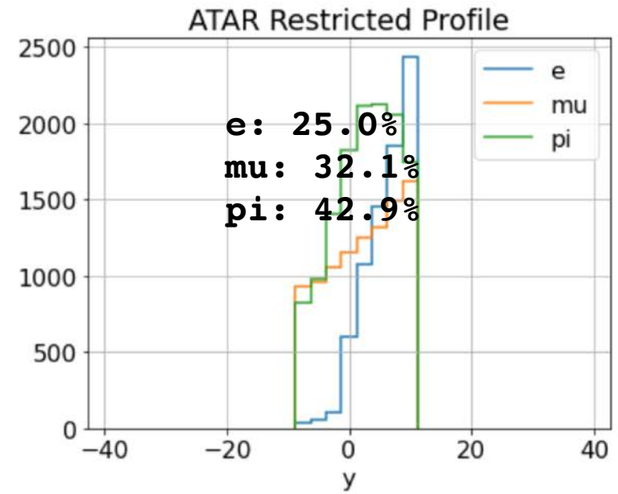

- 65 MeV/c, after tuning
  - **Rate: 633 kH / 46 % in ATAR Box**
  - Mean X = 0.3 mm
  - Mean Y = 0.2 mm
  - Sig X = 23 mm
  - Sig Y = 10.1 mm

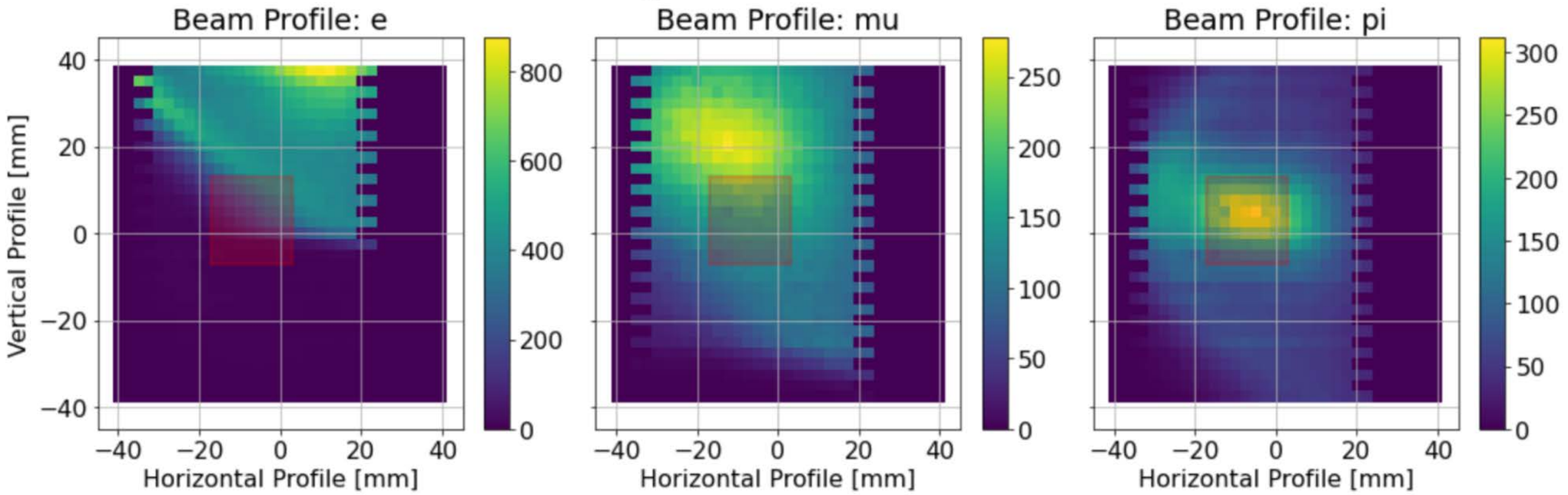


# Profiles and rates on the ATAR



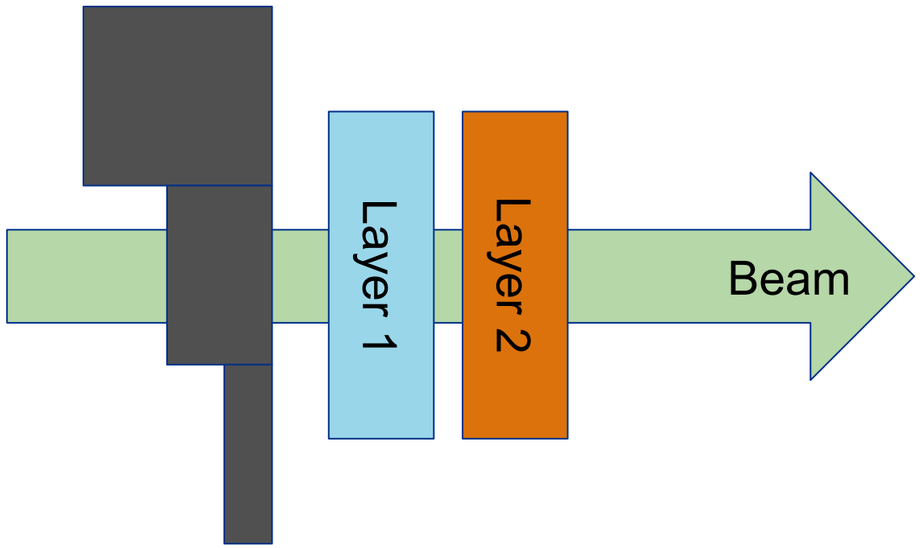



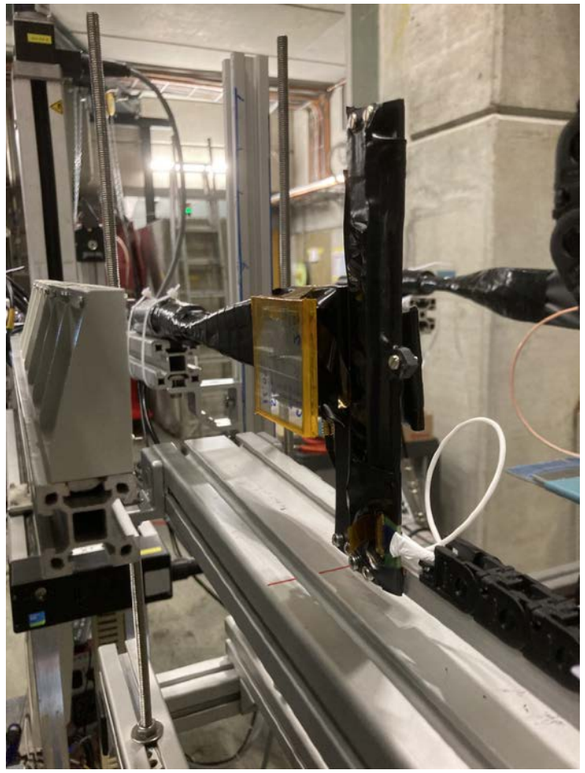



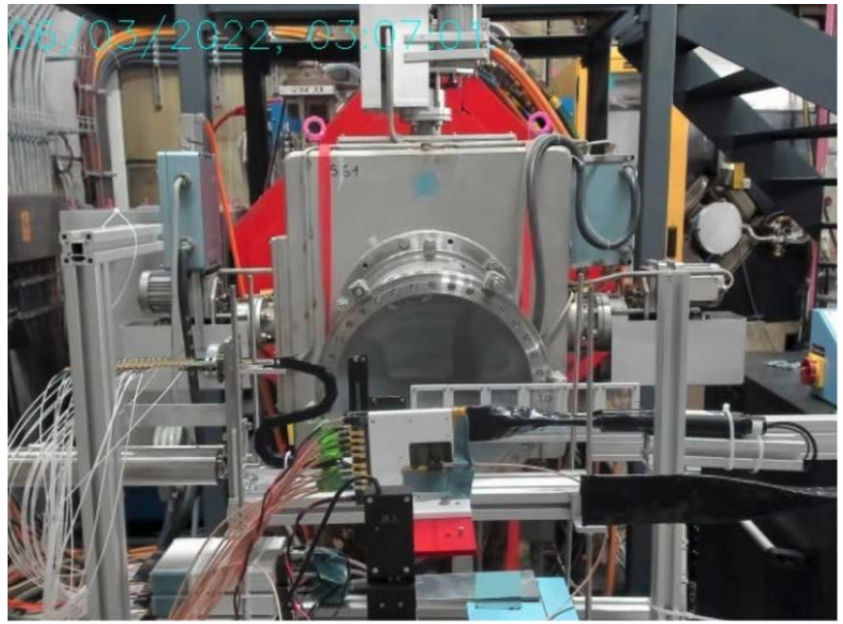



# Range scans

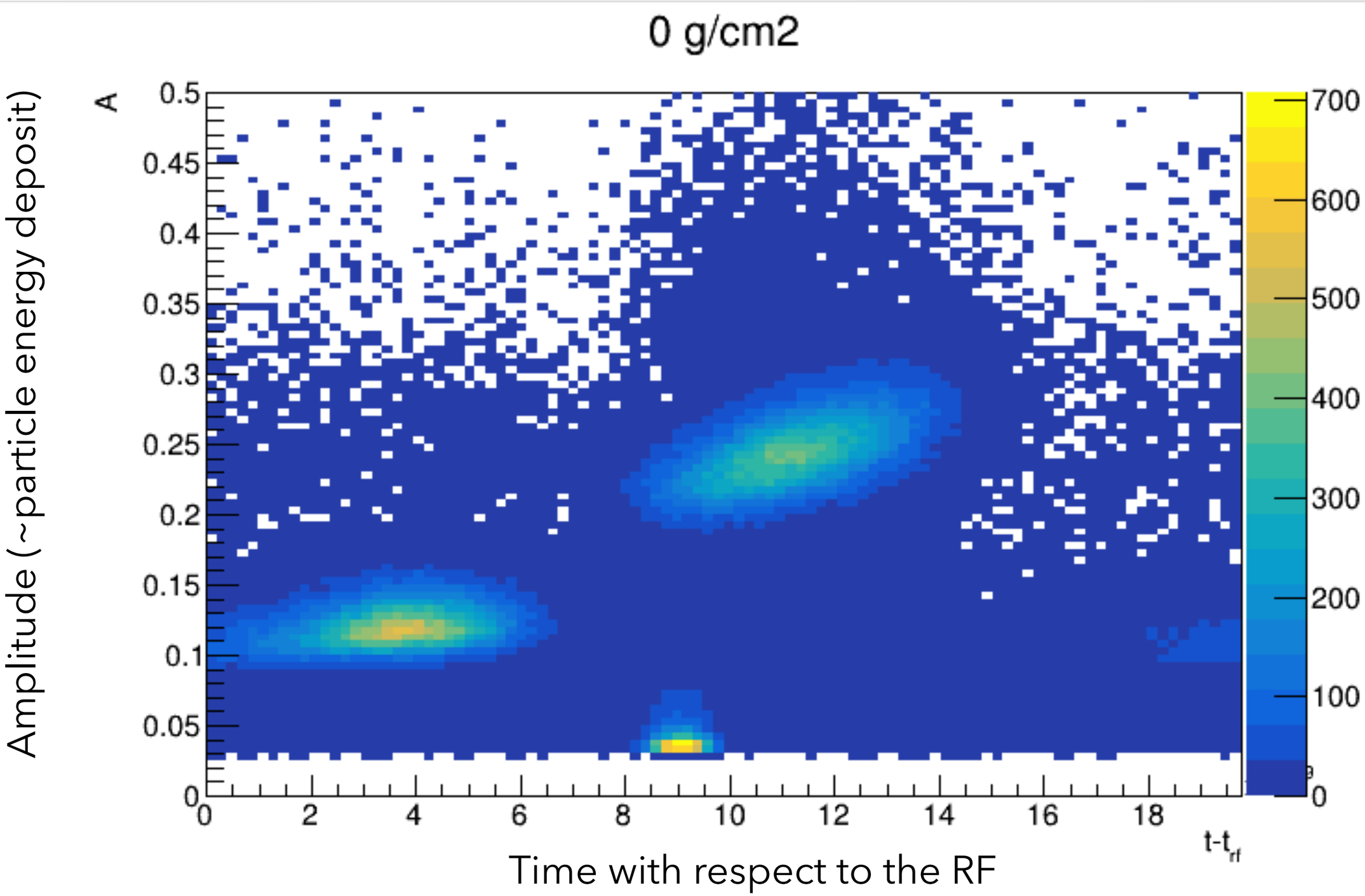
## Degraders



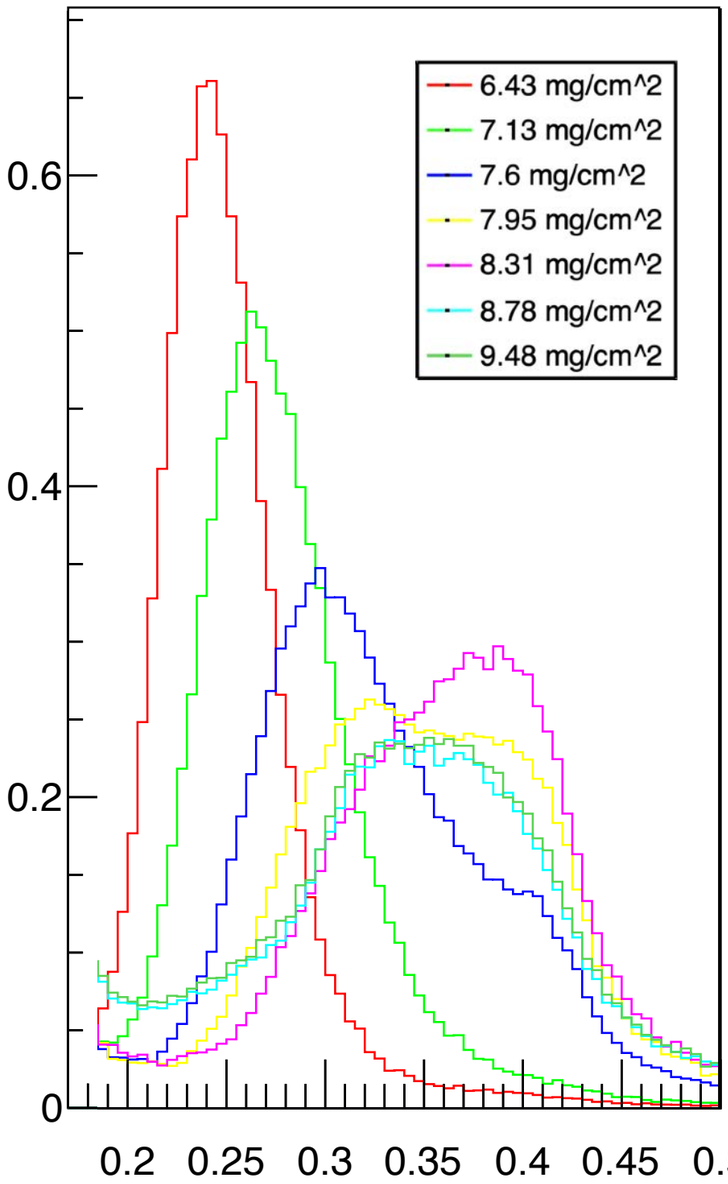



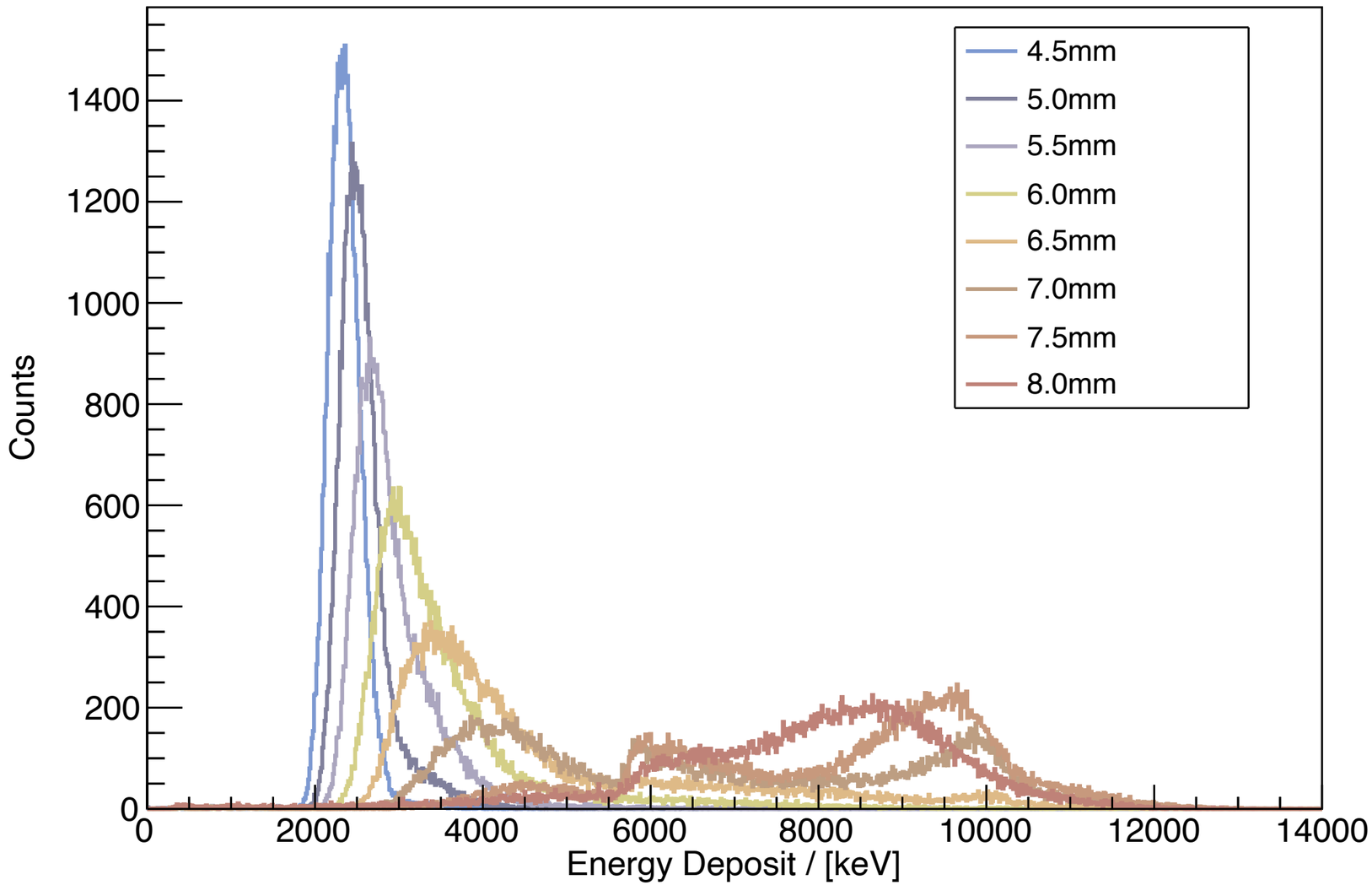


# Bouncing over the Bragg peak

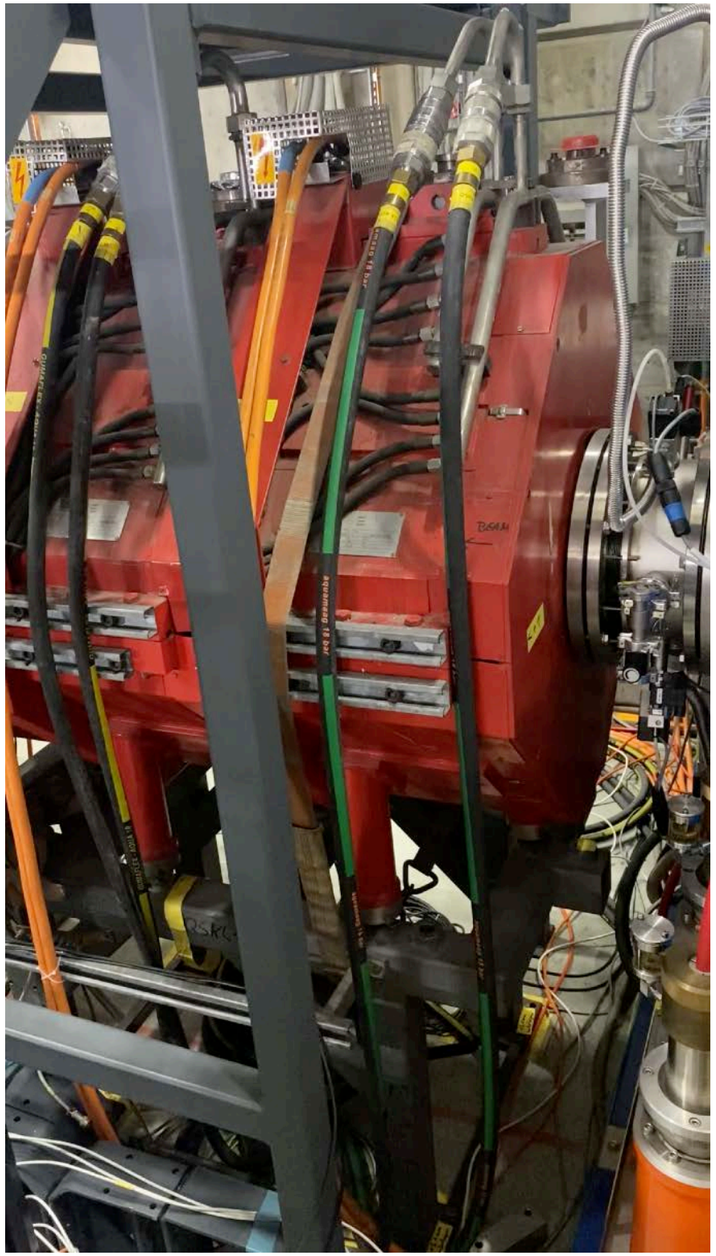


# Range Scans


6.43 mg/cm^2
7.13 mg/cm^2
7.6 mg/cm^2
7.95 mg/cm^2
8.31 mg/cm^2
8.78 mg/cm^2
9.48 mg/cm^2
0.6
0.4
0.2
0
0.2
0.25
0.3
0.35
0.4
0.45
0.5

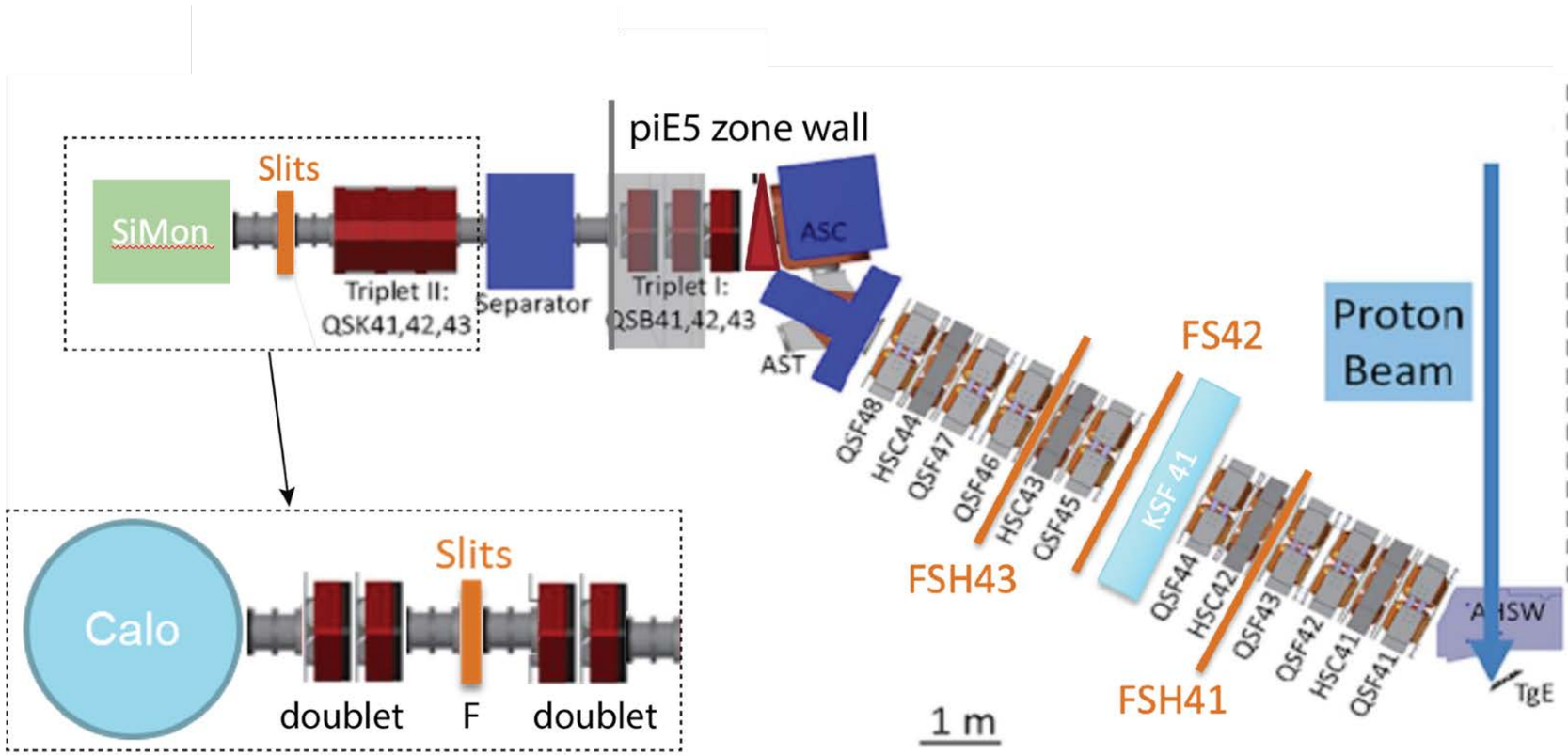

4.5mm
5.0mm
5.5mm
6.0mm
6.5mm
7.0mm
7.5mm
8.0mm
Counts
1400
1200
1000
800
600
400
200
0
0
2000
4000
6000
8000
10000
12000
14000
Energy Deposit / [keV]

# Questions?



How magnets applaud

How to understand it and how
to continue?
(see Peter Kammel's talk)



# Beam profilers at piE5

- We used p = 85 MeV/c, a balance between the rate and correct TOF in terms for background
- With the momentum slit fully opened (**8%**) and no separation, a pion rate of $R_\pi = 1.38 \cdot 10^8$ Hz **and a beam content of** 79% e−, 18% π−, 3% μ− was estimated from measurements
- With spin rotator +/- 275 kV, $R_\pi = 3.5 \cdot 10^7$, a ~ 45 mrad separation of the pion and electron beam (~ 33 mm physical separation at the target position). Electrons to pions: 0.2.
- 5x5x3 mm^3 pill counter (beam profiler) movable in X-Y direction

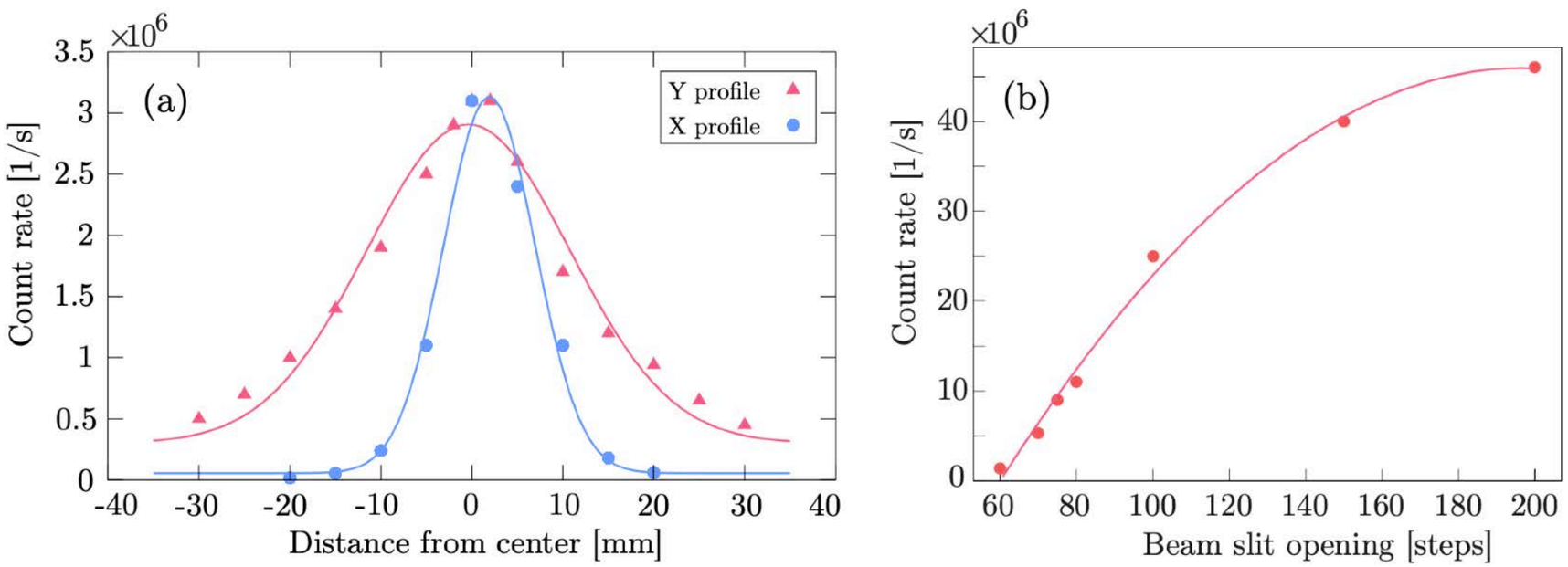



Figure 4.20: (a) Beam profile measured ∼30 cm upstream of the target position with the small volume $5 \times 5 \times 3$ mm remotely controlled movable counter. (b) Count rate in function of the beam slit opening (in steps of the motor of the slit)