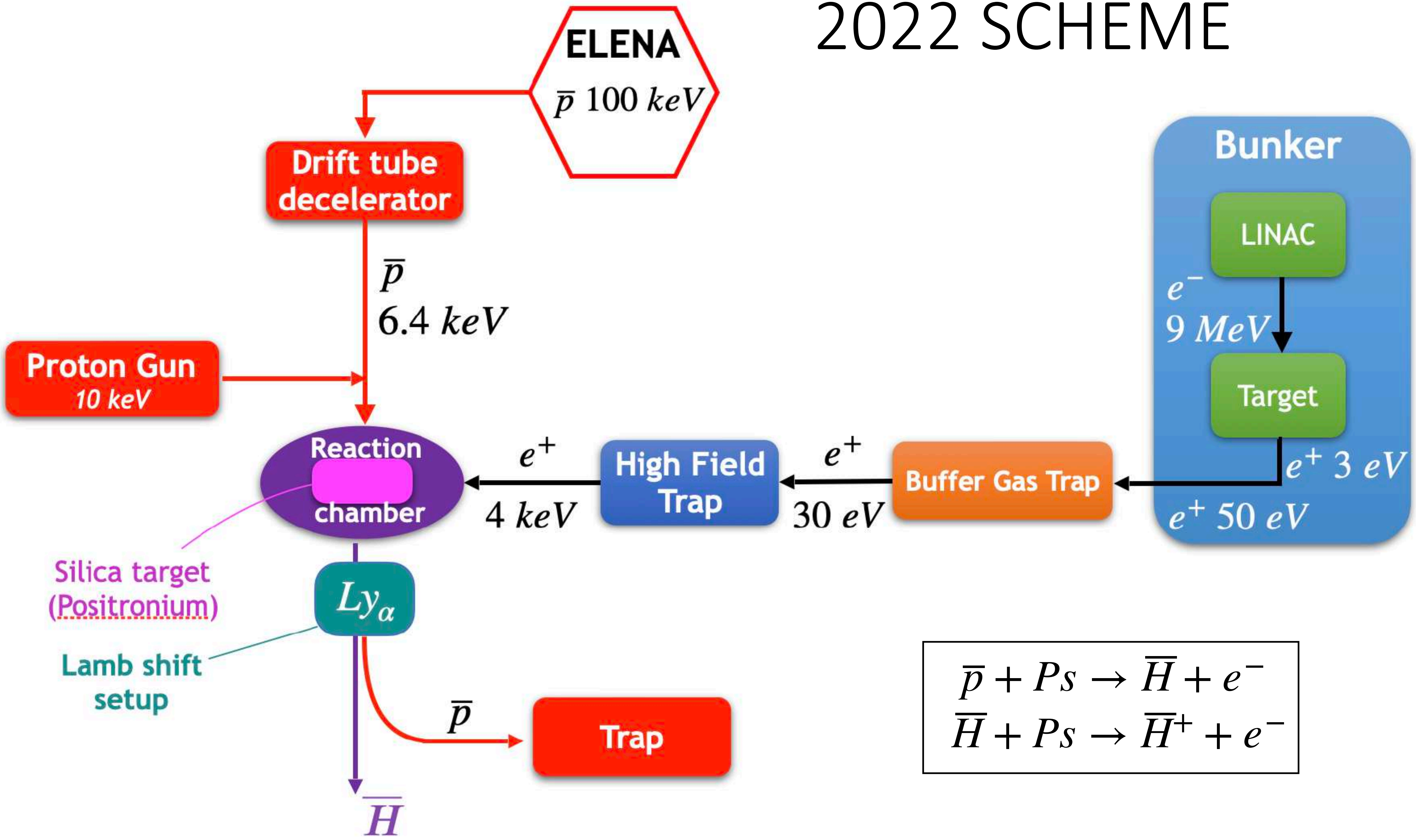
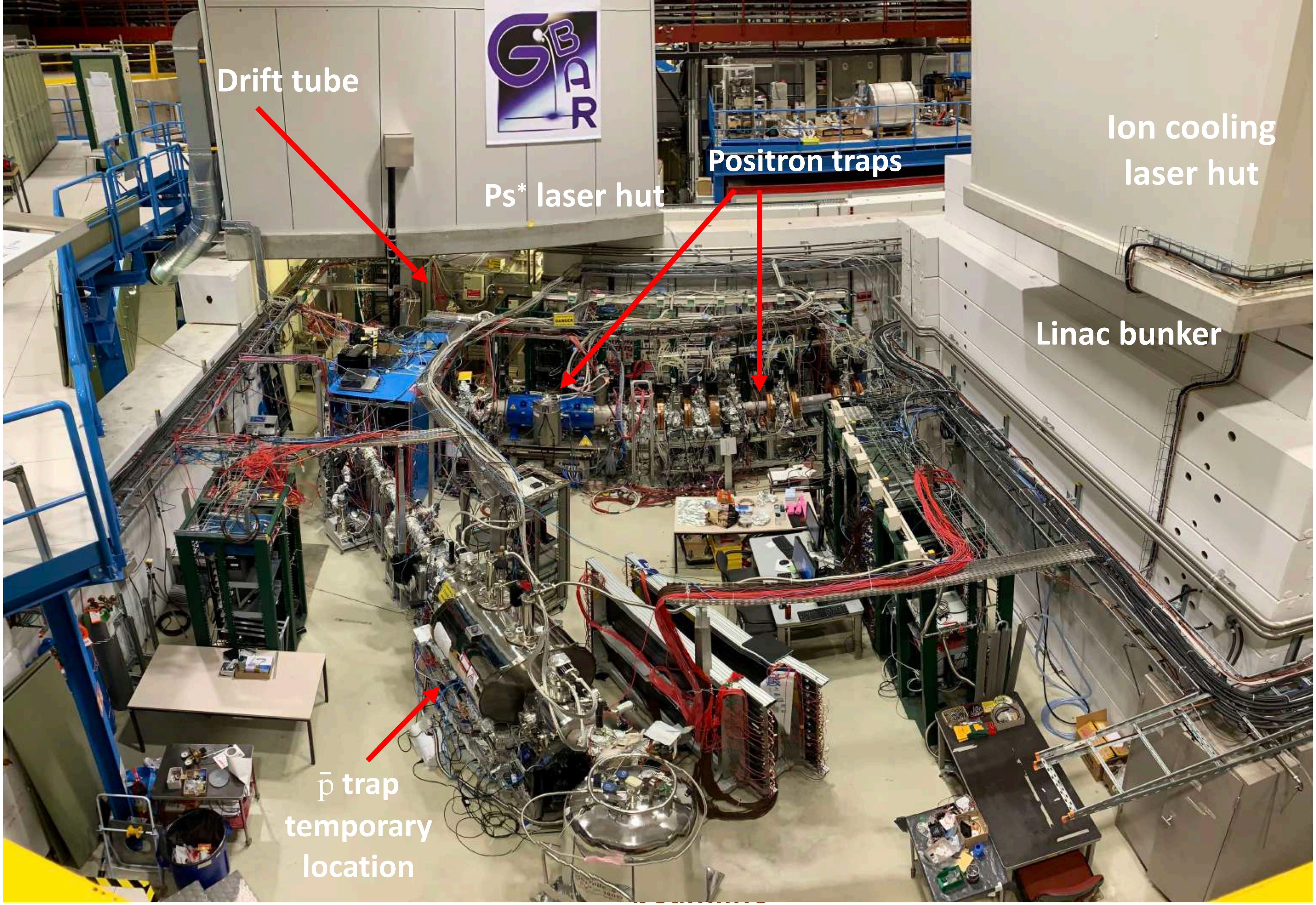
GBAR status report 2022

2022 SCHEME



$$\bar{p} + Ps \rightarrow \bar{H} + e^-$$
$$\bar{H} + Ps \rightarrow \bar{H}^+ + e^-$$


Drift tube
Ps* laser hut
Positron traps
Ion cooling laser hut
Linac bunker
$\bar{p}$ trap temporary location

Positron production

Linac accelerating cavity exchanged Feb 2022

- Higher current acceptance without RF power reflection
- Same Energy and Beam Current at lower RF level
- Lower stress for RF elements
- 7.3 MW —> 5.5 MW, can use other klystron types

Several minor problems + exchange of klystron Oct. 2022

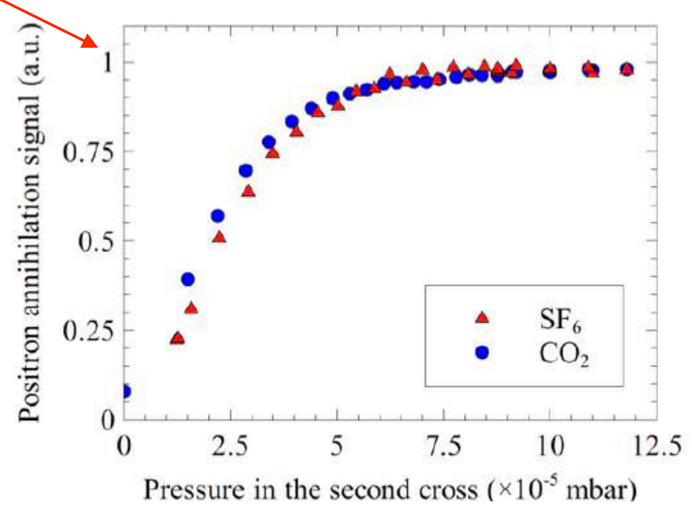
- —> > 2 months without e^+
- —> $3 \times 10^7\, e^+ / \mathrm{s}$

Expertise performed Jan. 2023 , waiting for power to condition

Replacement of BGT N_2 gas by SiC re-moderator

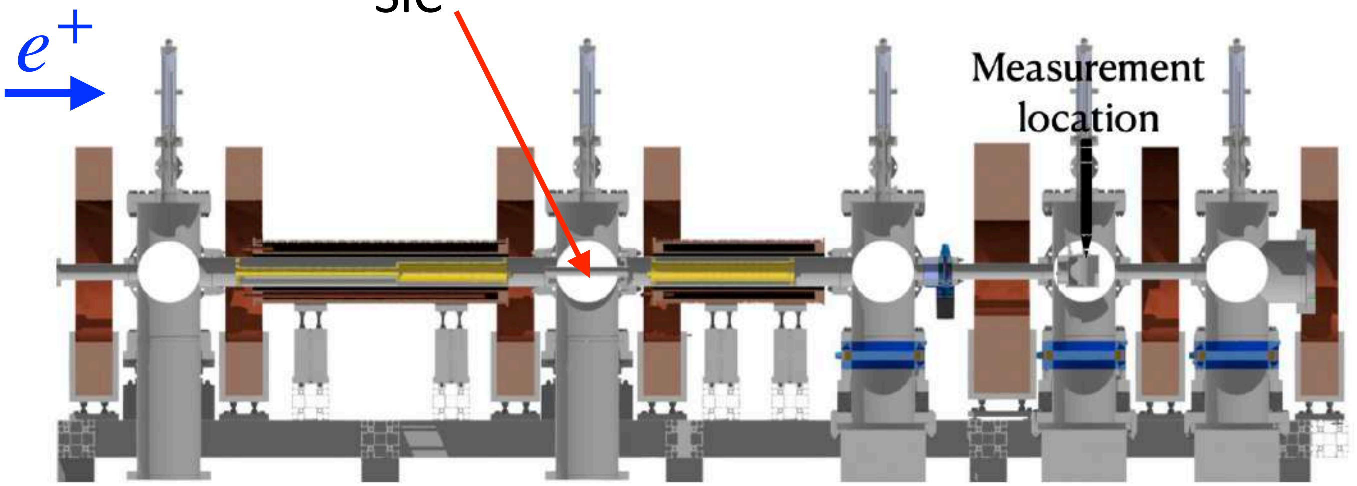
- Uses pulsed time structure of primary positron beam
- Requires bunching 2.85 μs to 700 ns
- Re-moderator efficiency: 60-70 %
- Obtained 40% trapping efficiency, i.e. gain > 3 in 2021
- 2022 magnetron orbit to transfer downstream
- 2023 implement SiC re-moderation as routine

40% trapping efficiency



A.M.M Leite et al., Journal of Physics: Conf. Series 791, 012005 (2017)

SiC



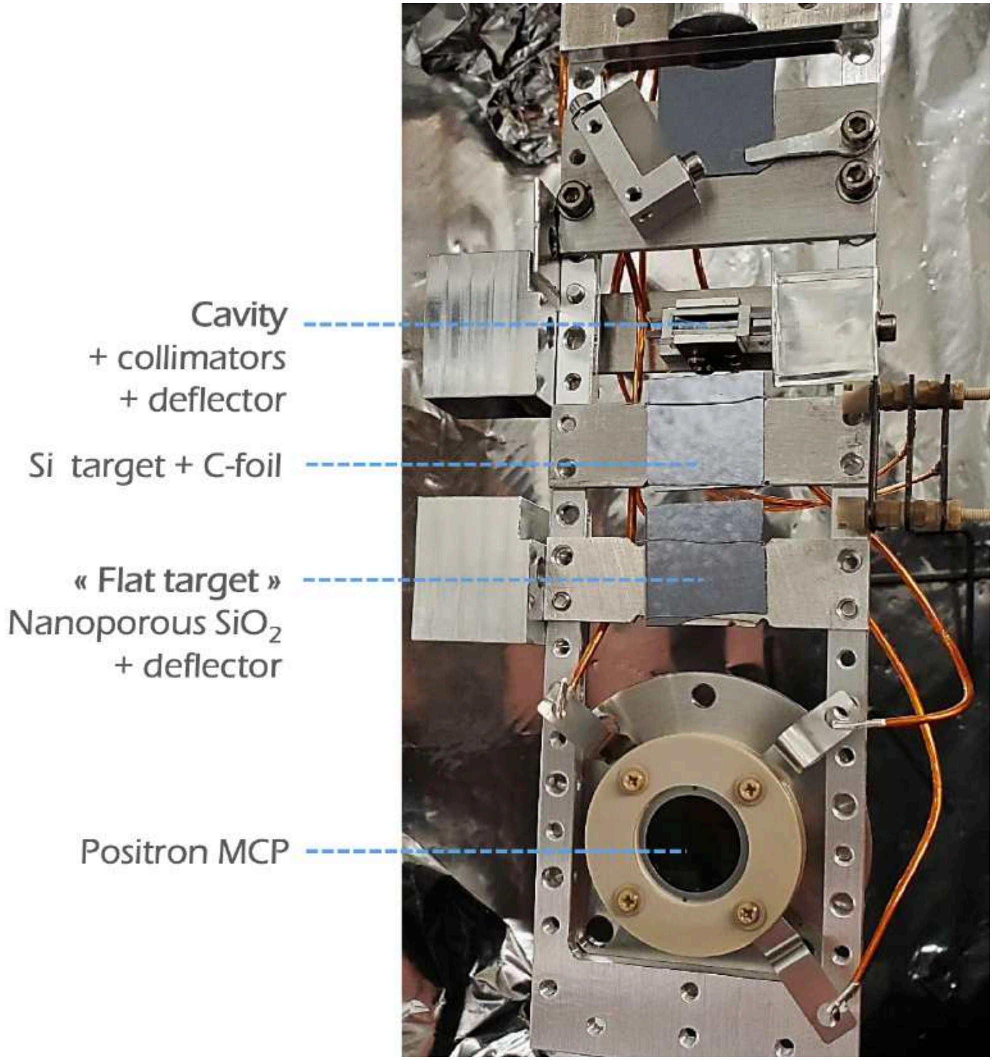
2022 routine operation of traps

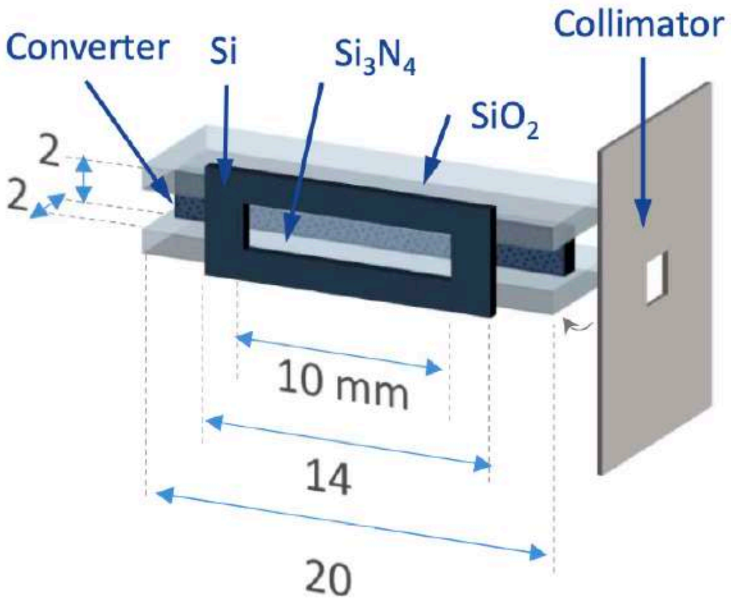
1.5×10^8 e+/ 110 s

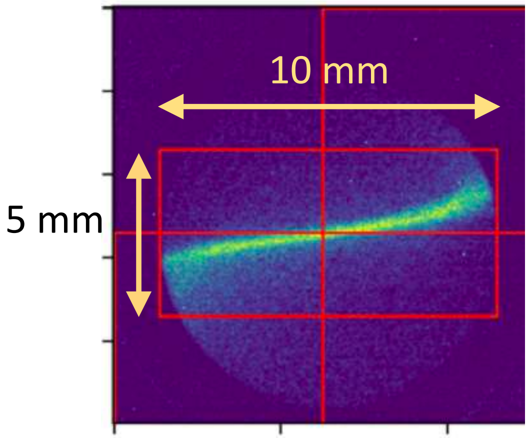
10^9 in 1000 s

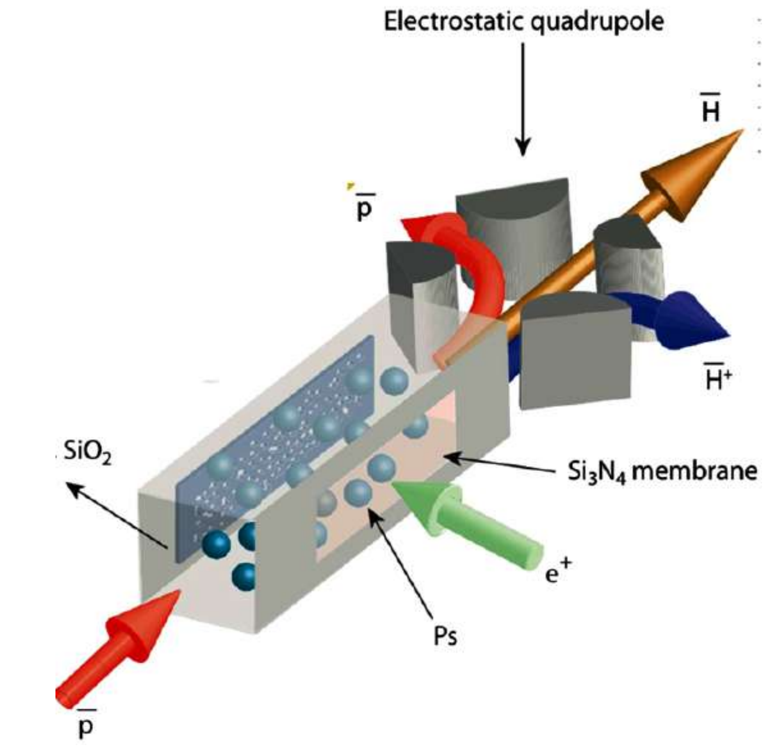
P. Blumer et al., NIMA 1040, 167263 (2022)

Focusing beams to targets



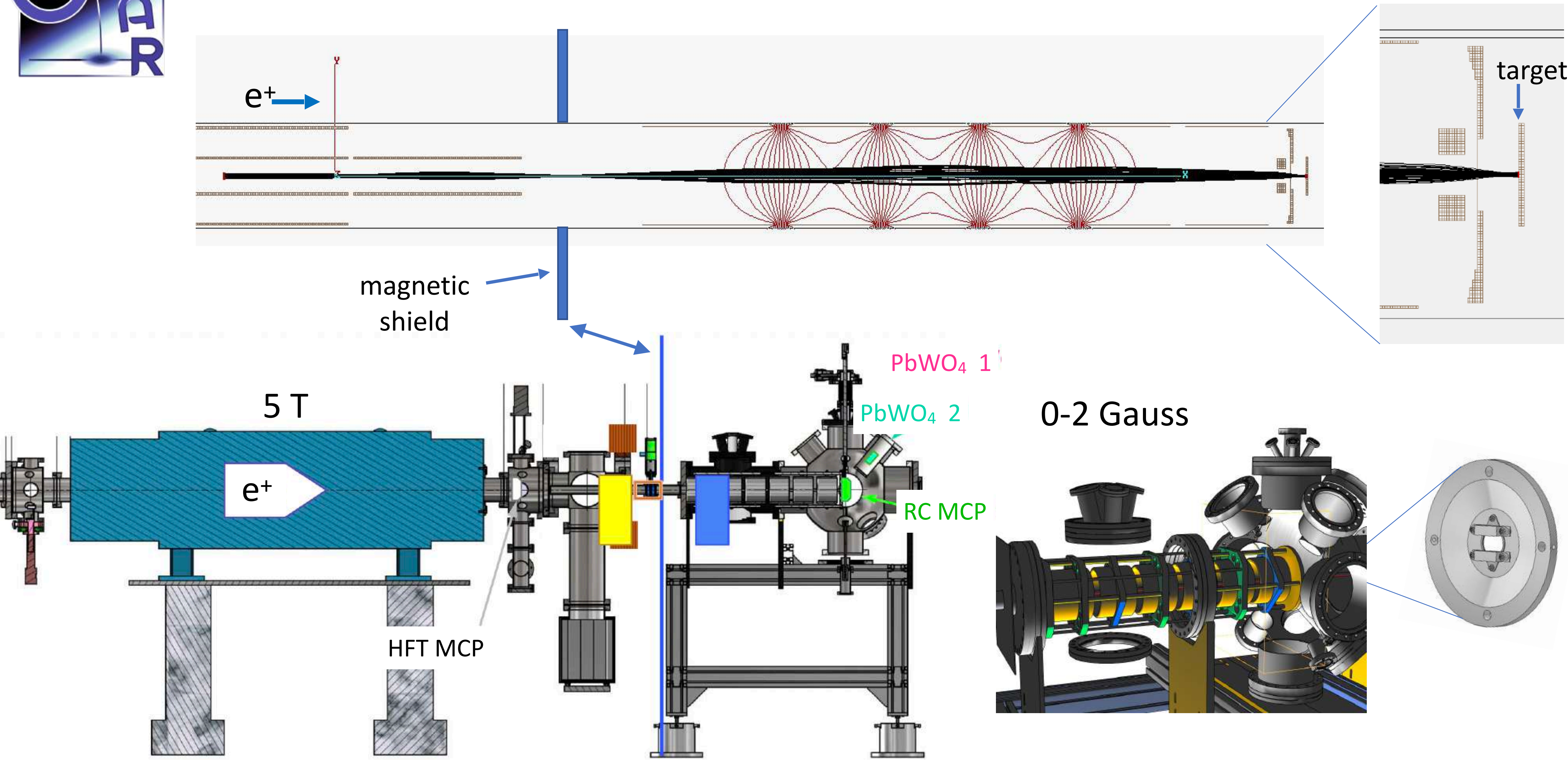






But:
$\bar{p}$ beam transmission through cavity only few percent
—> used flat target in 2022

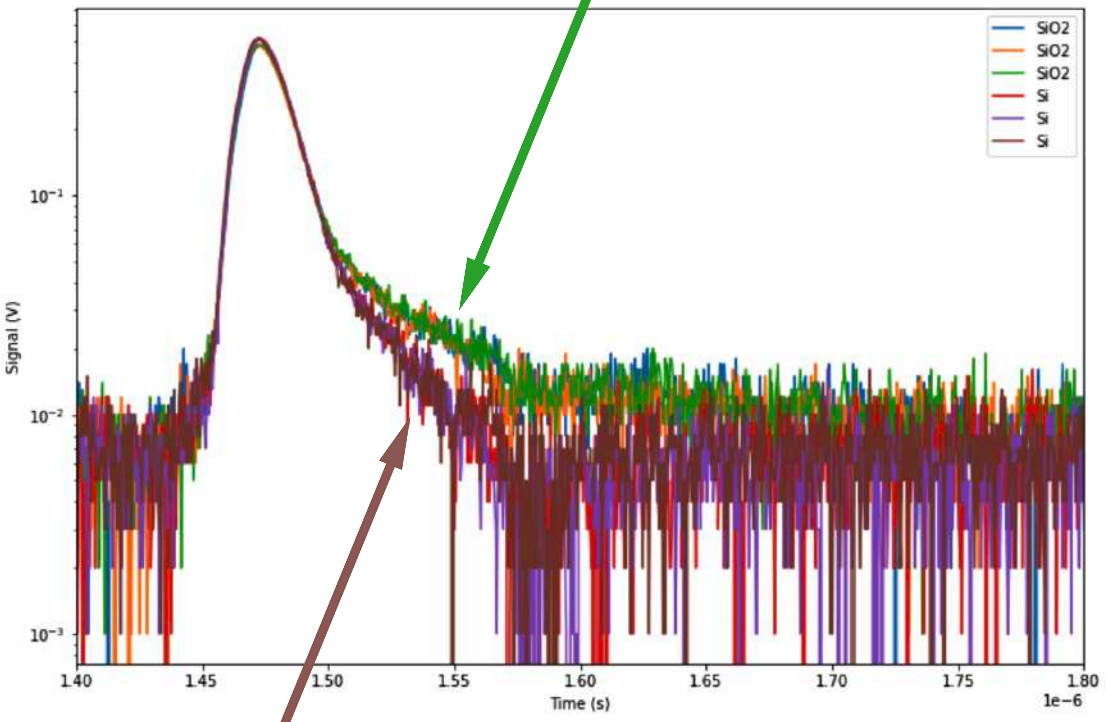
Focusing e^+ beam to target



1.5×10^8 e^+ —> 5×10^7 e^+ on target plane —> ~ $1 \pm 0.2 \times 10^7$ oPs

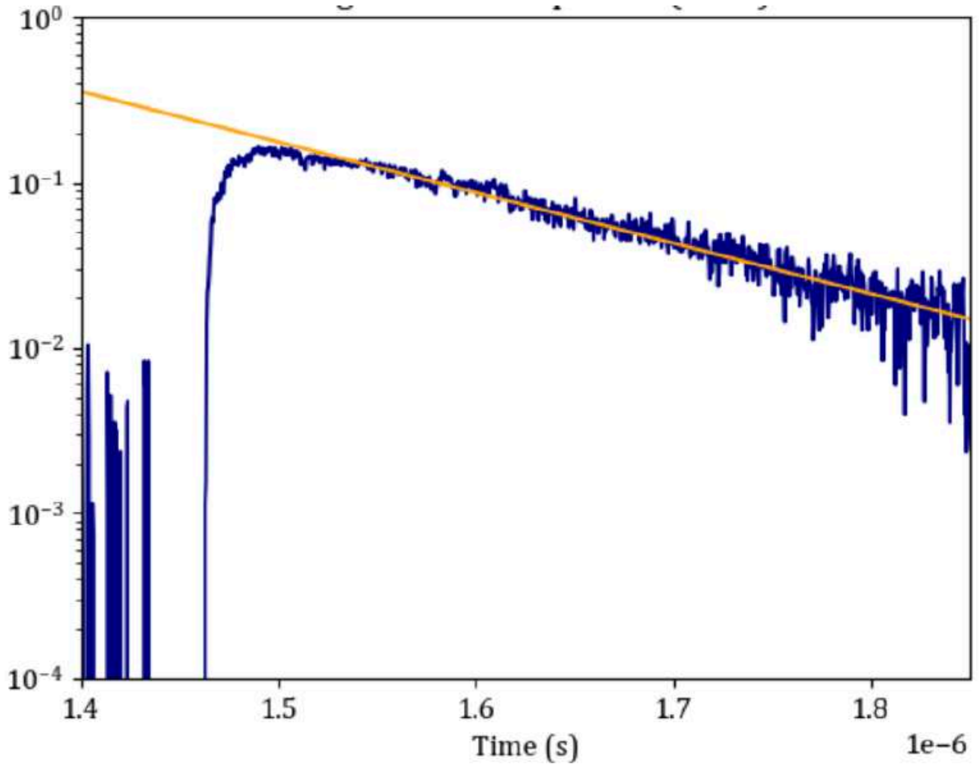
$e^+ \rightarrow Ps$ conversion

SiO2 target —> oPs



Si target

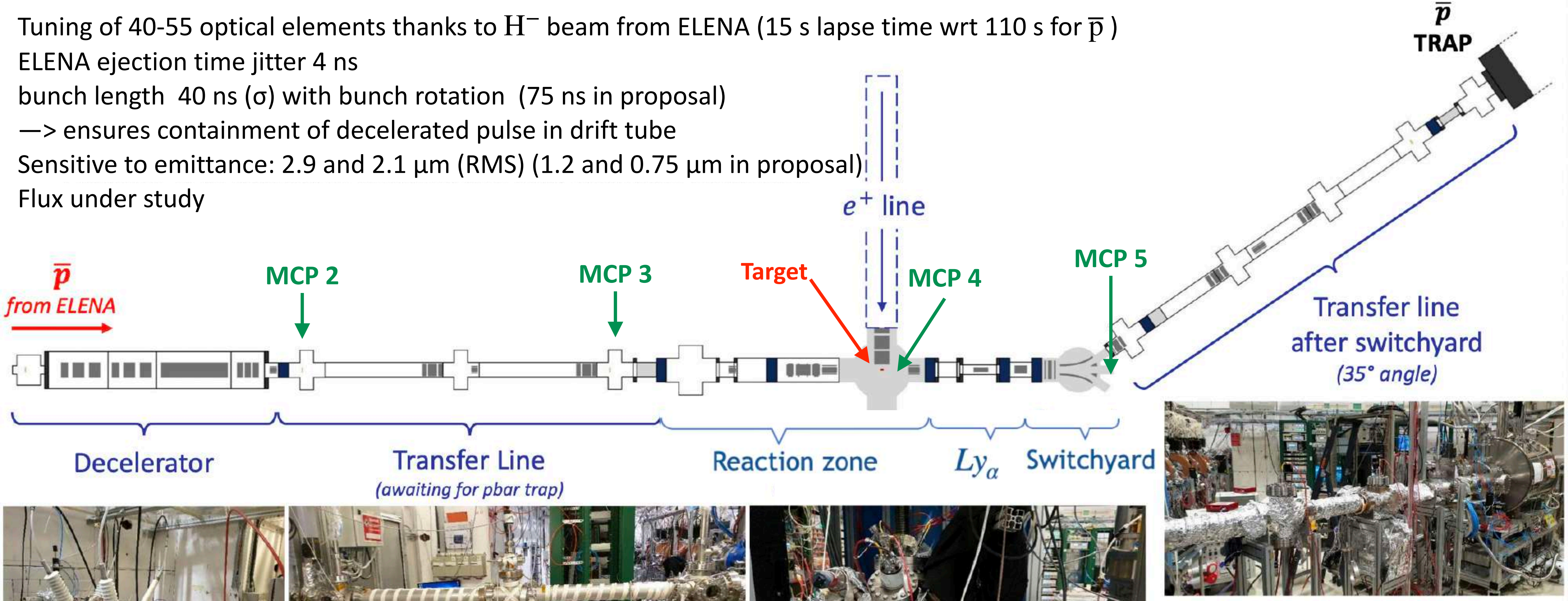
142 ns long lifetime component

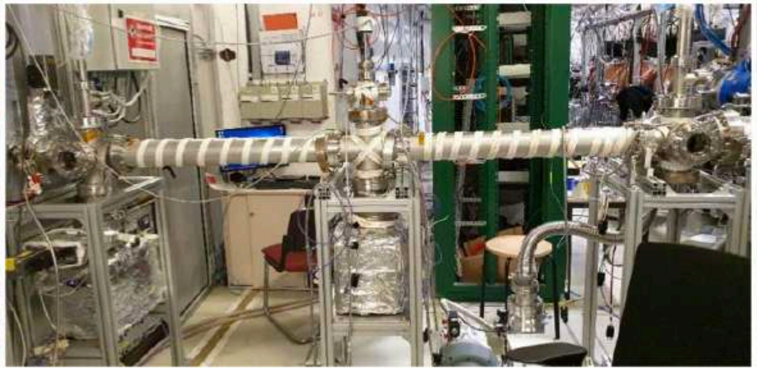


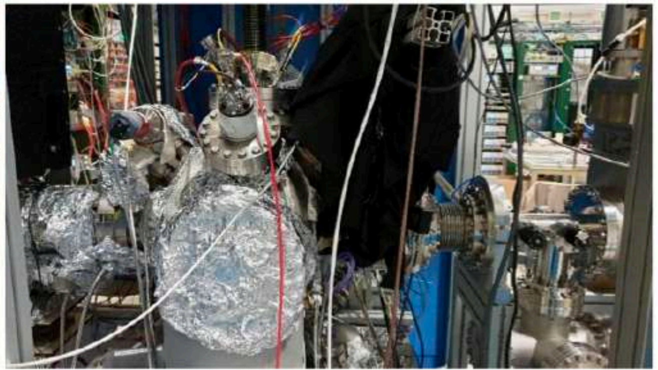
oPs conversion eff $\gtrsim$ 17% (expected 20%)

Antiproton beam line in 2022

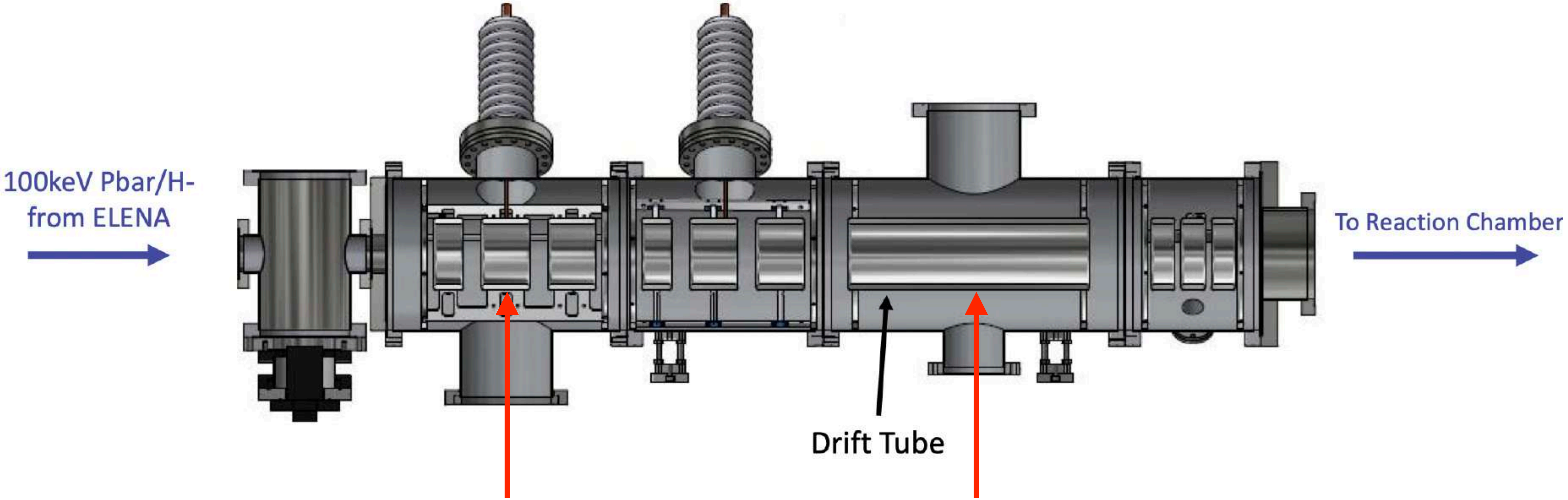
Tuning of 40-55 optical elements thanks to H^- beam from ELENA (15 s lapse time wrt 110 s for $\overline{\mathrm{p}}$)
ELENA ejection time jitter 4 ns
bunch length 40 ns (σ) with bunch rotation (75 ns in proposal)
—> ensures containment of decelerated pulse in drift tube
Sensitive to emittance: 2.9 and 2.1 µm (RMS) (1.2 and 0.75 µm in proposal)
Flux under study







$\bar{p}$ deceleration

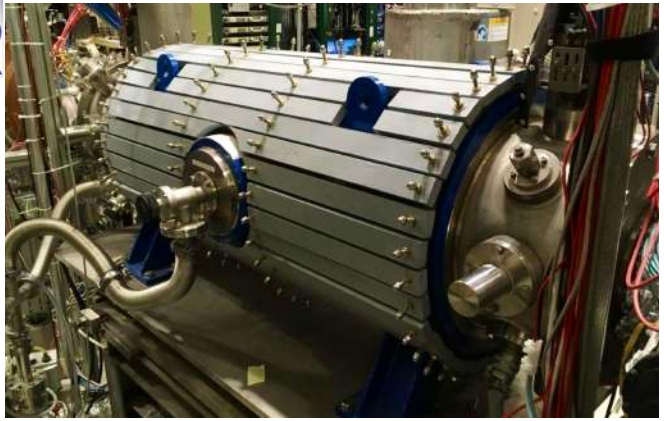


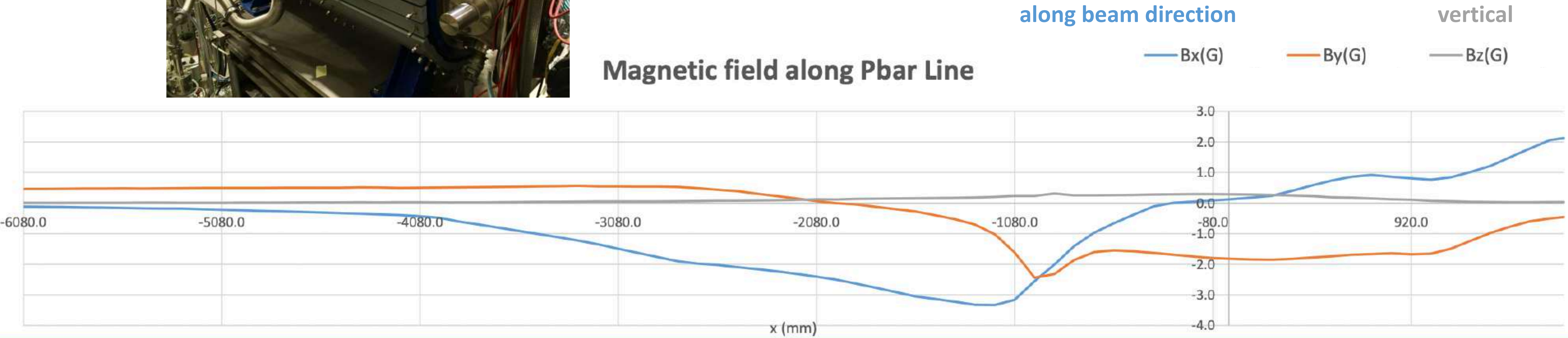
Bunch length
after deceleration
89 ns (σ)

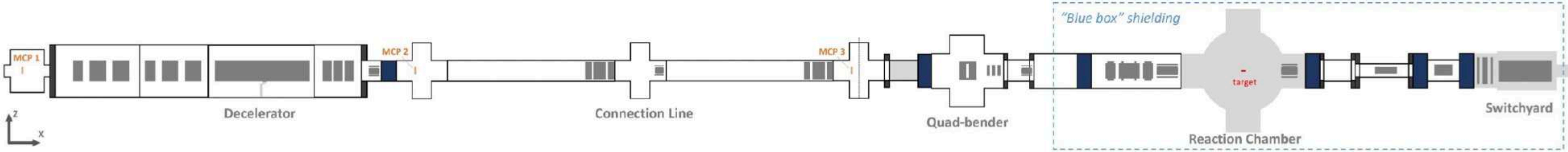
60 kV

ramped up to 94 kV 3 s before $\bar{p}$ bunch
switched to 0 in 30 ns while bunch is in the tube
50-150 V drop due to 10-30 µA leakage —> 6.05-6.15 keV

$\bar{p}$ beam steering

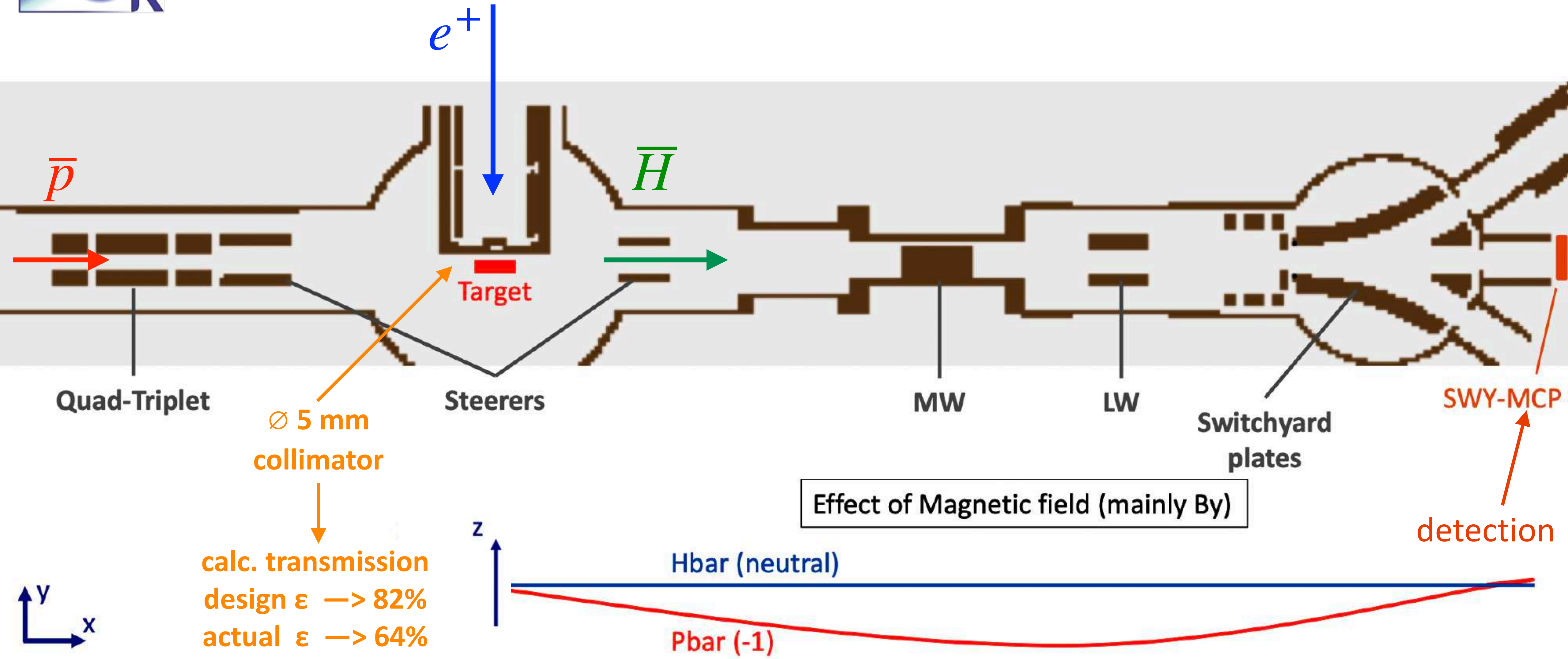






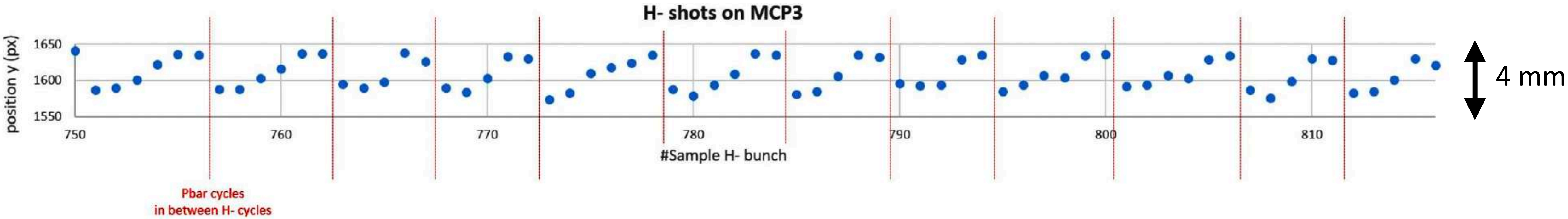
2 Gauss zone

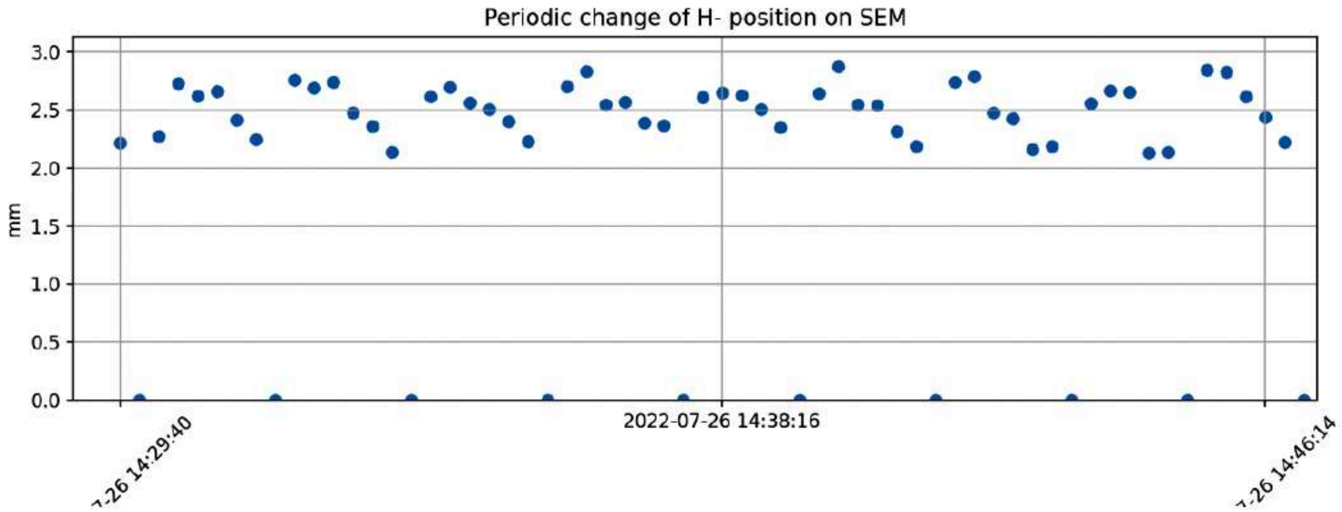
$\bar{p}$ beam steering



Effect of AD magnets ramps on H^{-} beam

100 keV not decelerated in GBAR



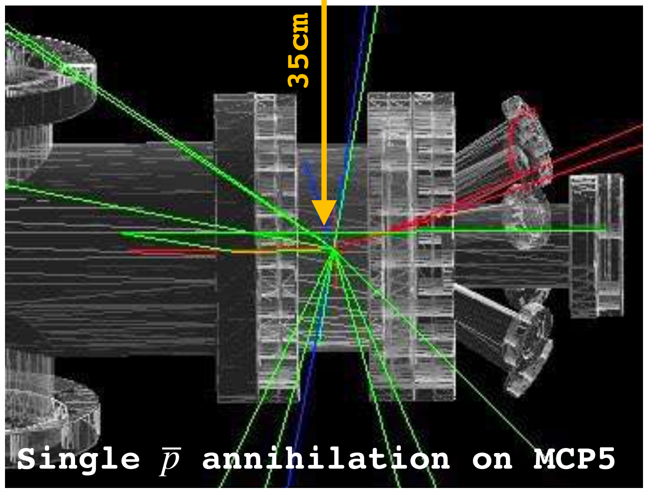


Will try to adjust ELENA beam line steering as a function of time within AD cycle

measurement of antiproton flux with a CMOS sensor

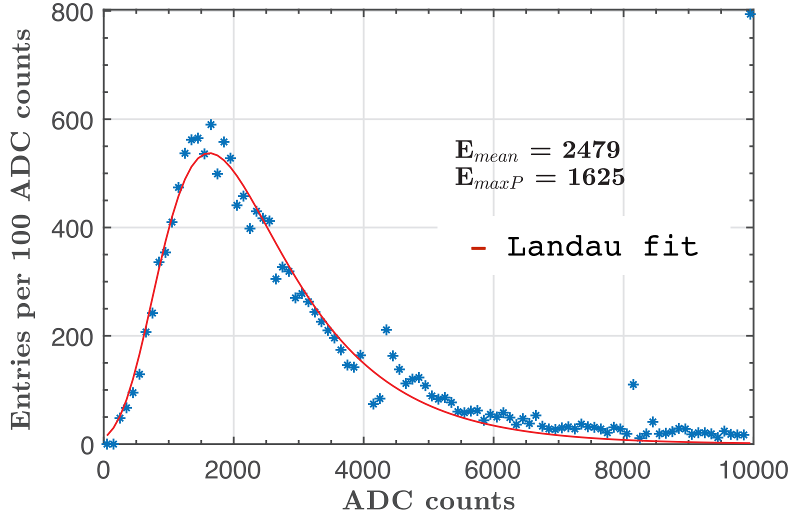
- High granularity (5M pixel), highly efficient tracking detector
- Small depletion volume, low Z - insensitive to γ rays
- 10^7 annihilating $\overline{p}$ yield typ. 500 hits (area ~0.5cm²)
- 2.5 … 3 pion tracks / $\overline{p}$ on MCP materials
- Assume ~ 3.5 charged tracks/$\overline{p}$ with 20% (estimated) error
- More precise result expected from MC (ongoing)

CMOS camera without lens

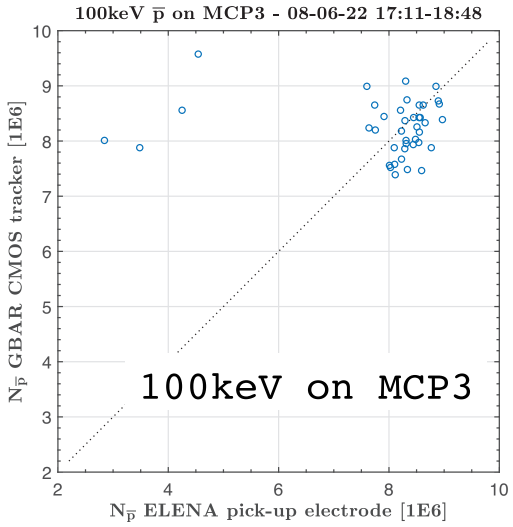


Preliminary Results

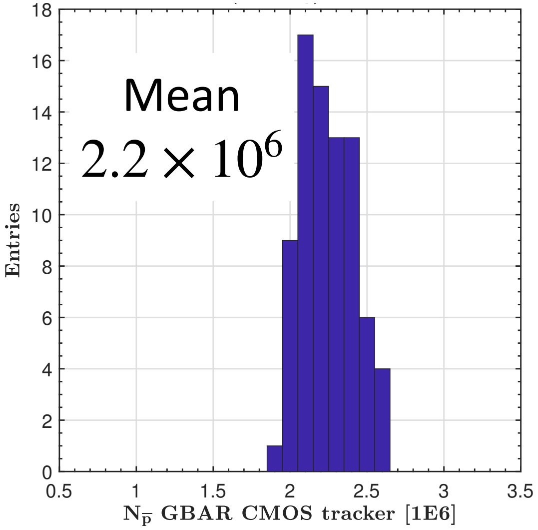
Energy deposit in CMOS



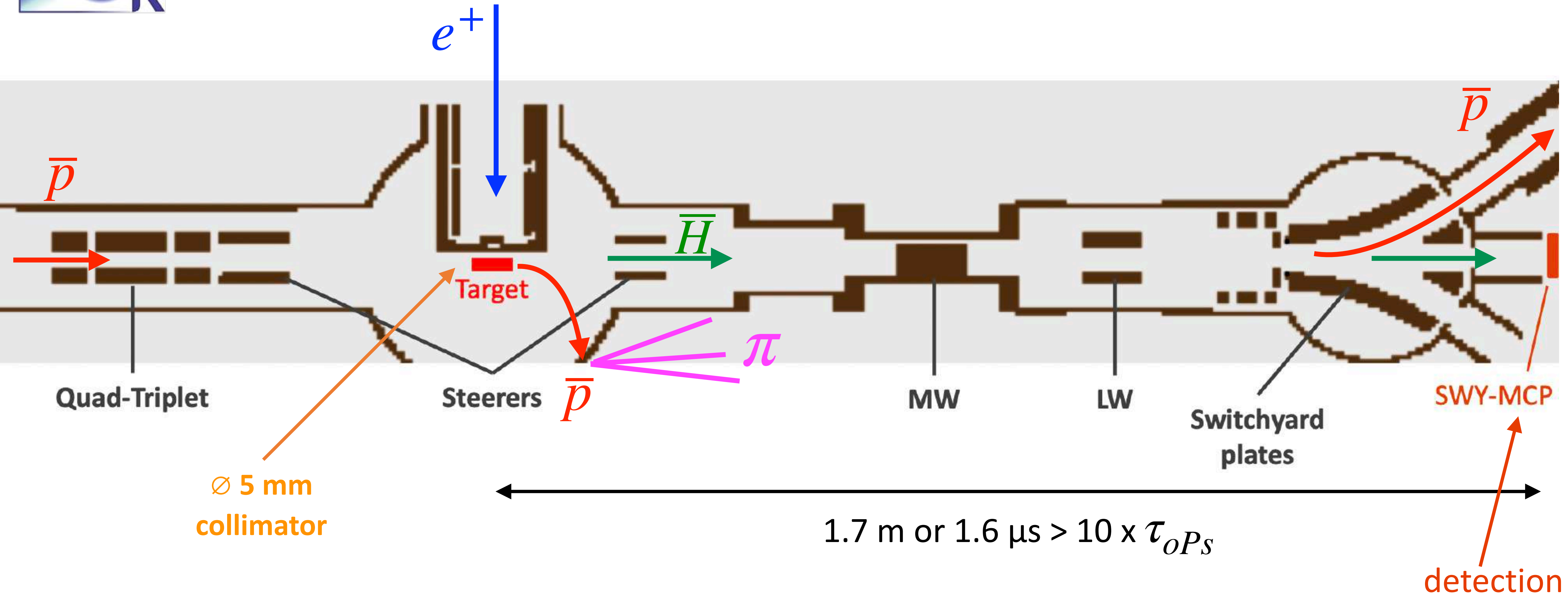
Comparison with ELENA



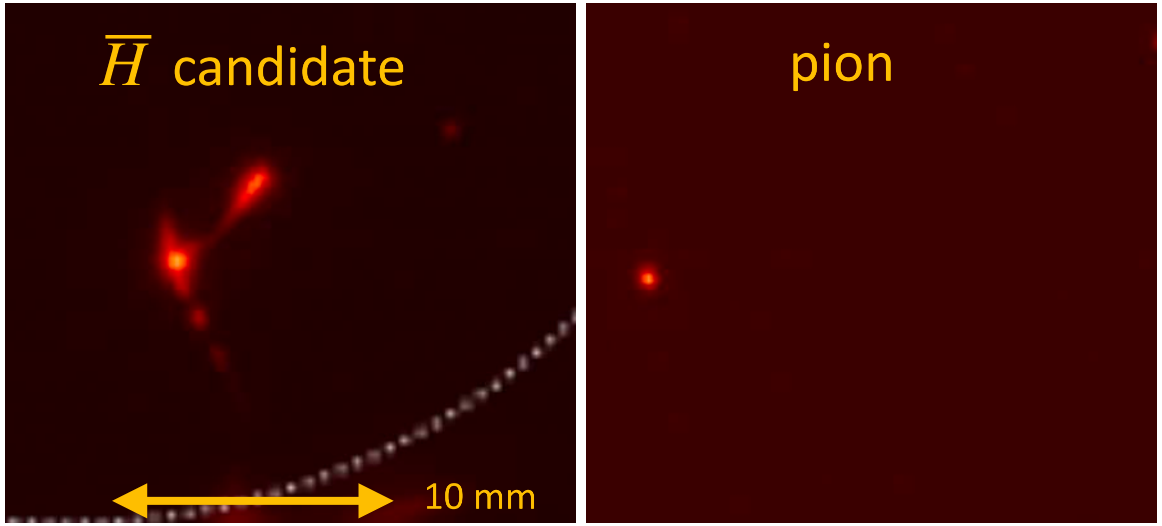
6keV $\overline{p}$ on MCP5



Mixing Ps and $\overline{p}$



Mixing Ps and p̄



- $2.2 \pm 0.25 \times 10^6\ \overline{p}$ at $6\ keV$
- $5 \times 10^7\ e^+$ on target —> $9 \pm 2\ 10^6\ Ps$
  —> expect $0.5 - 2\ \overline{H}$ per 100 spills
- Detection with MCP 5 synced with $\overline{p}$ beam and time of flight between target and detector
  - Electrical signal in 360 ns window (~ $\overline{p}$ bunch length x 4)
  - Image integrated in 1 µs window
- Background only due to pions from $\overline{p}$ annihilations
  8500 spills with $\overline{p}$ only —> estimate 0.08 background per 100 spills
- Signal
  7000 spills with $\overline{p}$ and e^+
- Other data taken with small number of $\overline{p}$ —> differentiate signal/backgd electrical waveforms or image shapes
- —> Detection of a significant $\overline{H}$ signal is possible for the expected rate
- Analysis ongoing

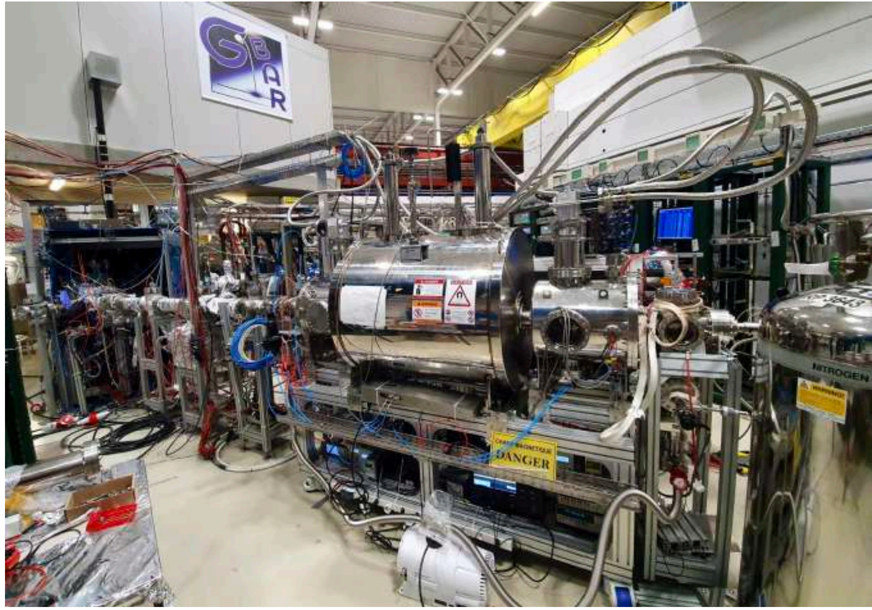
Antiproton trap

Now in temporary location

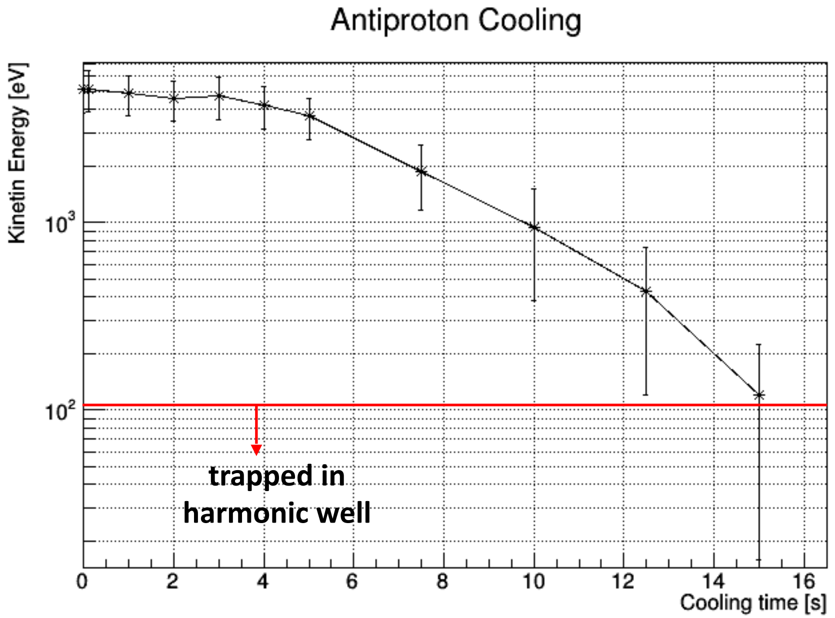
With $\approx 2 \times 10^5\ \overline{p}$ incident:

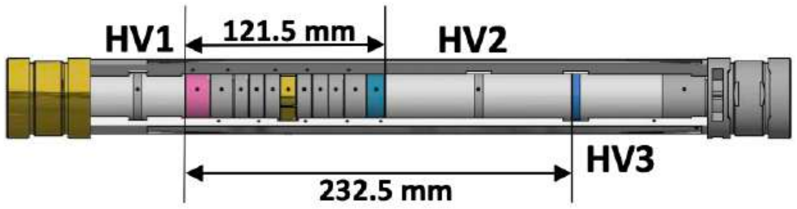
40-70% trapping efficiency (dep. well length)

Cooling time with $10^5\ \overline{p} + 10^7\ e^-$ at 5T: 15 s from 6 keV to 100 eV

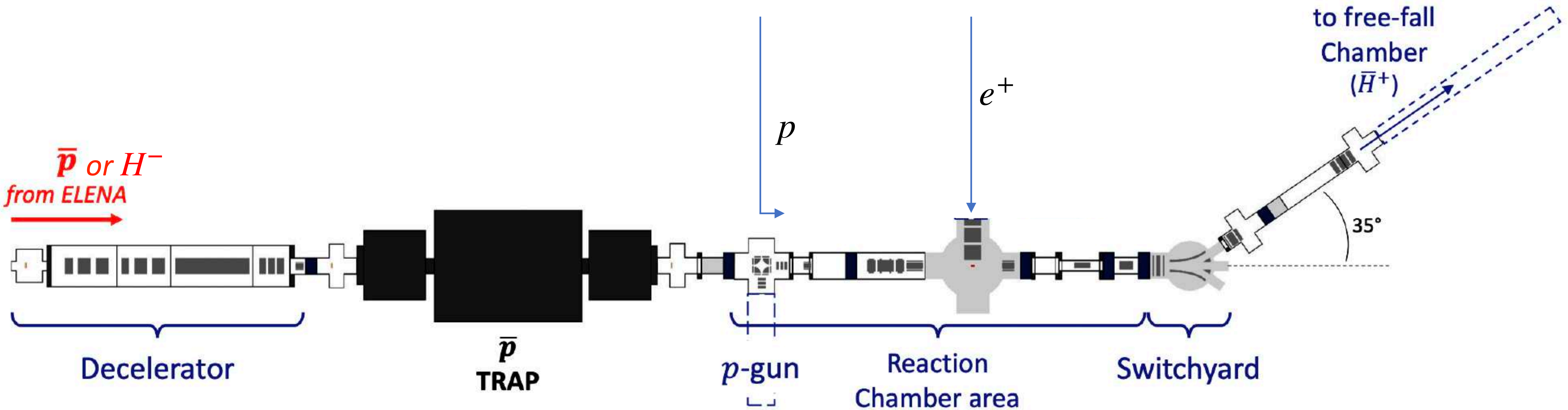


100 ℓ LHe / 2 months





Antiproton beam line (planned)



Activities in home labs

- LKB Paris: - stopping power of Be^+ in Sr^+ crystal (cooling dynamics)
  - Be^+/Sr^+ sympathetic cooling
  - photo-detachment laser
  - monitoring X-ray emission from $\overline{p}$ atom cascade
  - study of quantum interference measurement of $\overline{H}$ free-fall
- LKB & IJCLab Orsay: recycling $\overline{p}$
- Mainz: polarisation gradient cooling of ions
- Saclay: laser neutralisation of Elena H^- beam
- Stockholm: calculation of cross-sections

Outlook

- Preliminary analysis of 2022 data strongly suggests presence of $\overline{H}$ production

- <u>Plans for 2023</u>
  - SiC re-moderator and other scheduled improvements
  - Install antiproton trap
  - Steering to Ps tube target —> $1\ \overline{H}$ per shot
    —> $5\ \overline{H}(2S)$ per hour

  - Measure $\overline{H}$ production as a function of $\overline{p}$ energy
  - Detect *2S* states

GBAR collaboration

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