μ^- beams and beam development at PSI

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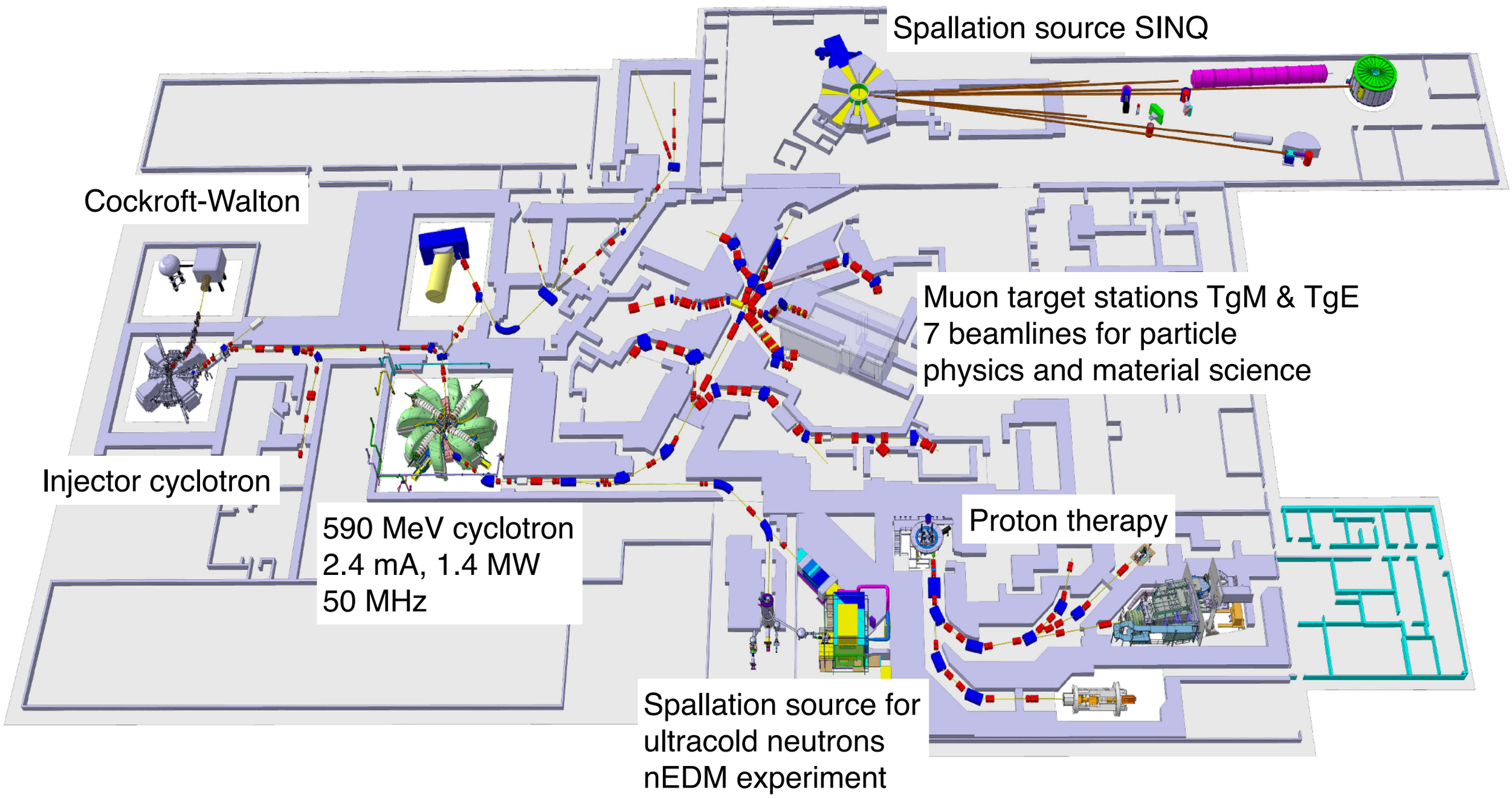
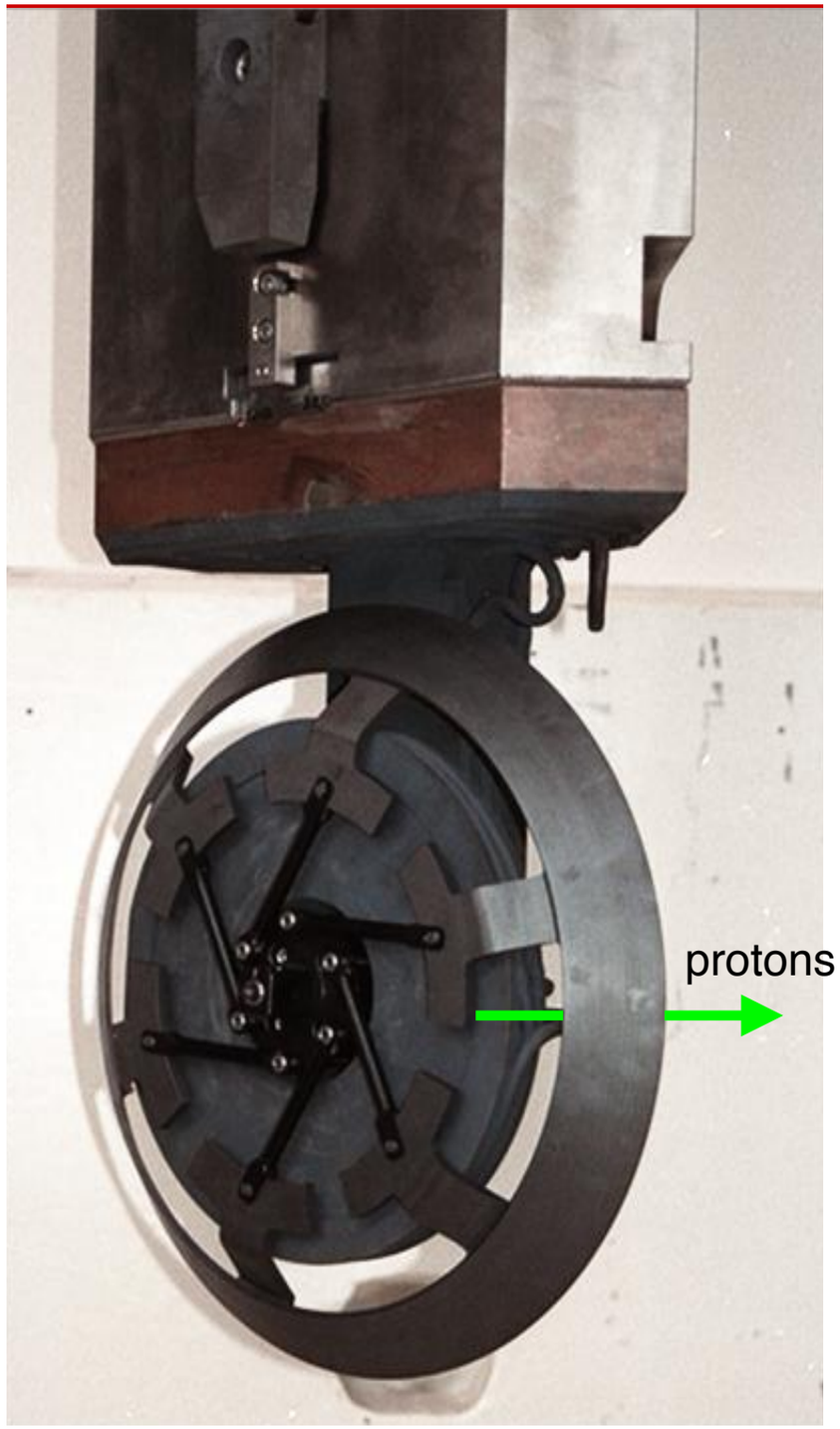
PSI Proton Accelerator HIPA

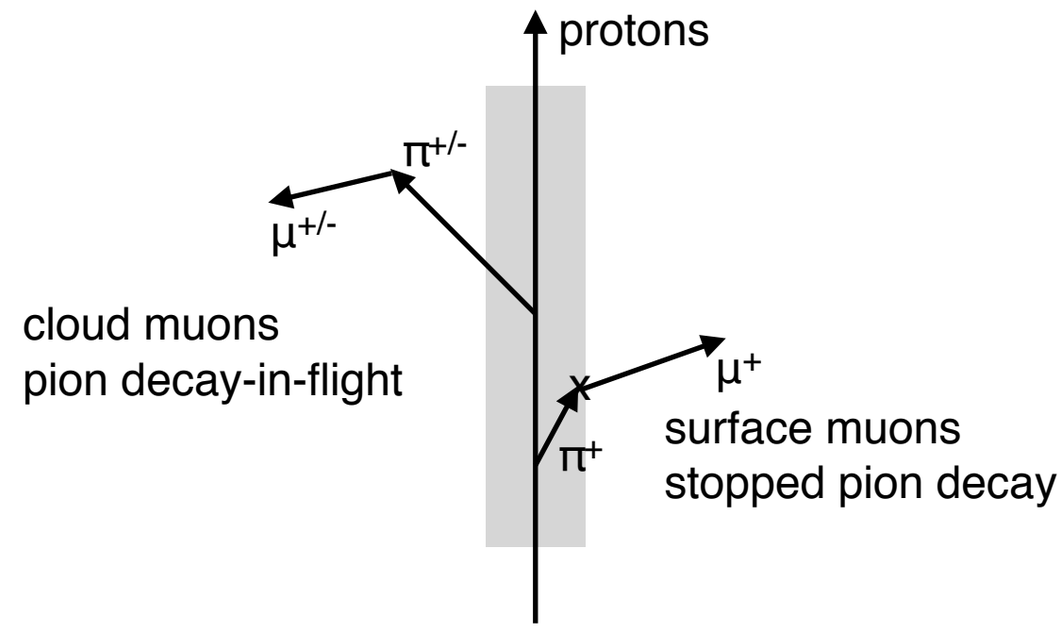


Muon Production Target TgE

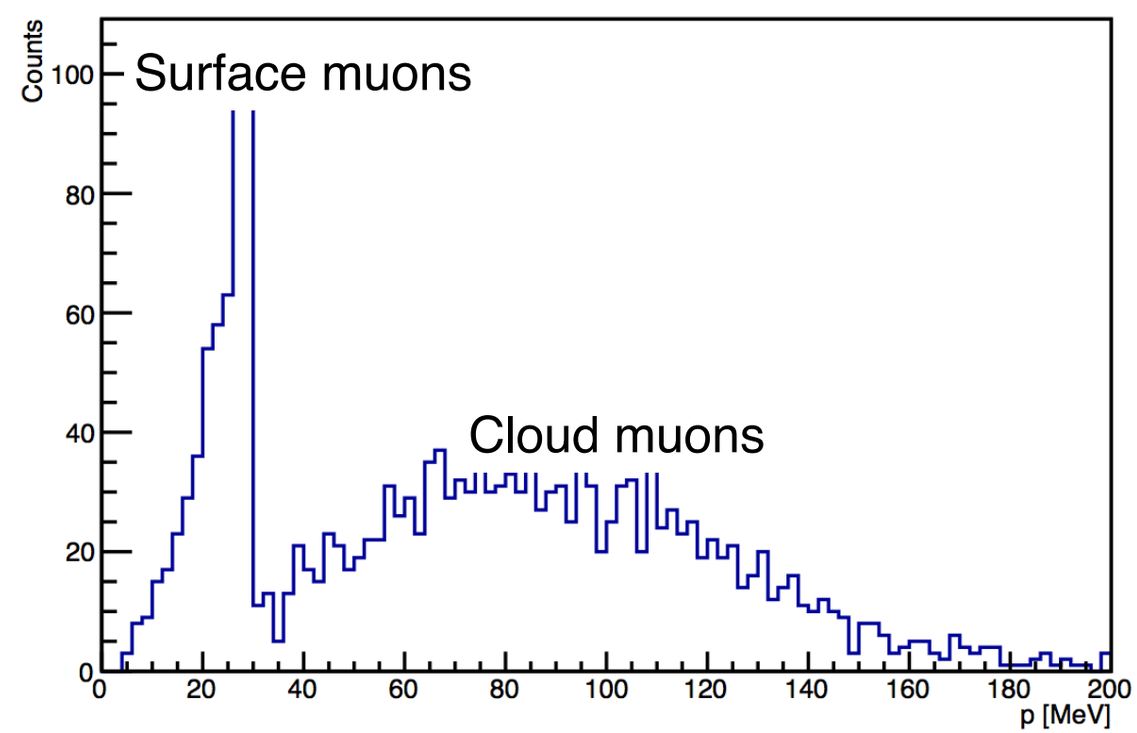
- 40 mm polycrystalline graphite
- ~40 kW power deposition
- Temperature 1700 K
- Radiation cooled @ 1 turn/s
- Beam loss 12% (+18% from scattering)



Surface and cloud muons



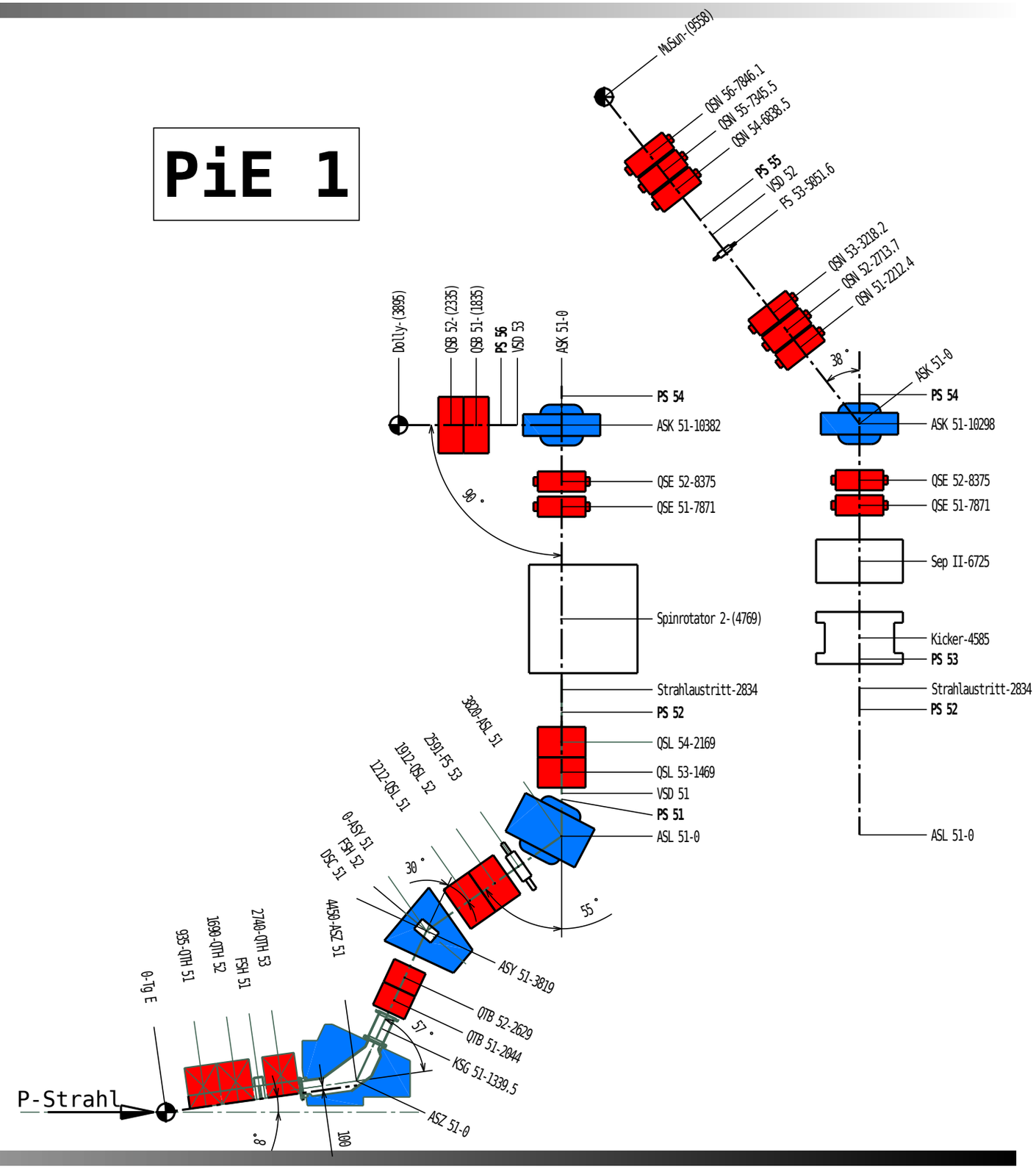
- Low-energy muon beam lines typically tuned to surface-μ^+ at ~ 28 MeV/c
- Contribution from cloud muons at similar momentum about 100x smaller
- Negative muons only available as cloud muons
- Time structure of cyclotron smeared out by pion lifetime → DC muon beams



Existing low-energy μ^- beams at PSI

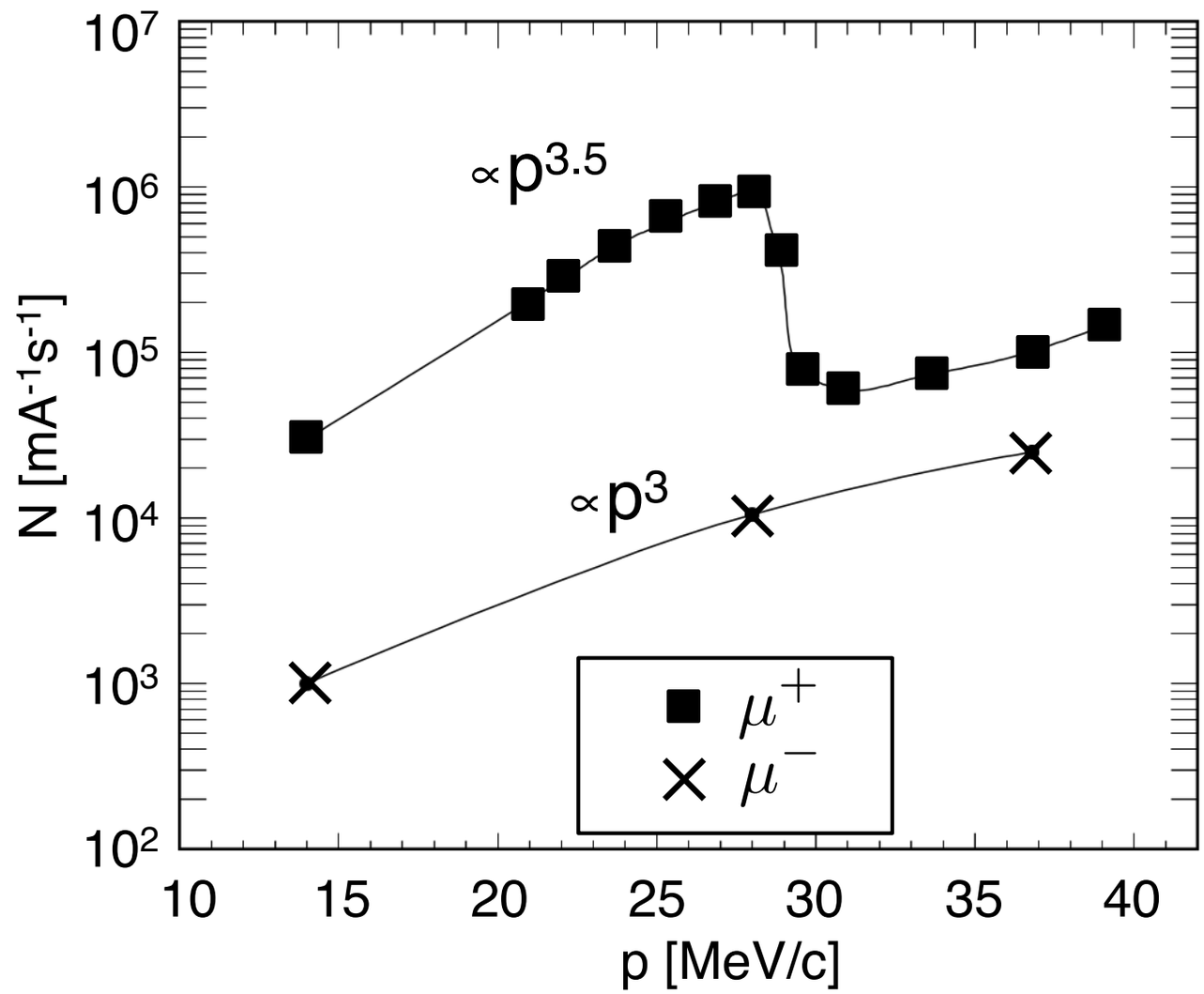
πE 1

- Medium-rate, high-precision beam line
- Shared between μSR and particle physics
- Home of MuSun experiment



πE1

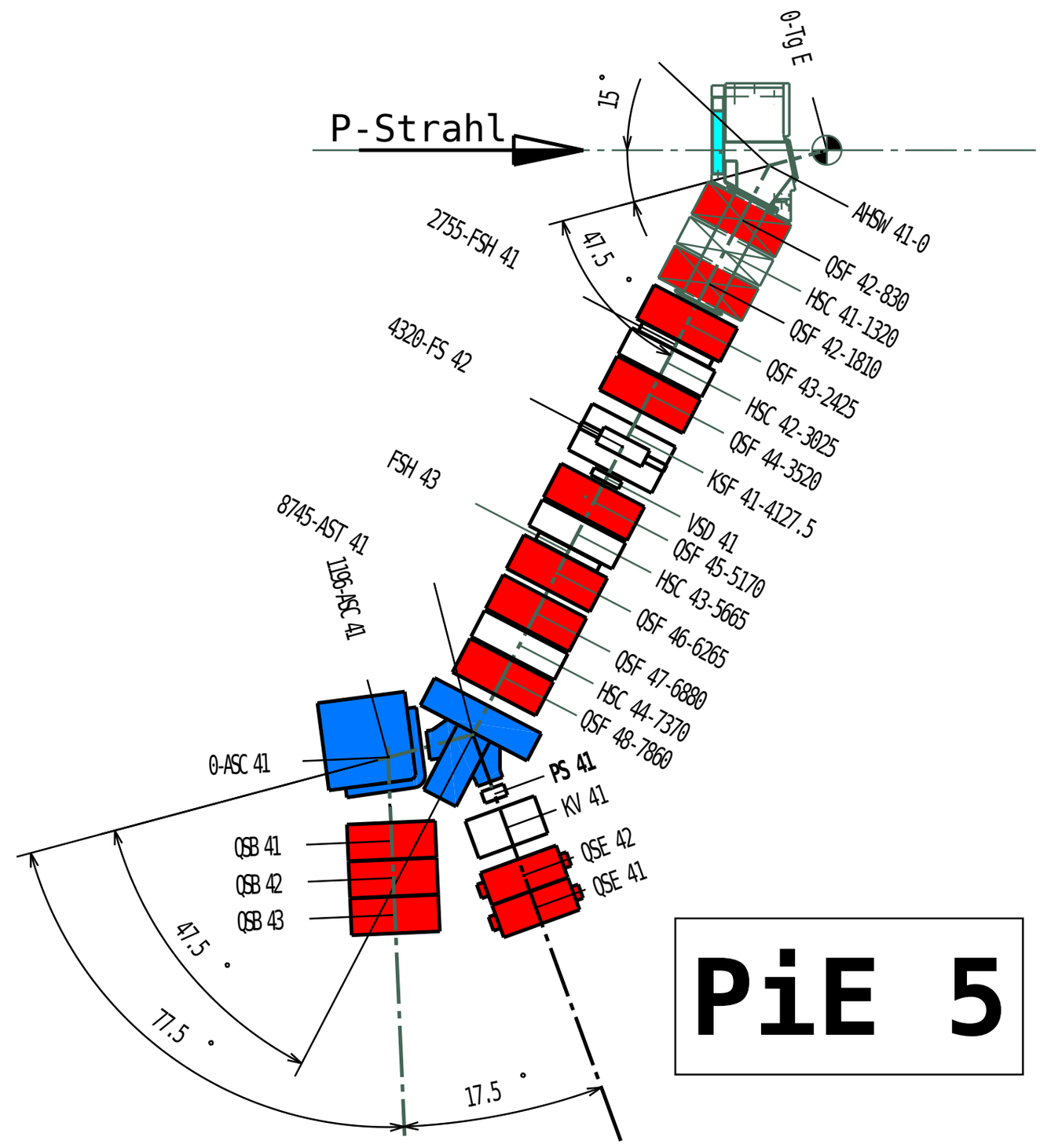
- Measured beam rates for low-energy muons
- Not stated explicitly, but probably for around 2% momentum bite
- $\sigma_{x,y}$ ~8 mm at final focus



⇨ ~ 20 kHz @ 28 MeV/c and 2 mA

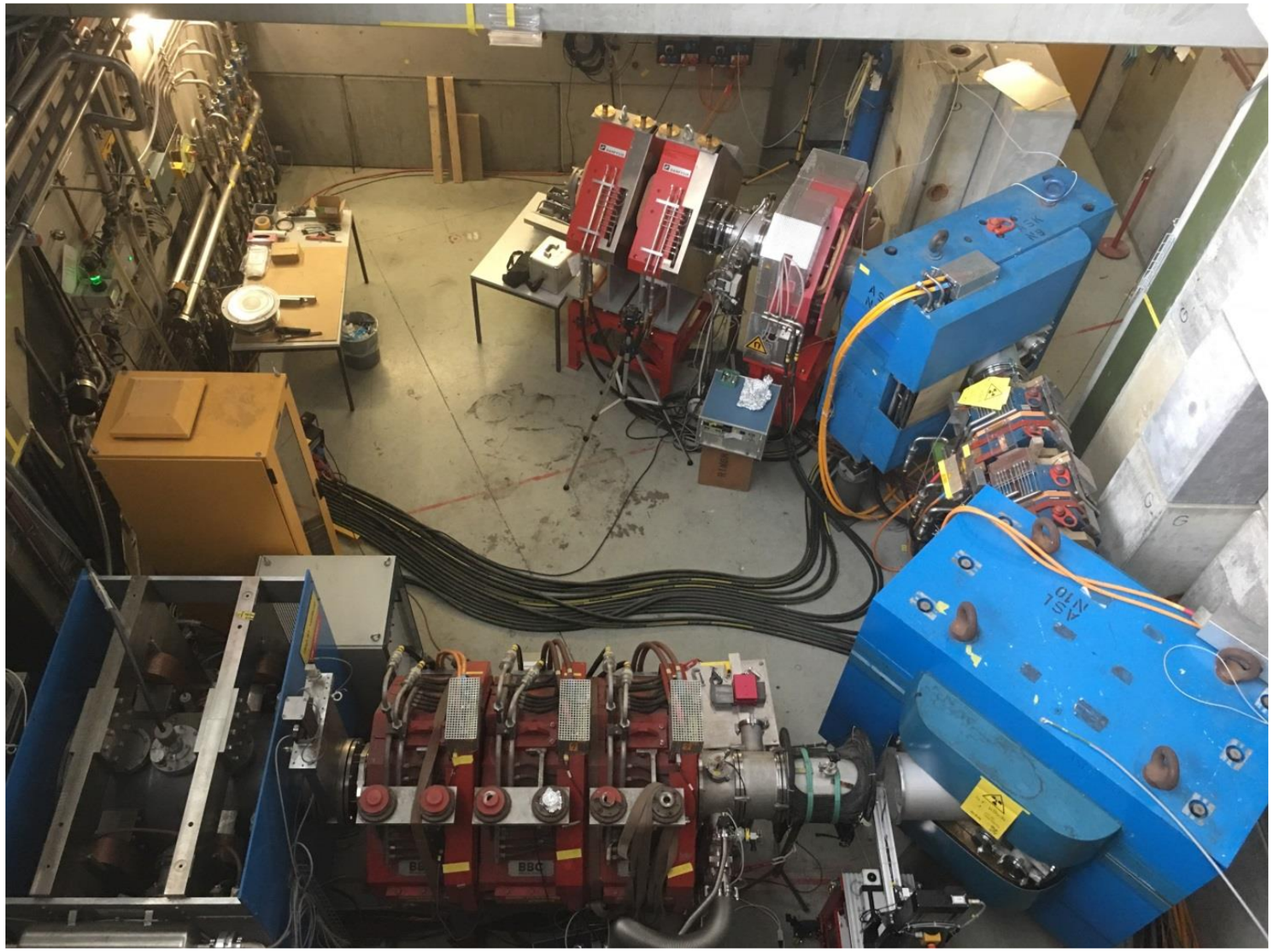
πE5

- High-rate, low-precision beam line
- Particle physics only
- Home of MEG II, Mu3e



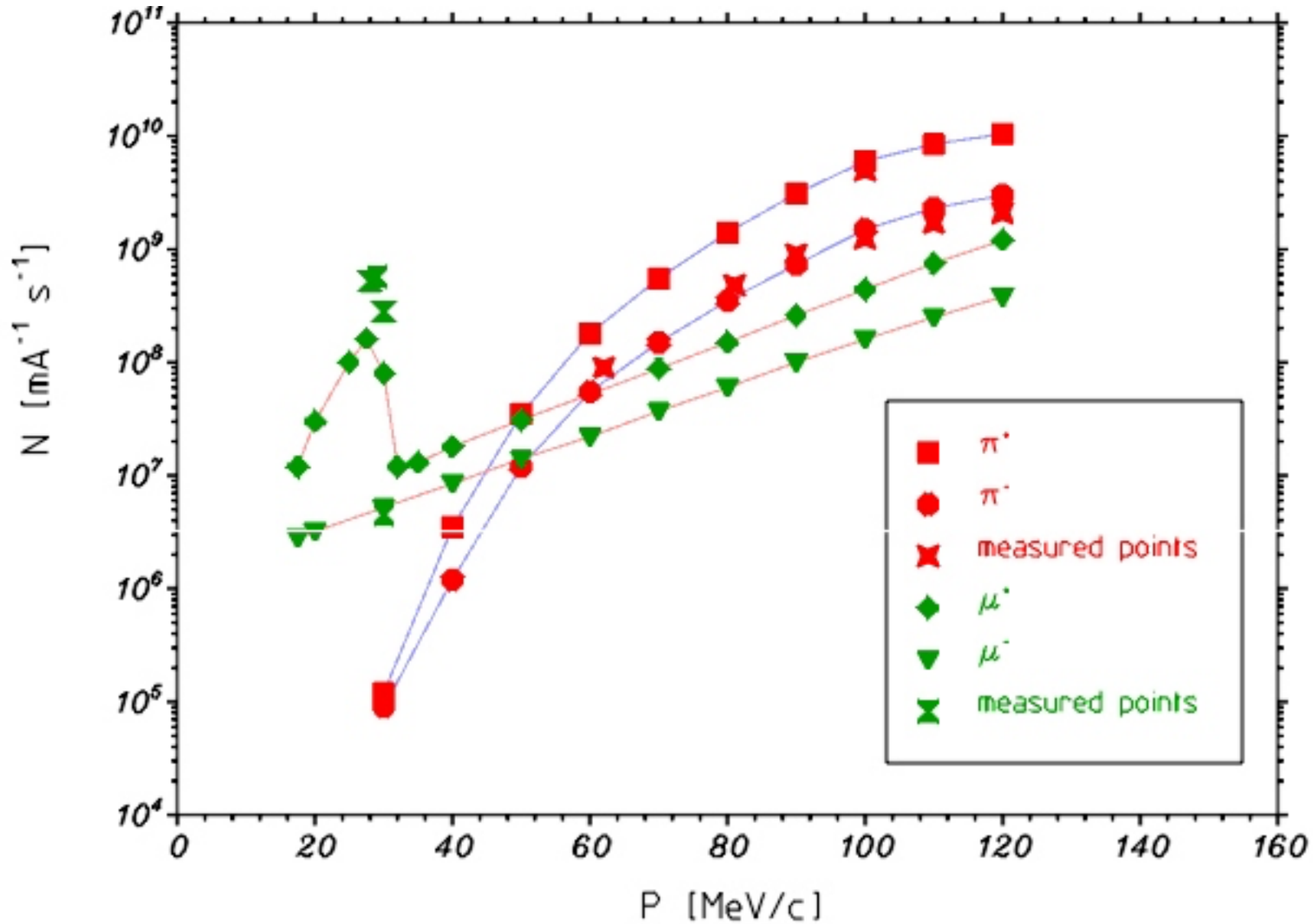
CMBL

- Compact muon beam line developed for Mu3e
- Severe space constraints
- Positioning of experiment and beam layout would need to be carefully studied



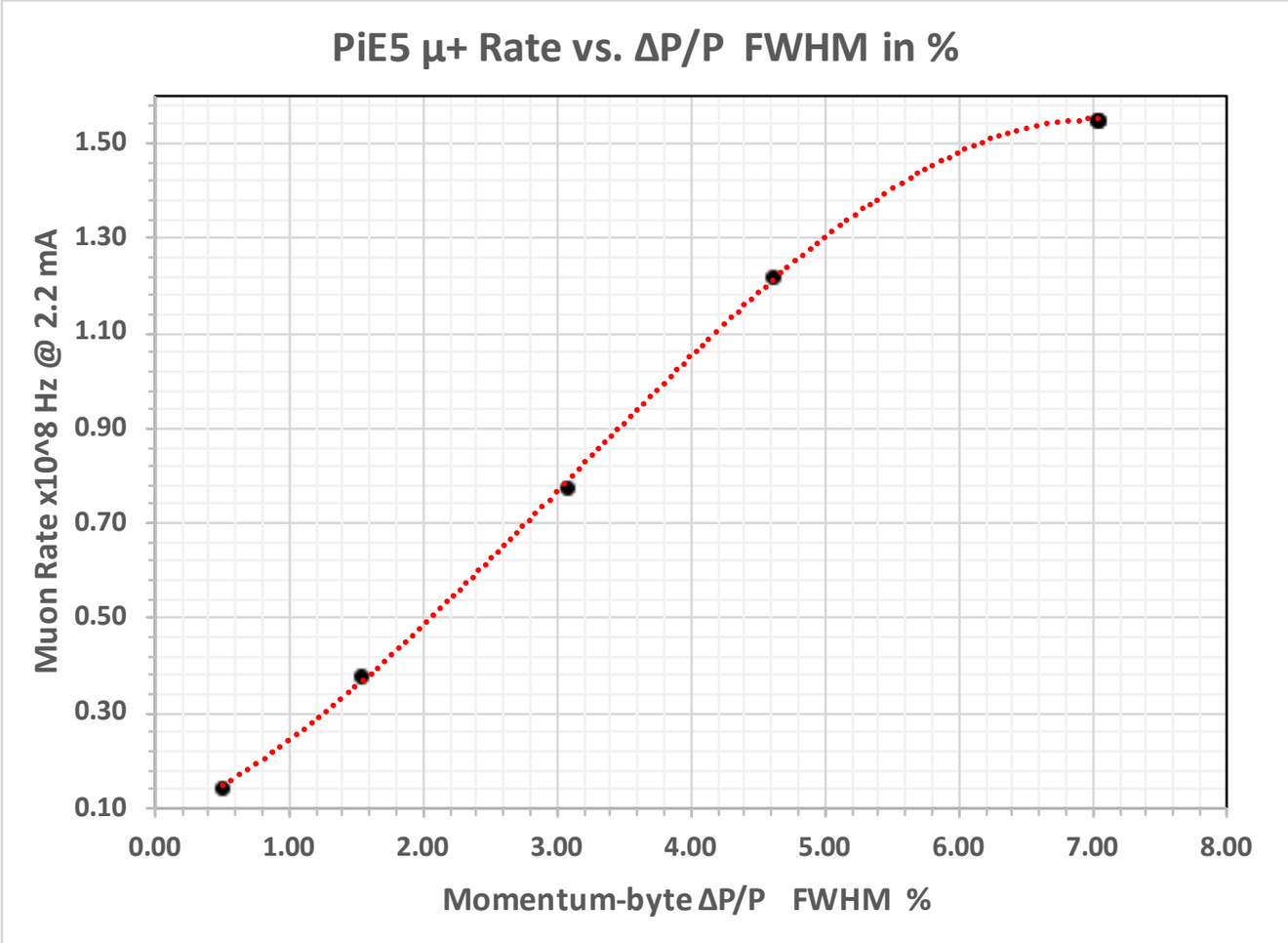
πE5

- Old measured rates to be taken with a grain of salt → were never reproduced in recent times
- Expect around 10^6 μ^-/s at 30 MeV/c and 8% momentum bite
- $\sigma_{x,y}$ ~15 mm at collimator
- Scaling as p^3 with momentum and roughly linear in momentum bite



From P.-R. Kettle's Logbook

- μ^- rate measurements at the centre of MEG magnet



- Cloud μ^--scans performed at COBRA centre with P_{beam} = -28 MeV/c (Log 17/70-73)

Slits 75: $R_\mu = 1.33 \cdot 10^5\ \mu^-\ s^{-1}$ at 2mA

Slits 105: $R_\mu = 3.9 \cdot 10^5\ \mu^-\ s^{-1}$ at 2mA

- (1)

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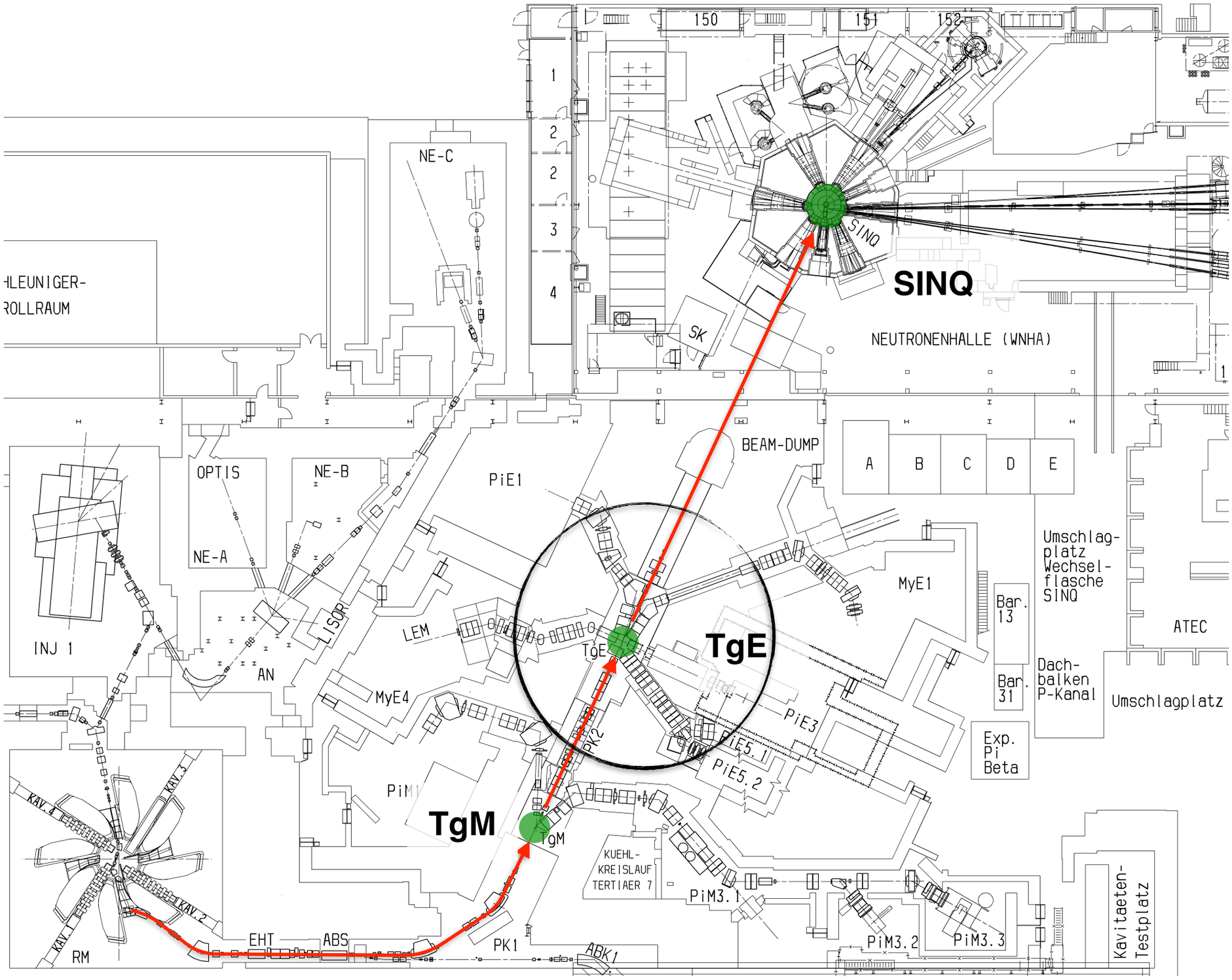
Beam developments at PSI

Floorplan PSI



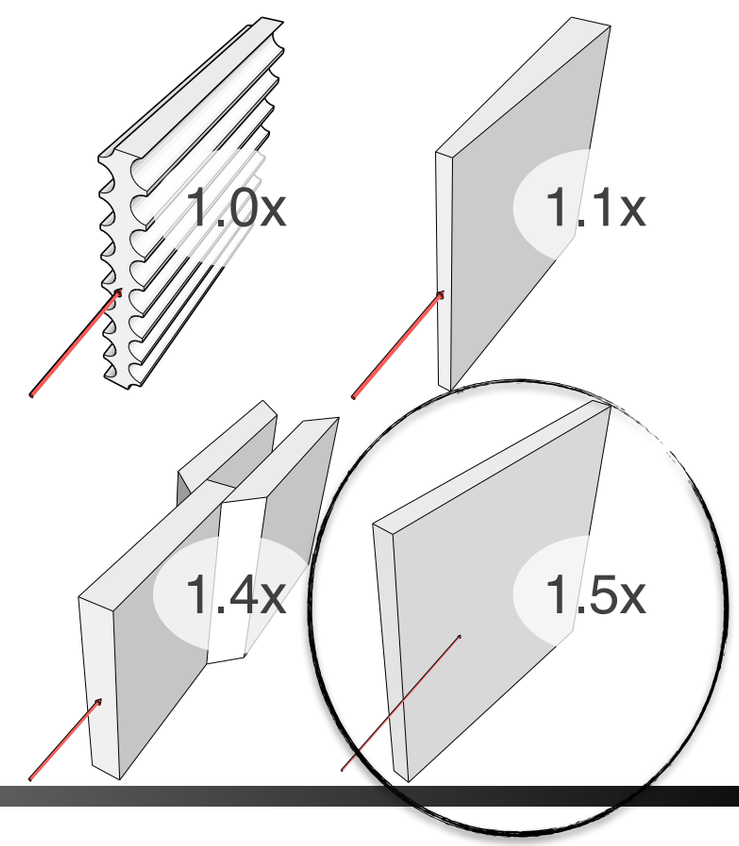
Performance of Standard Targets

- Realized that standard targets are as efficient in generating 28 MeV/c surface muons as spallation targets

Surface muon rates in μ^+/s for TgE geometry of different lengths

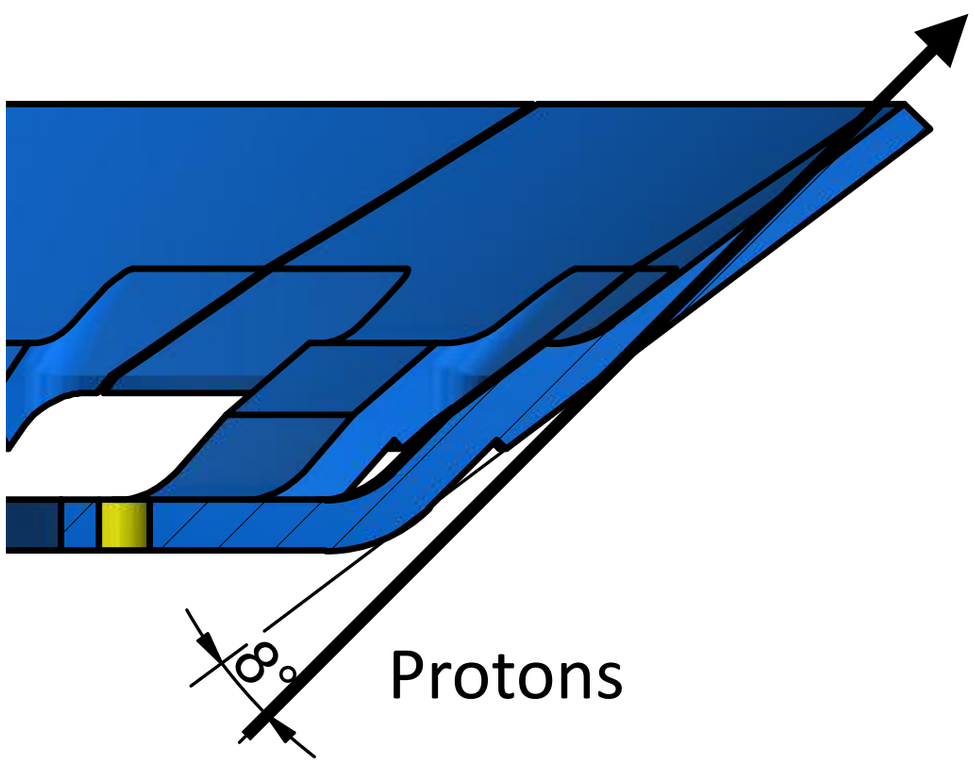
Length	Upstream	Downstream	Side
10	1.4×10^{10}	9.0×10^{9}	1.8×10^{10}
20	1.6×10^{10}	1.2×10^{10}	5.1×10^{10}
30	1.9×10^{10}	1.1×10^{10}	8.5×10^{10}
40	1.8×10^{10}	1.1×10^{10}	1.2×10^{11}
60	1.8×10^{10}	1.2×10^{10}	2.1×10^{11}

- After extensive target simulations: Slanted targets are even better!



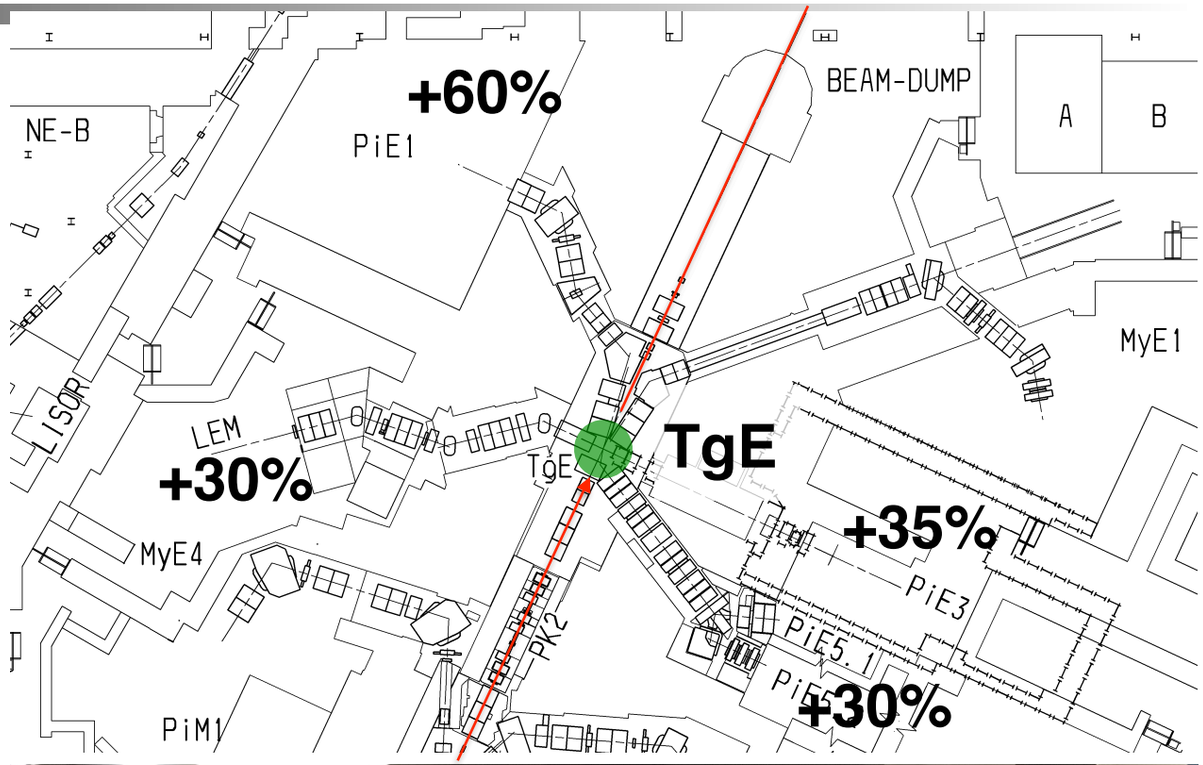
Test of HiMB Slanted Target

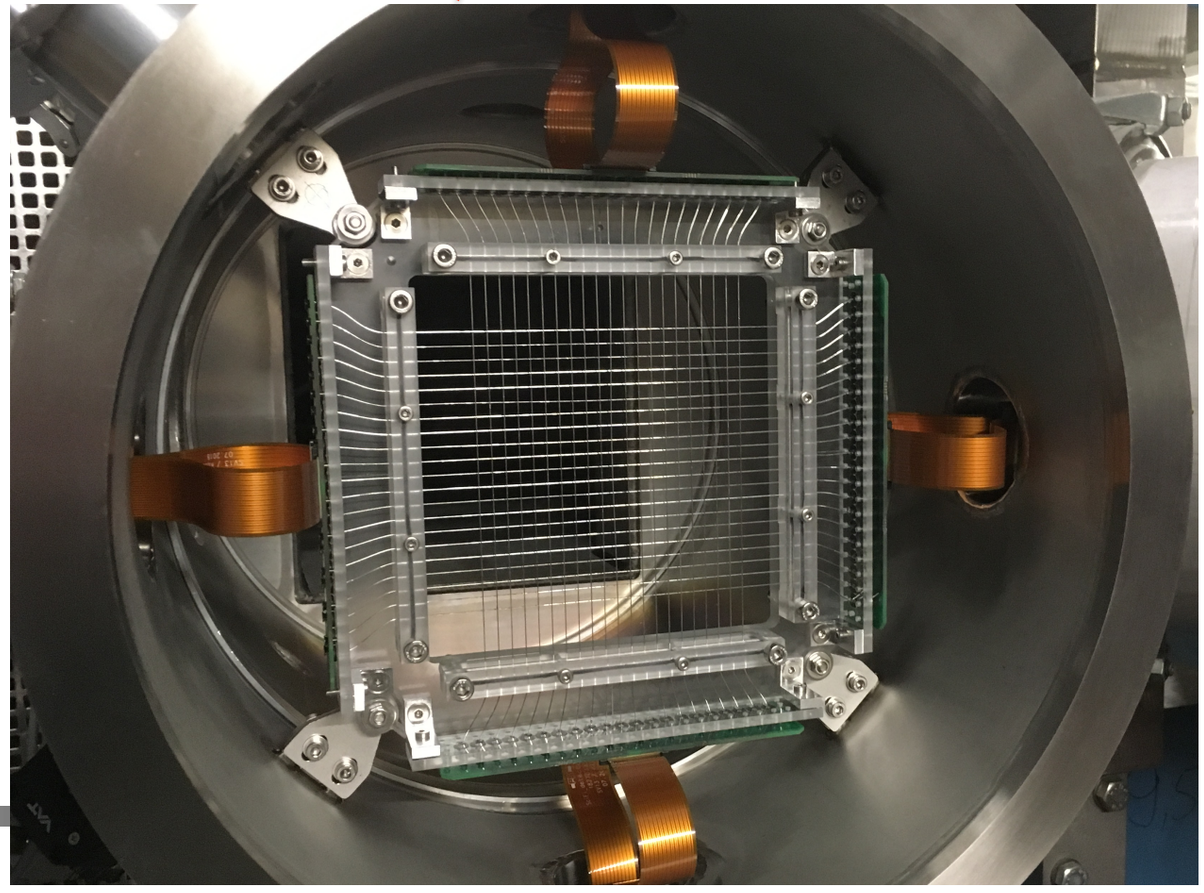
- Test of slanted target at TgE station
- To be installed in week 48 (Nov. 25th) for the remainder of the accelerator period
- Mechanical and thermal simulations completed and no show-stopper found



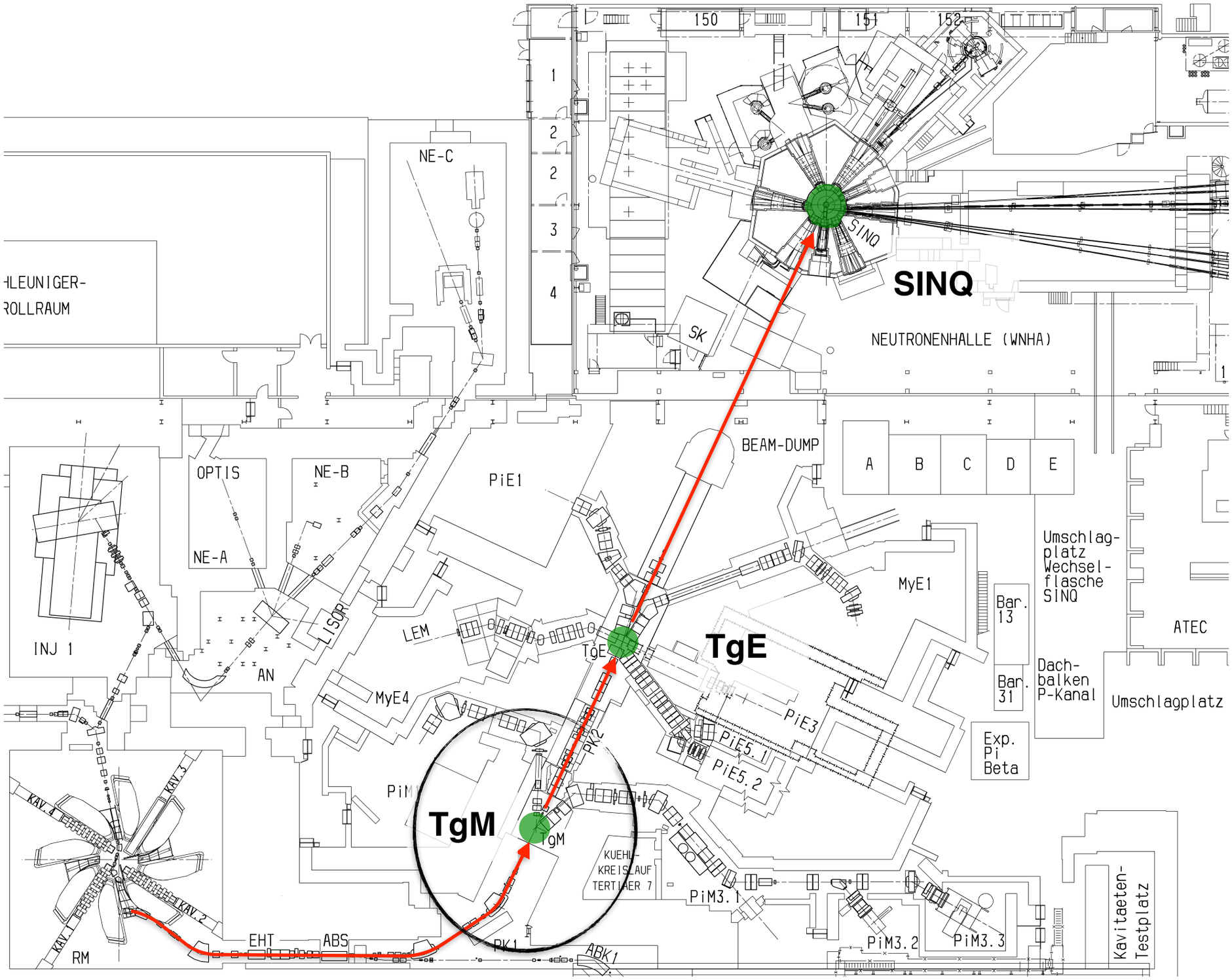
Test of HiMB Slanted Target

- 30-60% gain in surface muons expected
- Pions and cloud muons unaffected → no gain for μ^-
- Verification of expected beam intensities and profiles
- Measurements to be made in vacuum with new scintillating fibre based beam monitor and existing pill-scintillator scanning system

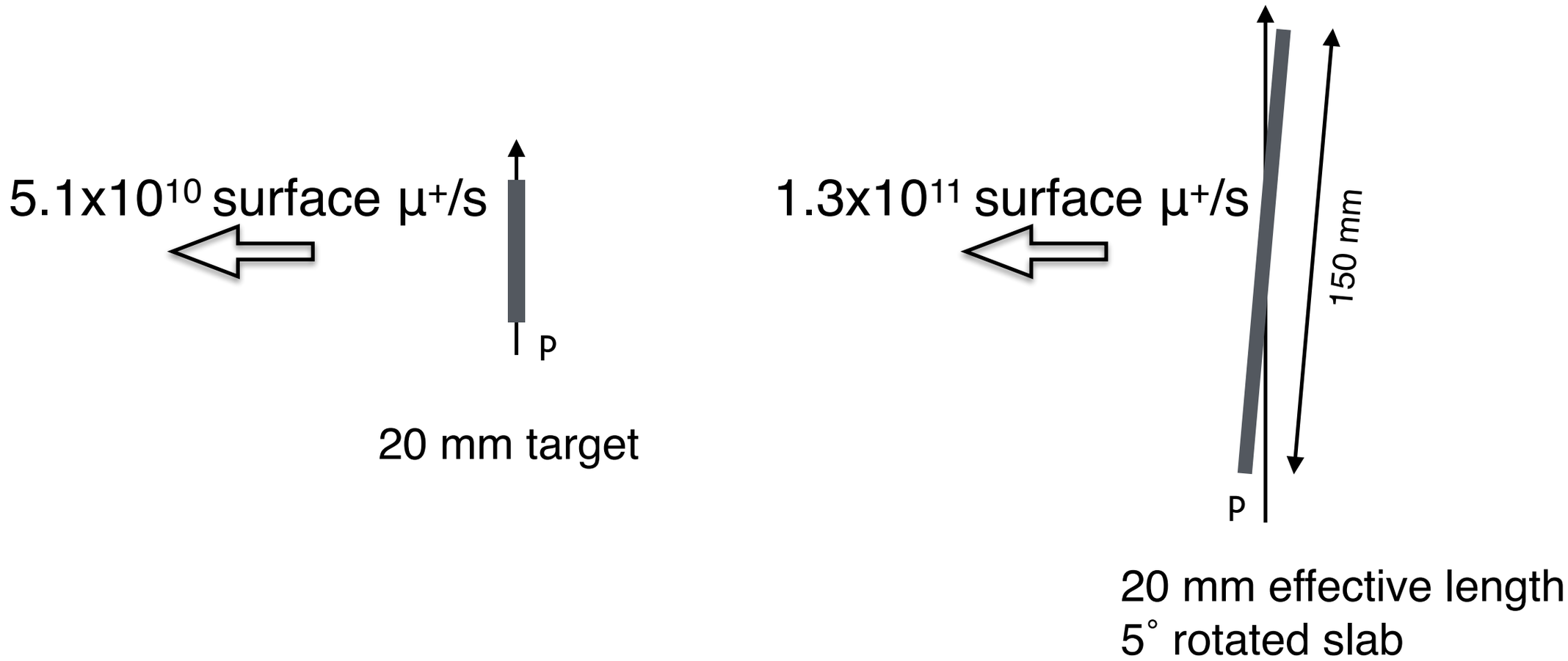




Floorplan PSI

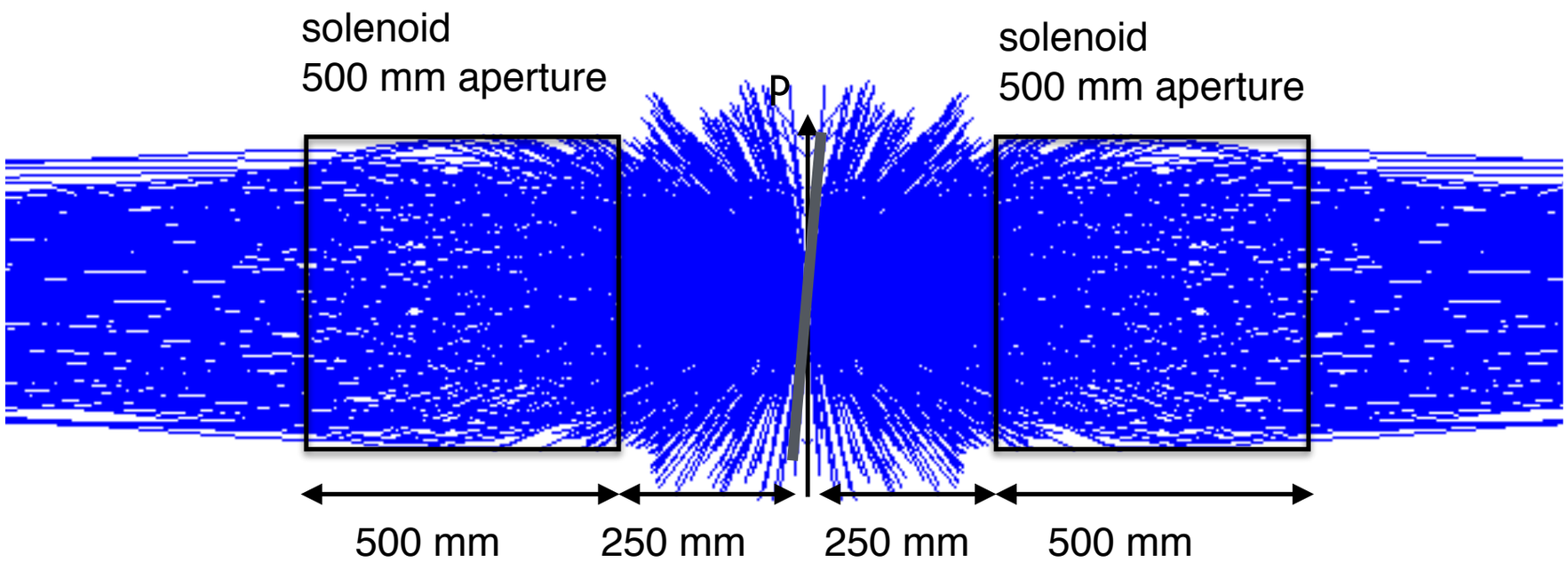


Target Geometry for new TgM*



- Change current 5 mm TgM for 20 mm TgM*
- 20 mm rotated slab target as efficient as Target E

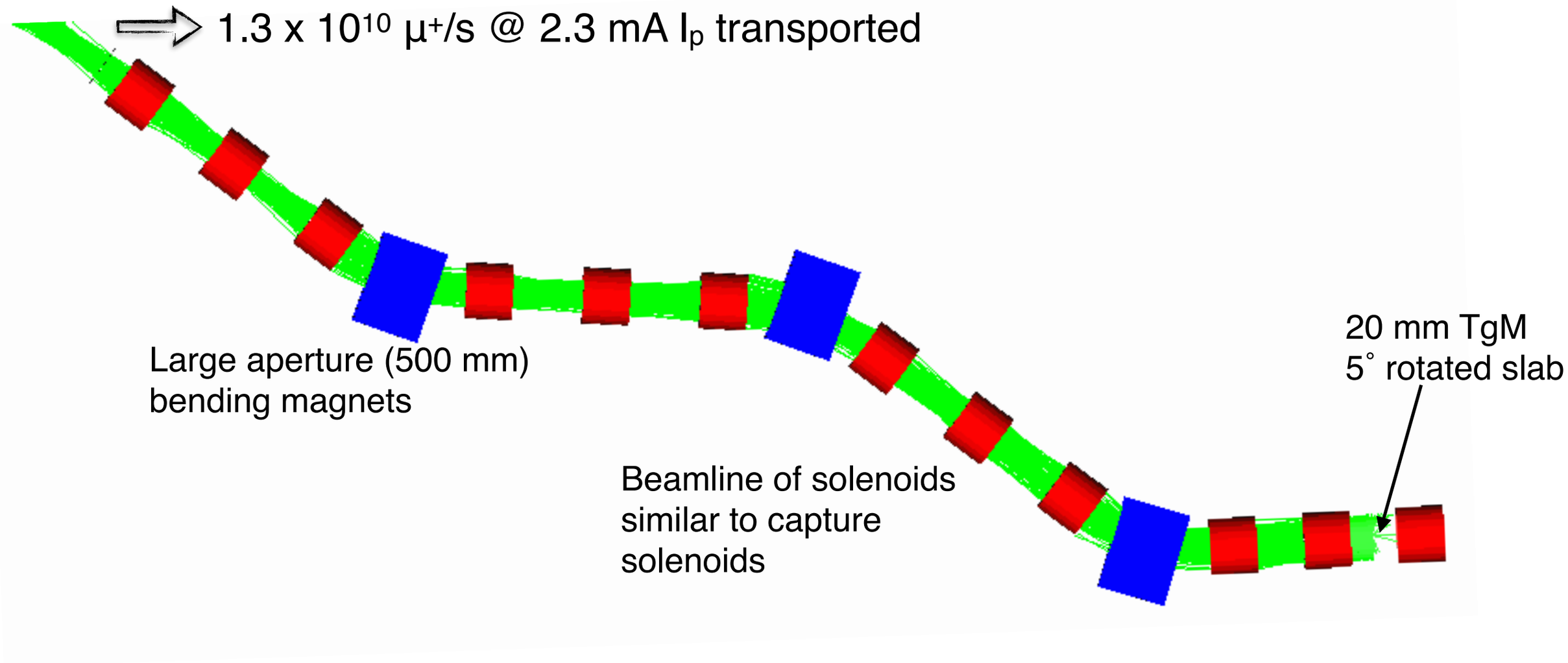
Split Capture Solenoids



- Two normal-conducting, radiation-hard solenoids close to target to capture surface muons

- Central field of solenoids ~0.35 T
- Field at target ~0.1 T

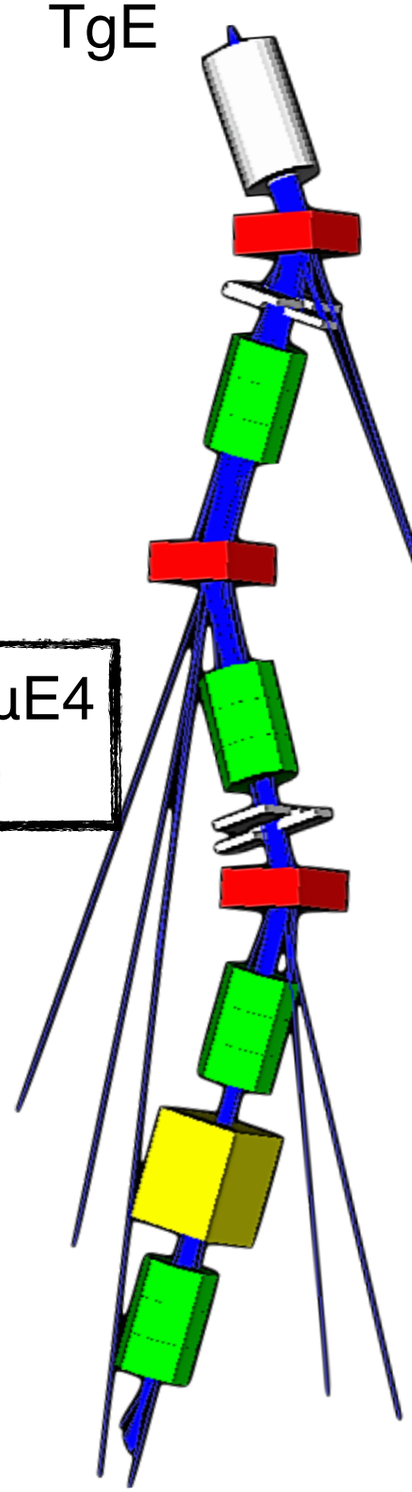
Solenoid Beamline: HiMB@EH



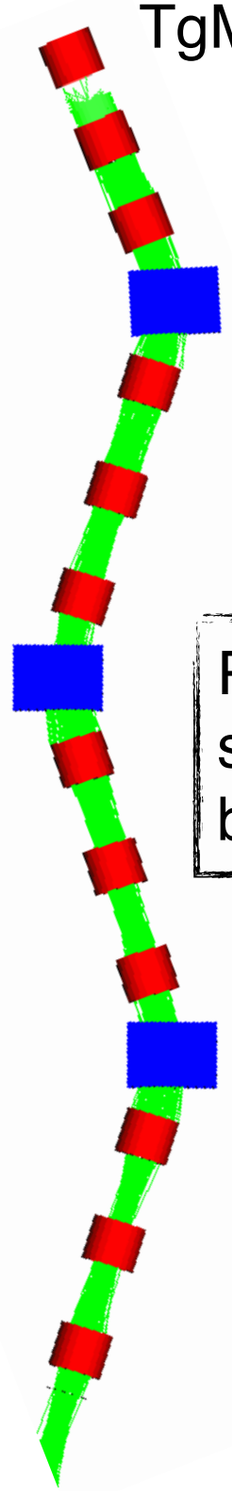
- First version of beam optics showing that large number of muons can be transported.
- Almost parallel beam, no focus, no separator, …
- Final beam optics under development

Solenoid Beamline: HiMB@EH

TgE		Source		TgM*
	1.2×10^{11} μ^+/s		1.3×10^{11} μ^+/s	
	7.2×10^{9} μ^+/s C ~ 6%	Capture	3.4×10^{10} μ^+/s C ~ 26%	
	5×10^{8} μ^+/s T ~ 7% Total ~ 0.4%	Transmission	1.3×10^{10} μ^+/s T ~ 40% Total ~ 10%	



Existing μE4 beamline



Proposed solenoid beamline

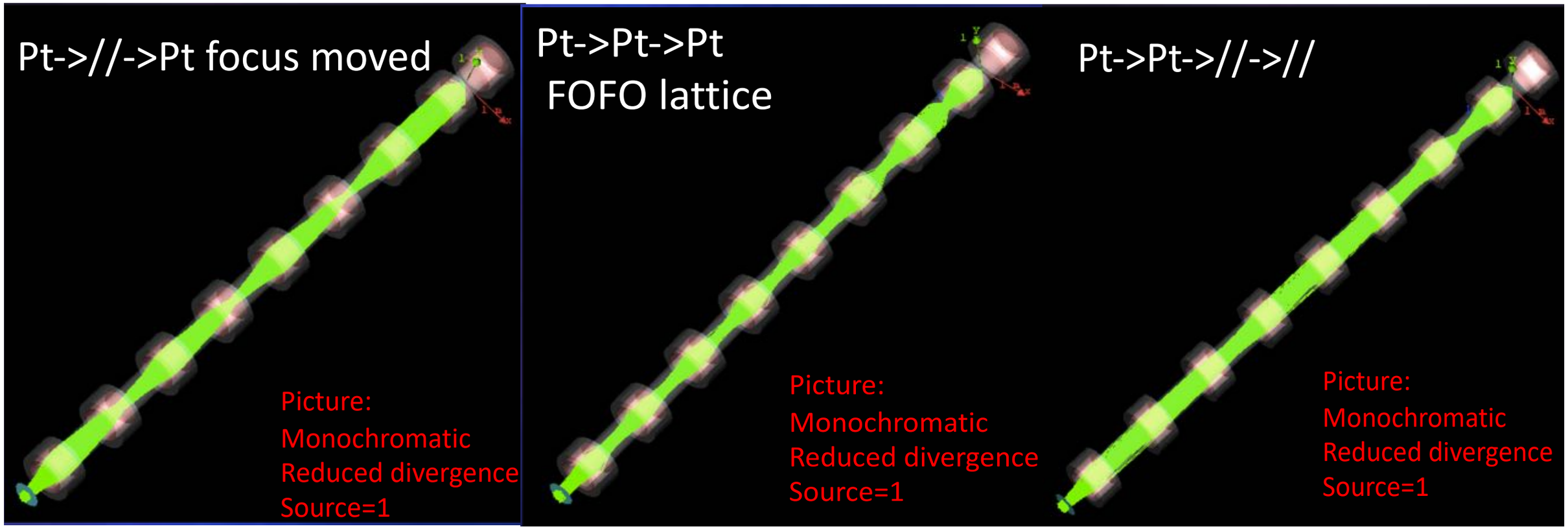
Gain due to high capture and transmission efficiency

Expect around 5×10^{7} μ^-/s at 28 MeV/c

Conclusions

- PSI the only place where an upgraded MuCap experiment could take place
- Potential for increased muon rates available. Suitability of πE5 will need to be carefully studied.
- HiMB project:
  Exciting prospects both for μ^+ and μ^- for experiments needing low-energy muons at ultra-high intensities

Beam optics development



- Trying different versions of beam transport optics
- Similar transmissions to simple optics achieved
- Final focus still quite large: σ ~ 50 mm