Antiproton production in ALICE

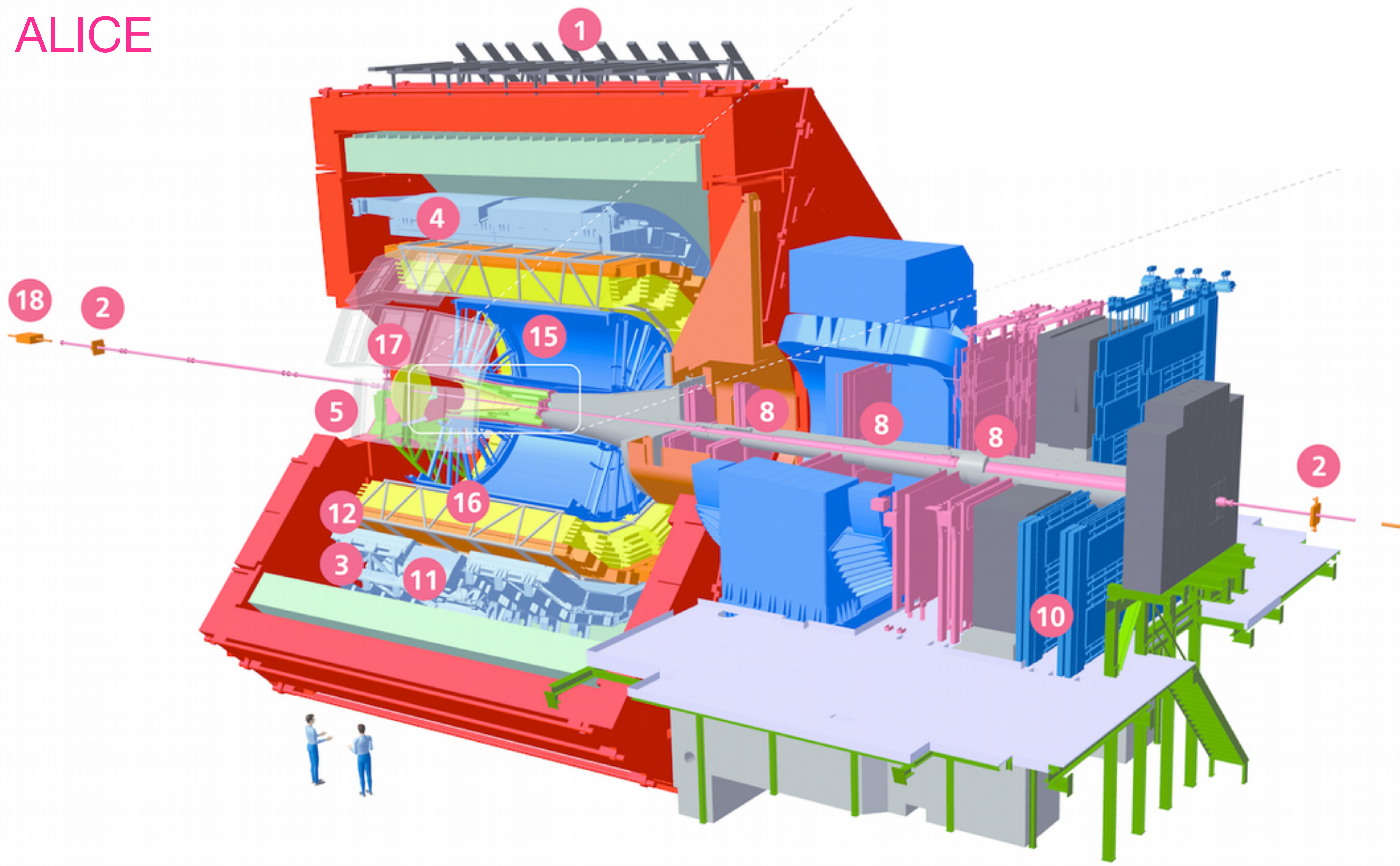
Charlotte Van Hulse
UAH

AdTCM

Fixed-target experiments at LHC – strong2020 workshop
22–24 June, 2022

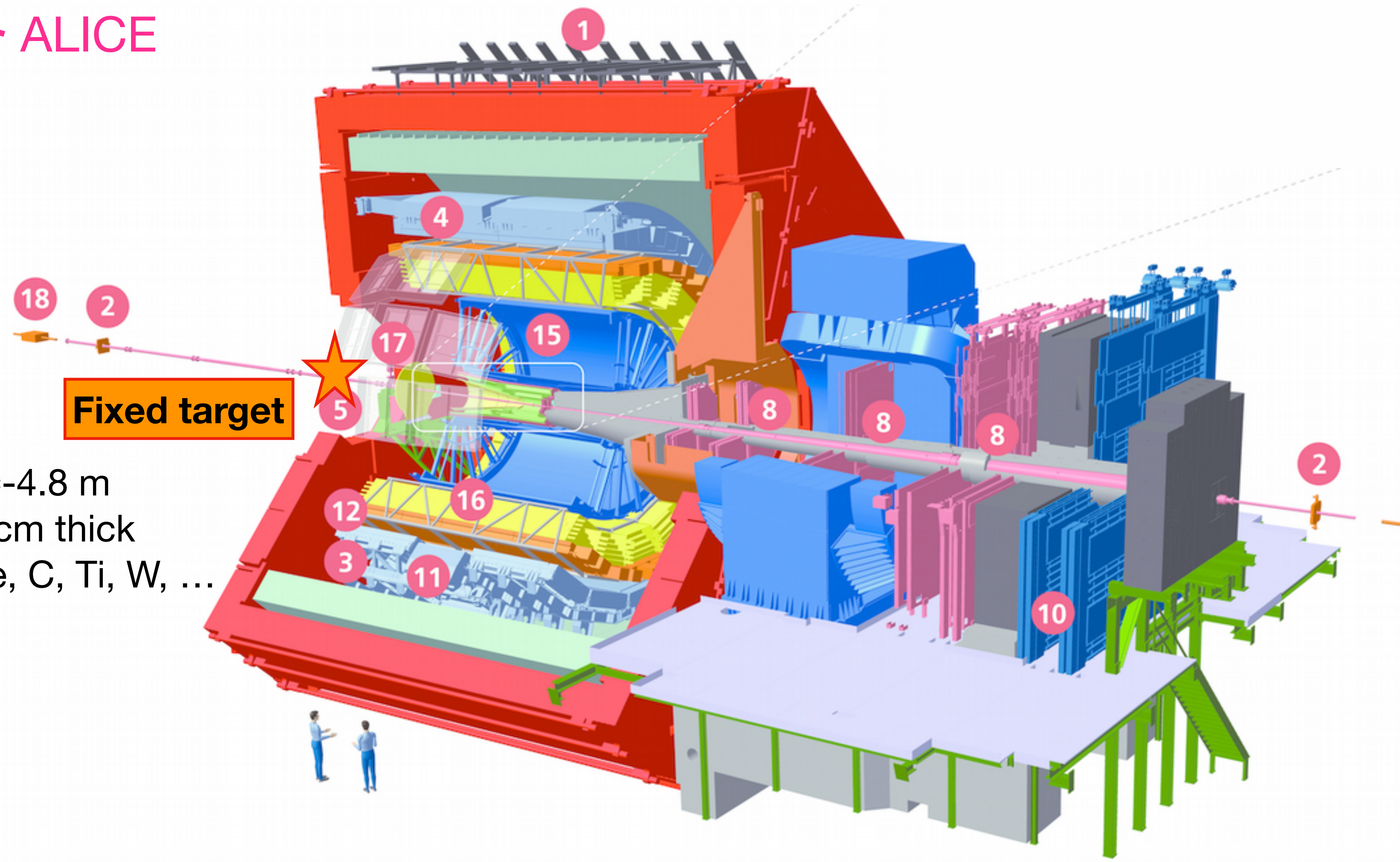
Fixed target at ALICE

ALICE



Fixed target at ALICE

ALICE



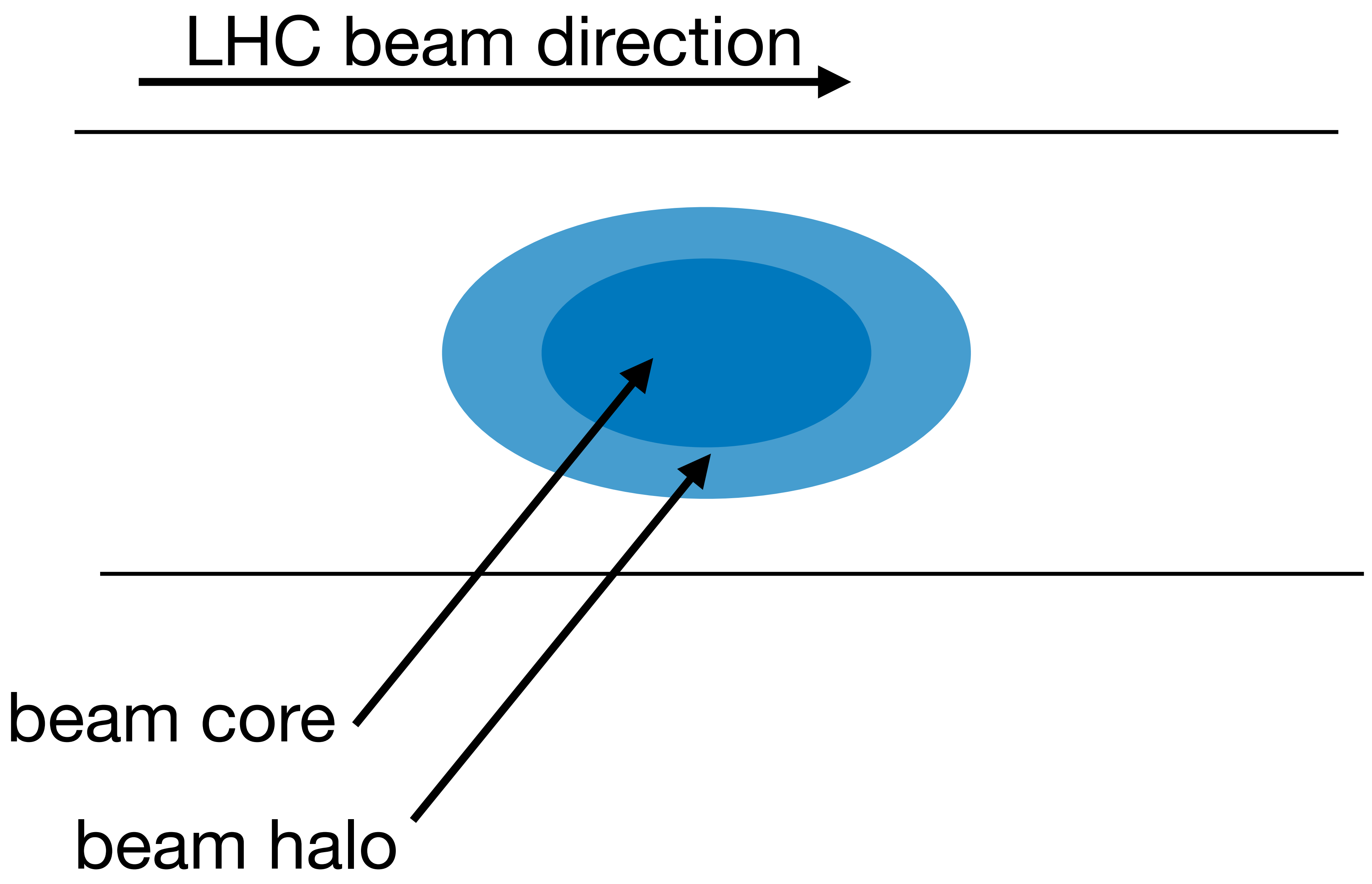
Fixed target

z≈-4.8 m
1 cm thick
Be, C, Ti, W, …

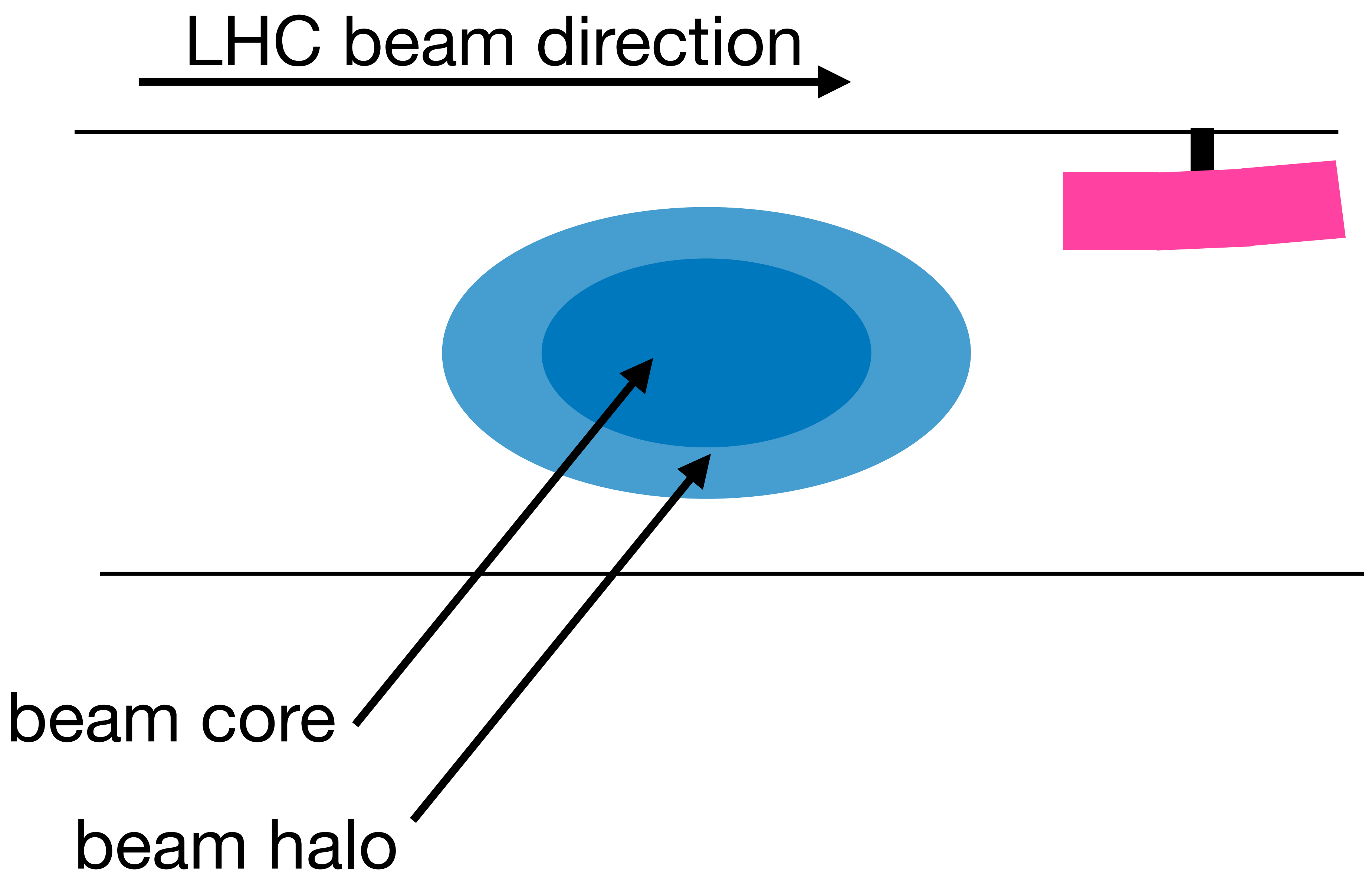
- 10^6 p/s on target
- Feasibility for usage of Pb beam needs to be studied

If approved, target installation during LHC LS3 (2026-2028)

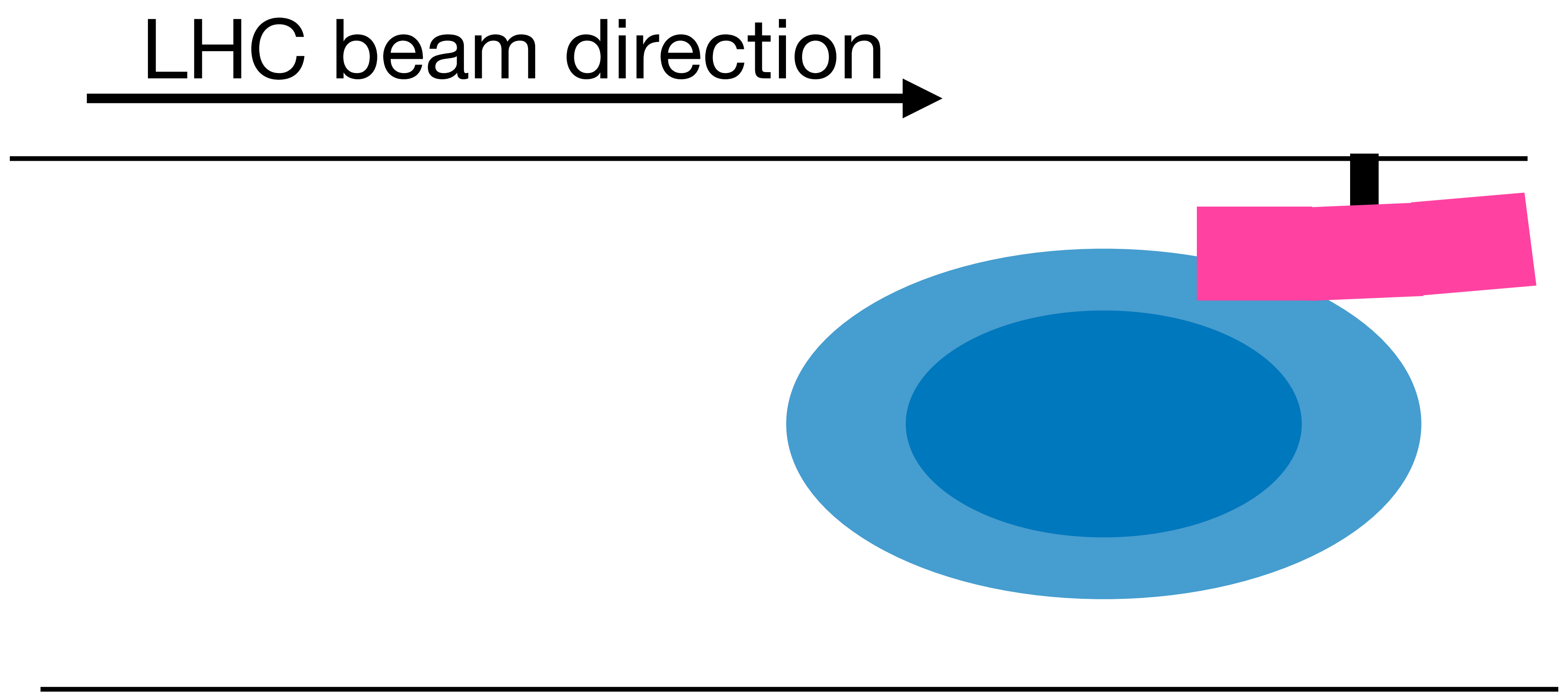
Realisation of beam interaction with fixed target



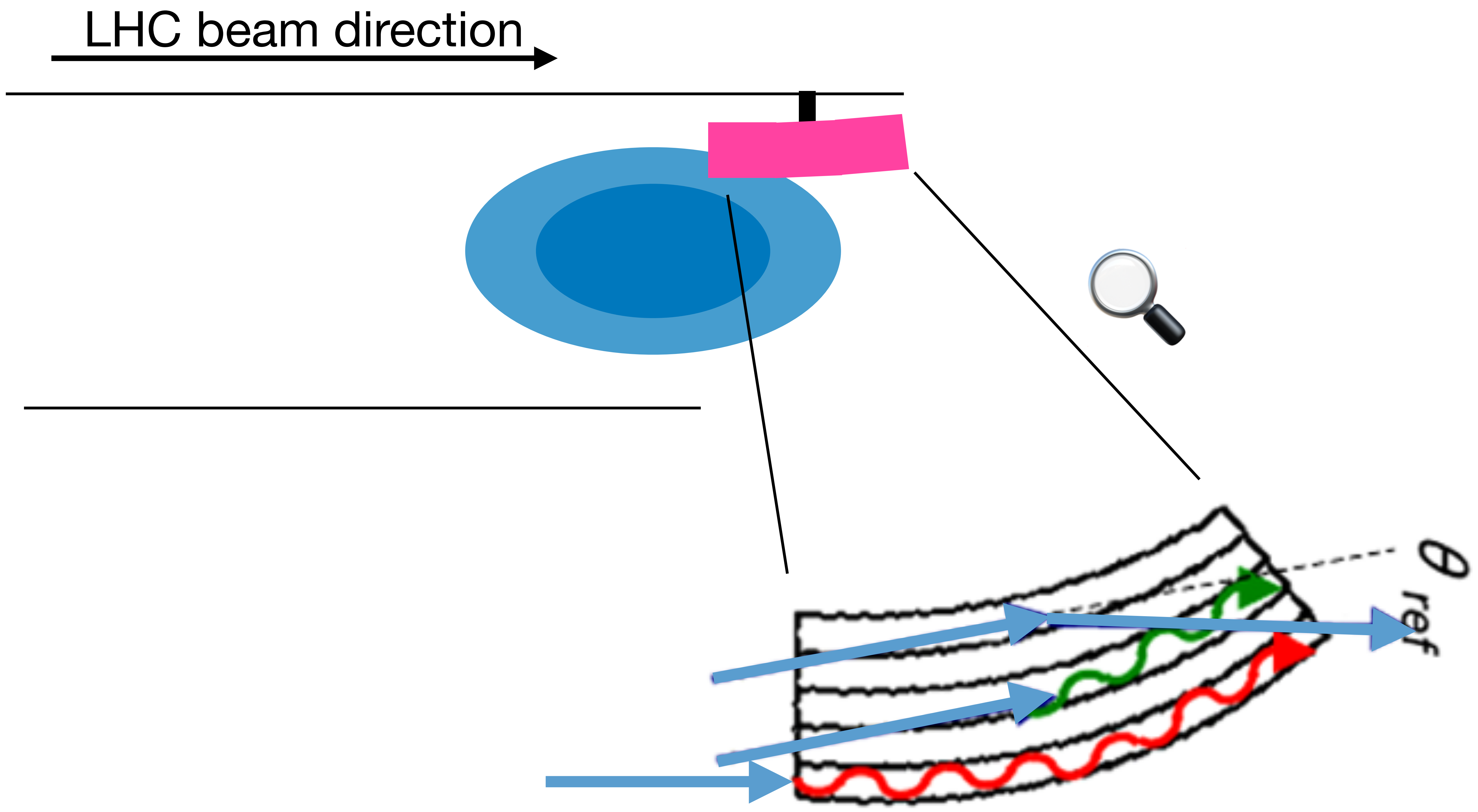
Realisation of beam interaction with fixed target



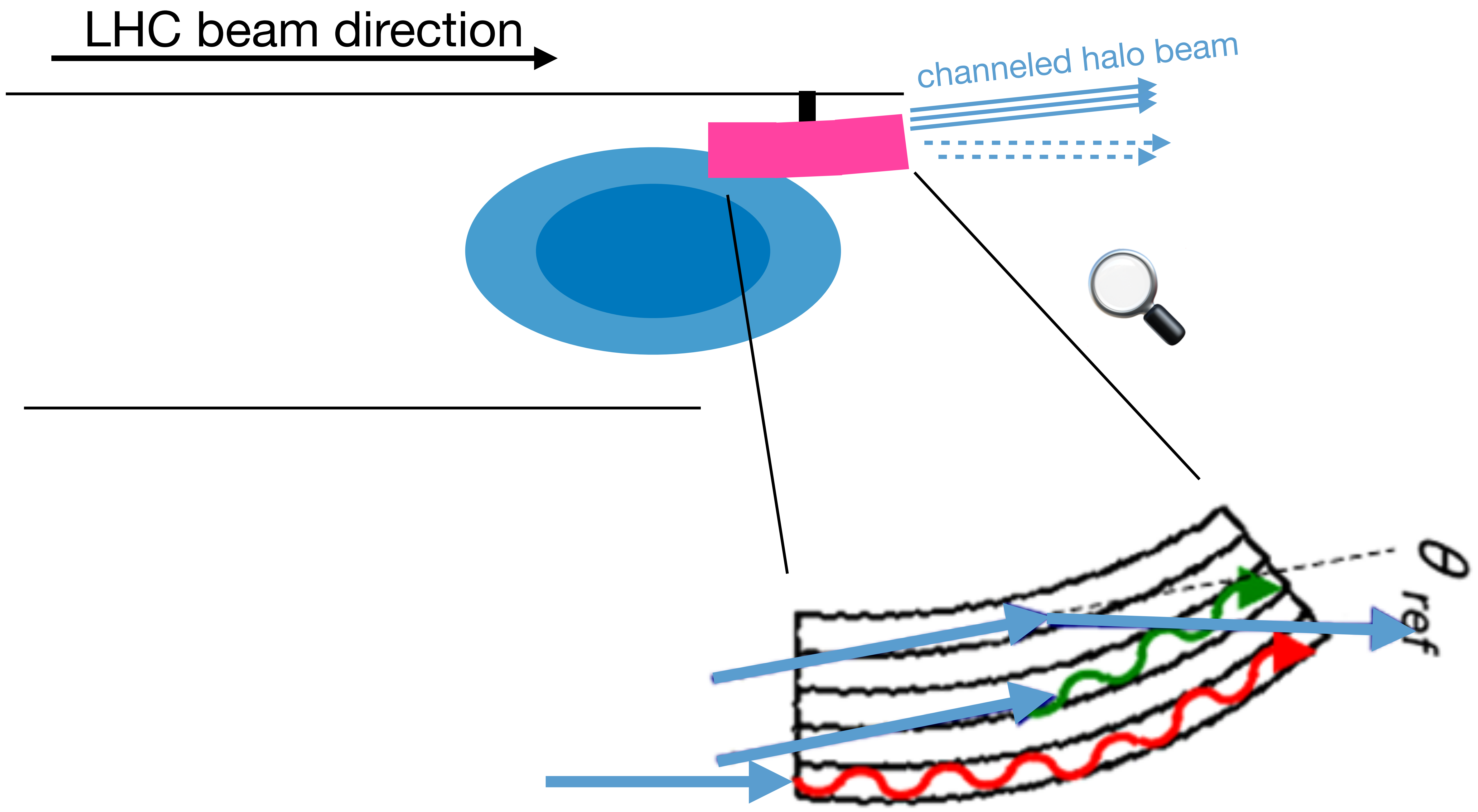
Realisation of beam interaction with fixed target



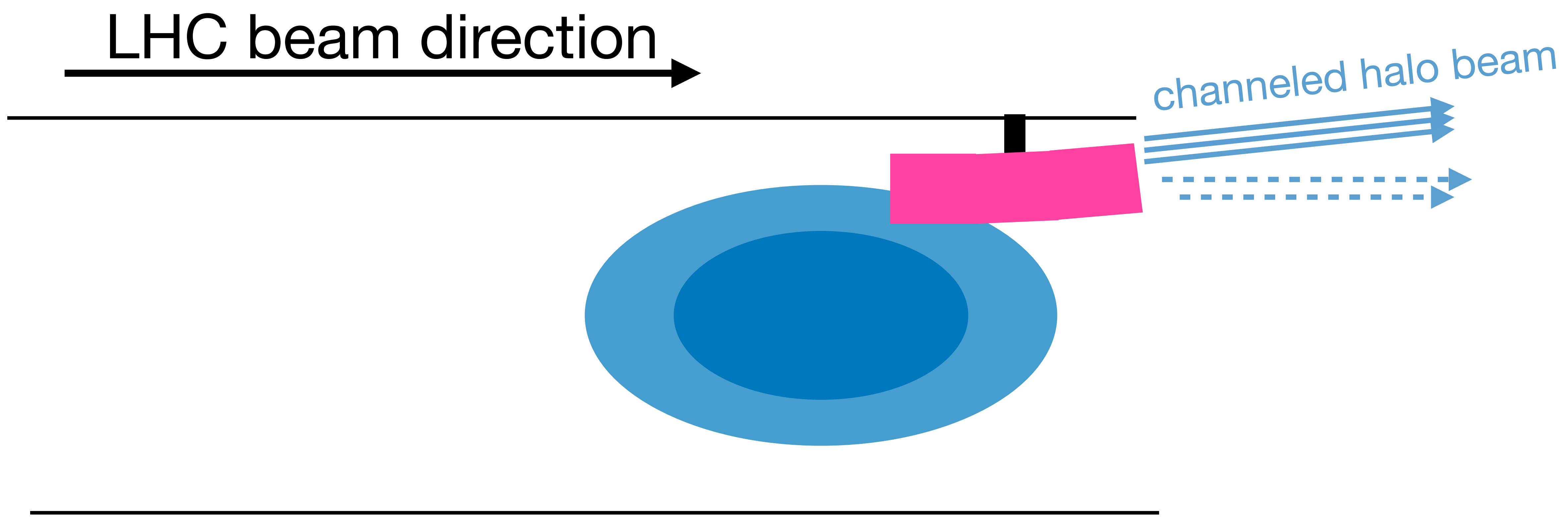
Realisation of beam interaction with fixed target



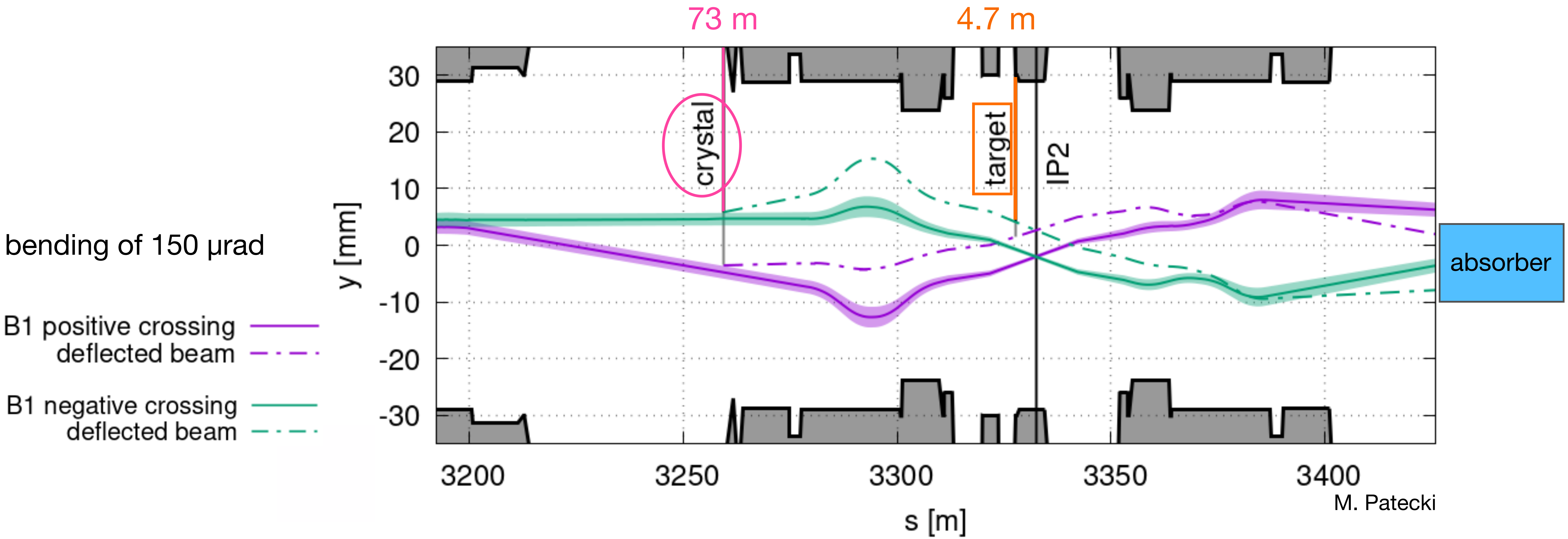
Realisation of beam interaction with fixed target



Realisation of beam interaction with fixed target



bending of 150 µrad



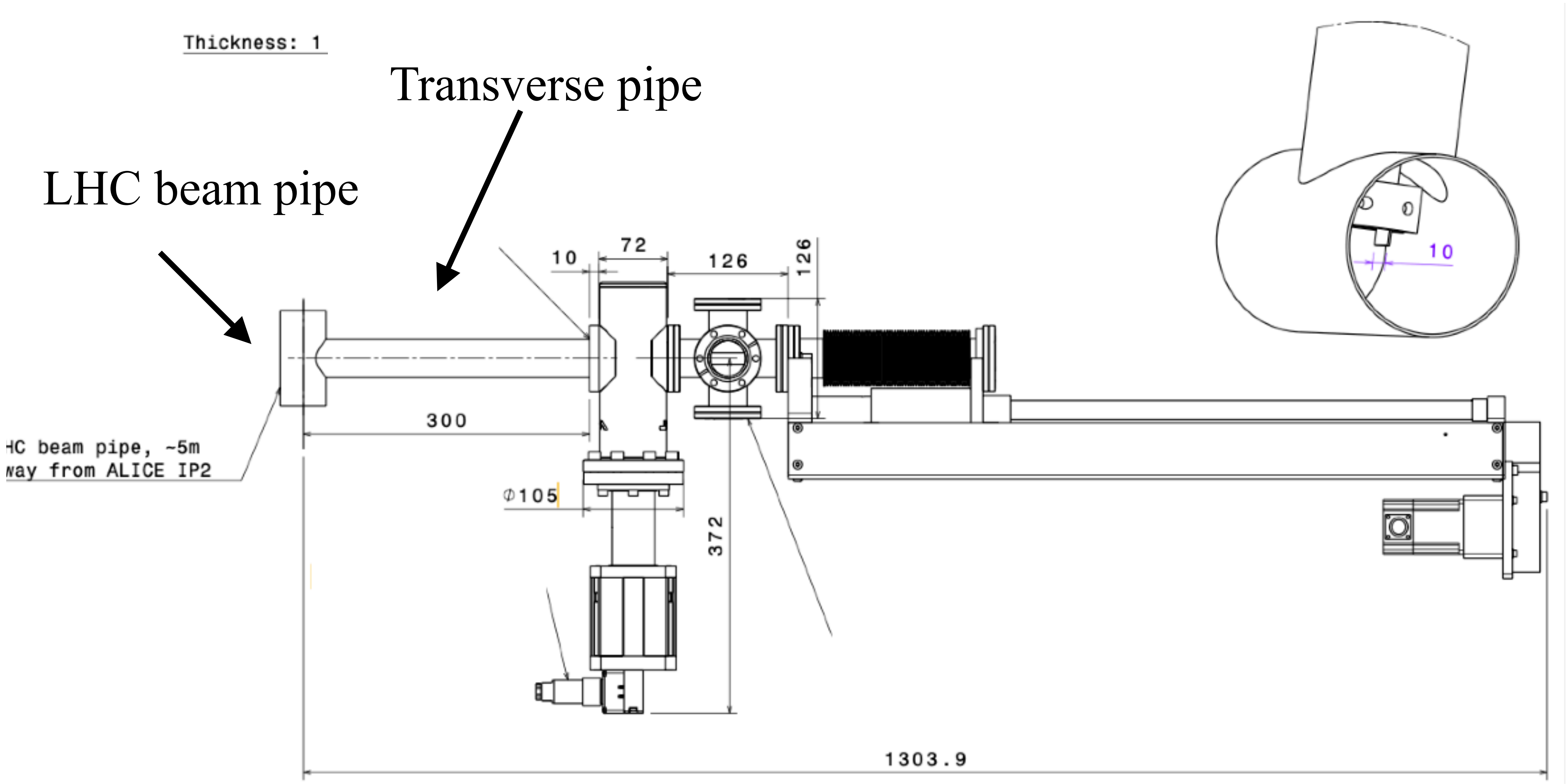
The target and FoCal

The target and FoCal

The target and FoCal

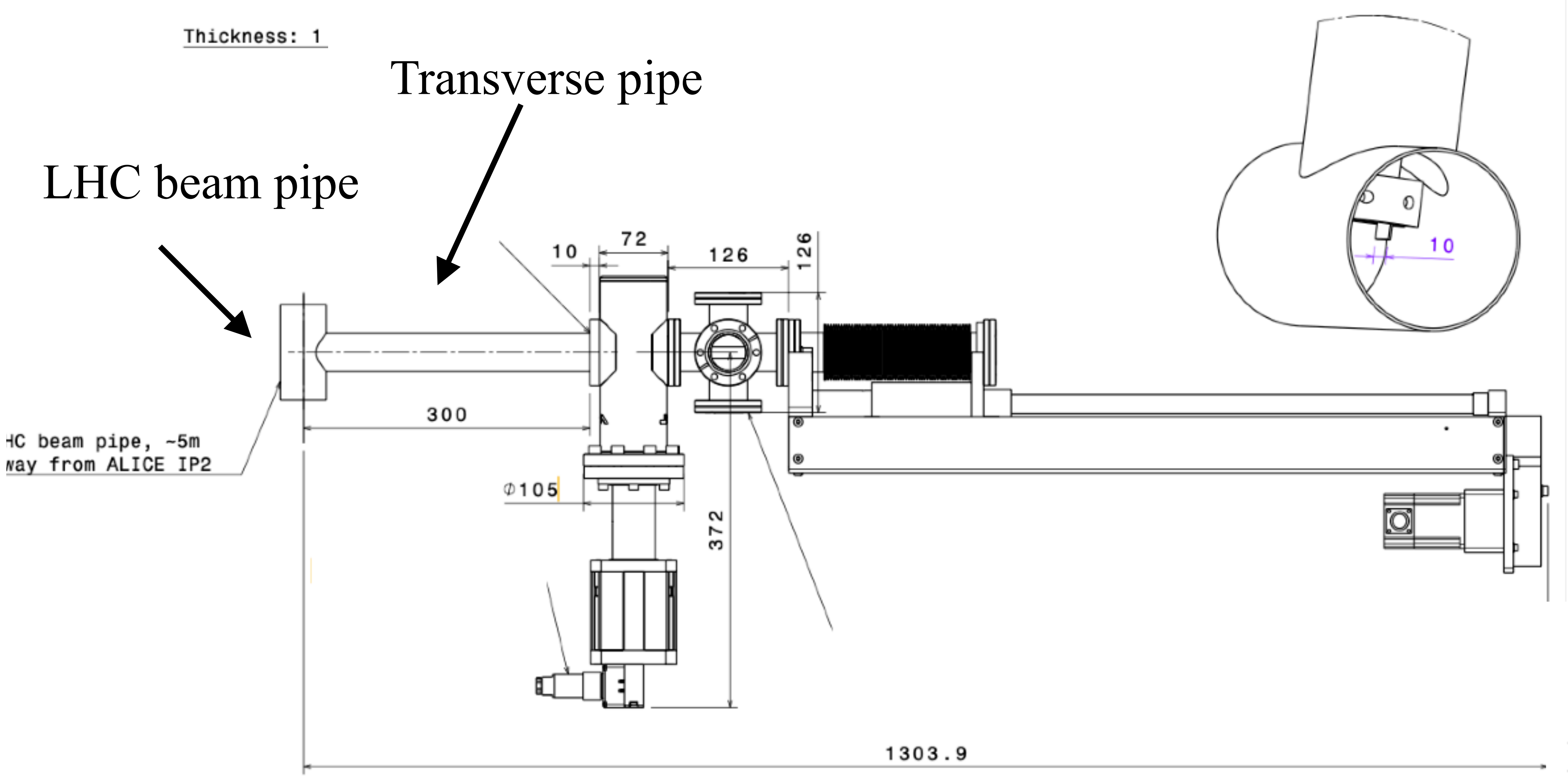
The target and FoCal

Target design

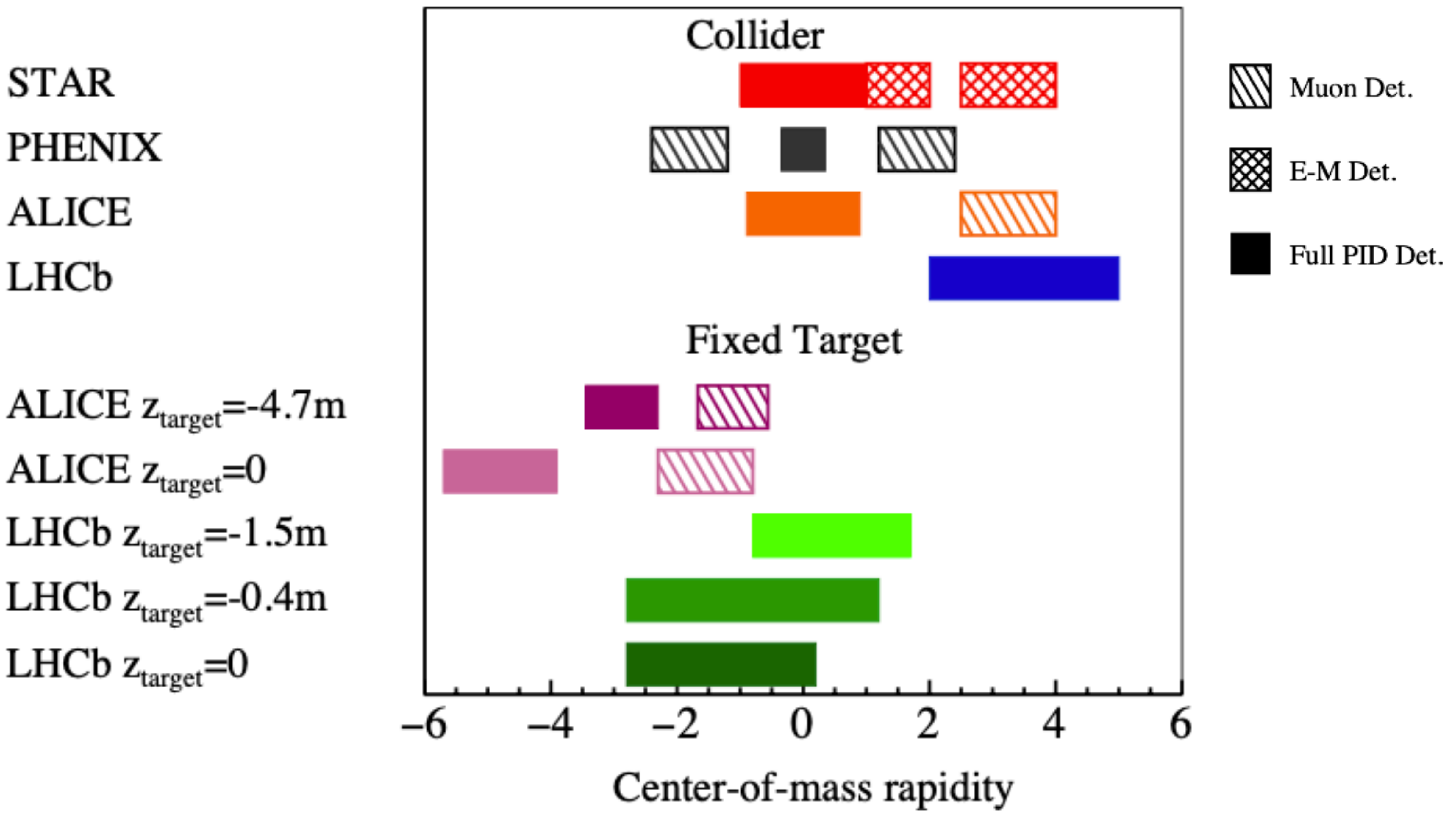


Space constraints in experiment + impact on Focal:
target position considered at present:
z=500 cm +/- 20 cm

Target design

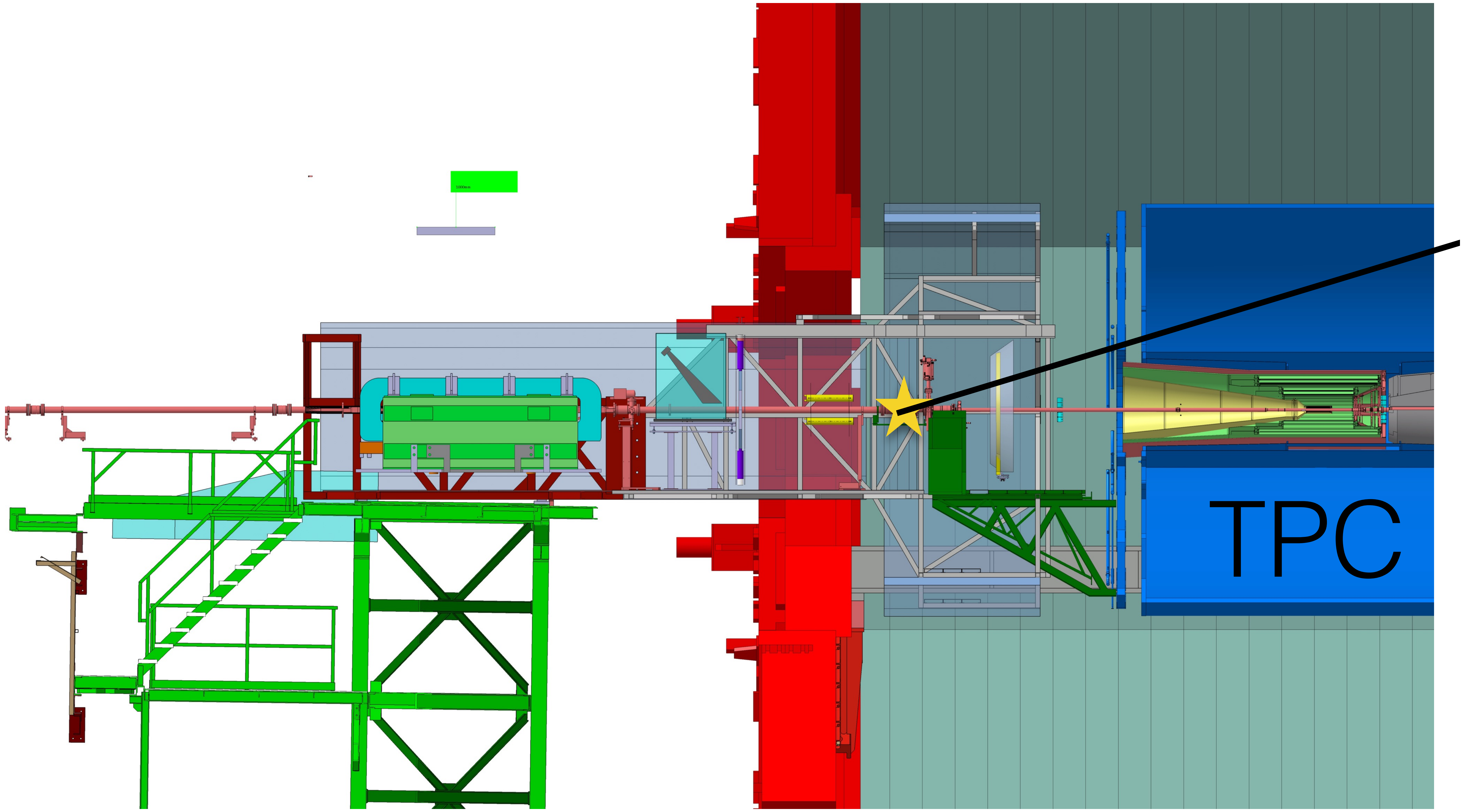


Space constraints in experiment + impact on Focal:
target position considered at present:
z=500 cm +/- 20 cm



Track reconstruction

Track reconstruction via TPC



Motivation for the measurements of anti-protons

$\bar{p}$ production cross section as input for determination of cosmic $\bar{p}$ spectrum

high-E $\bar{p}$ from interaction of primary cosmic rays (p, ^{4}He, ^{12}C, ^{14}N, ^{16}O) with interstellar matter (p, ^{4}He)

⇳

slow $\bar{p}$ from p beam with fixed target of C, N, O, He

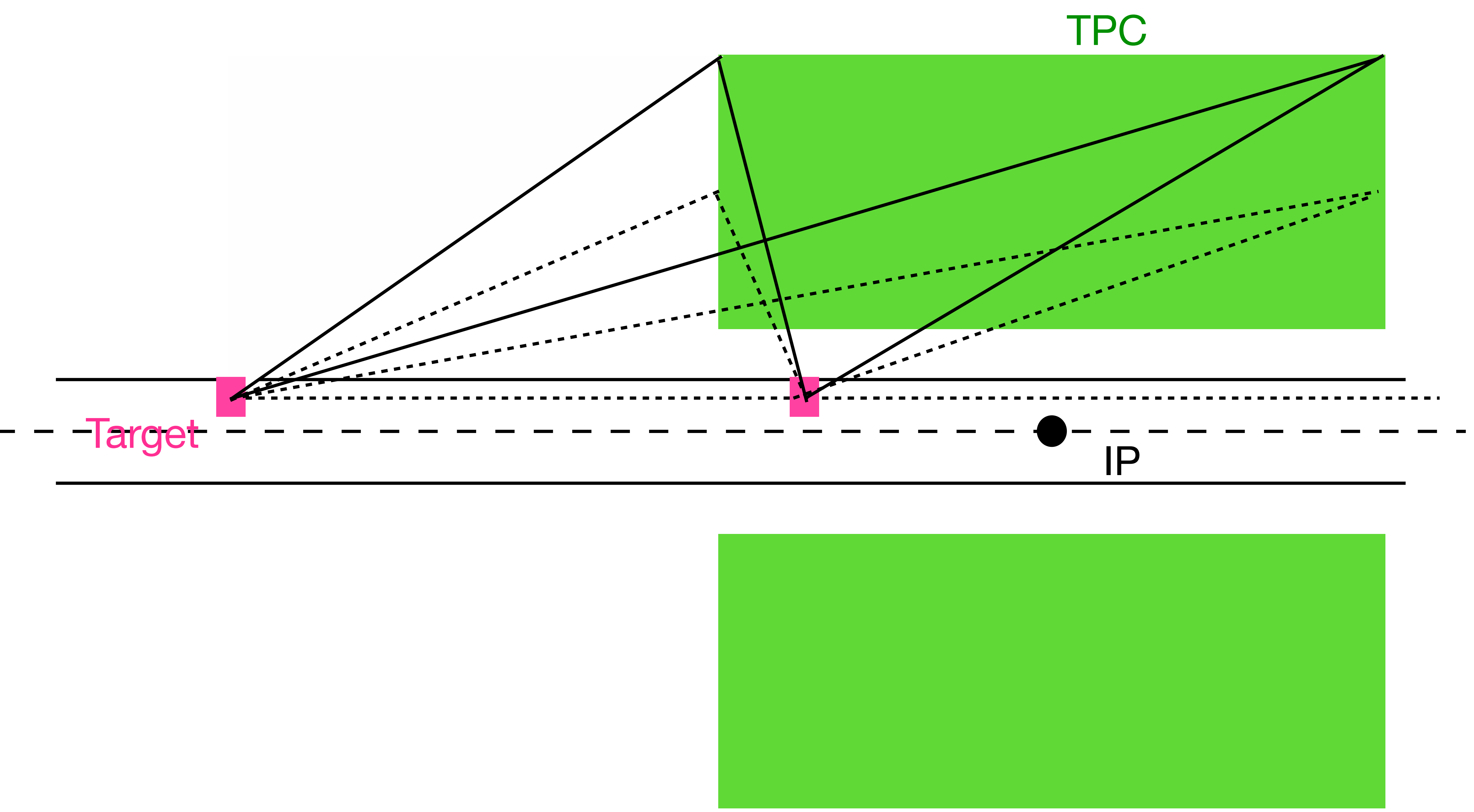
ALICE can measure $\bar{p}$ with momenta down to ~ 0 GeV.

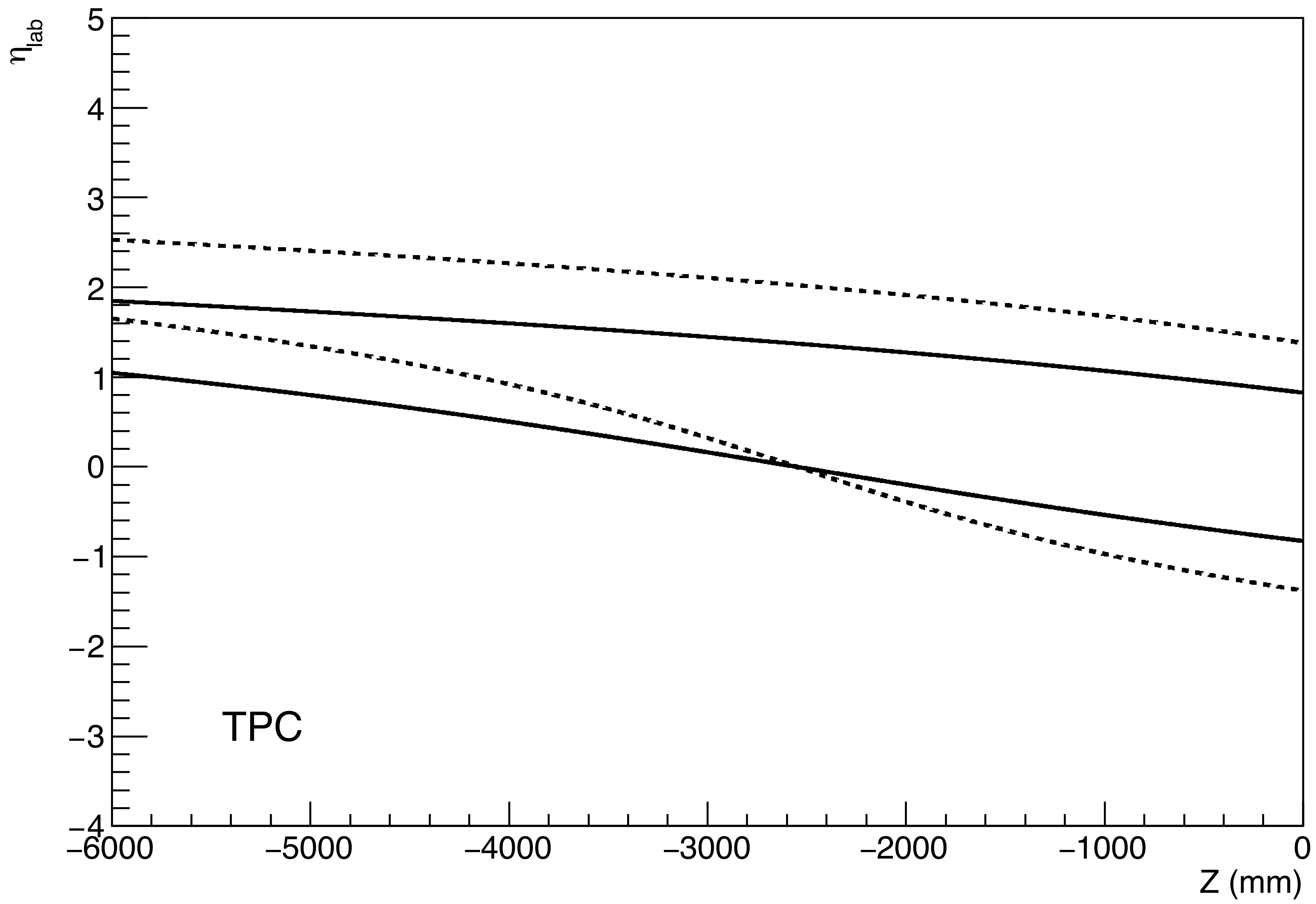
Simulation studies

- Simulation: PYTHIA8
- Consider target to be at z=495 cm
- Detector acceptance cuts
- Tracking efficiency and finite resolution of transverse-momentum reconstruction via parametrisation determined using the ALICE simulation and software package (See next talk by Rihan).

Only determined for charged hadrons

TPC acceptance

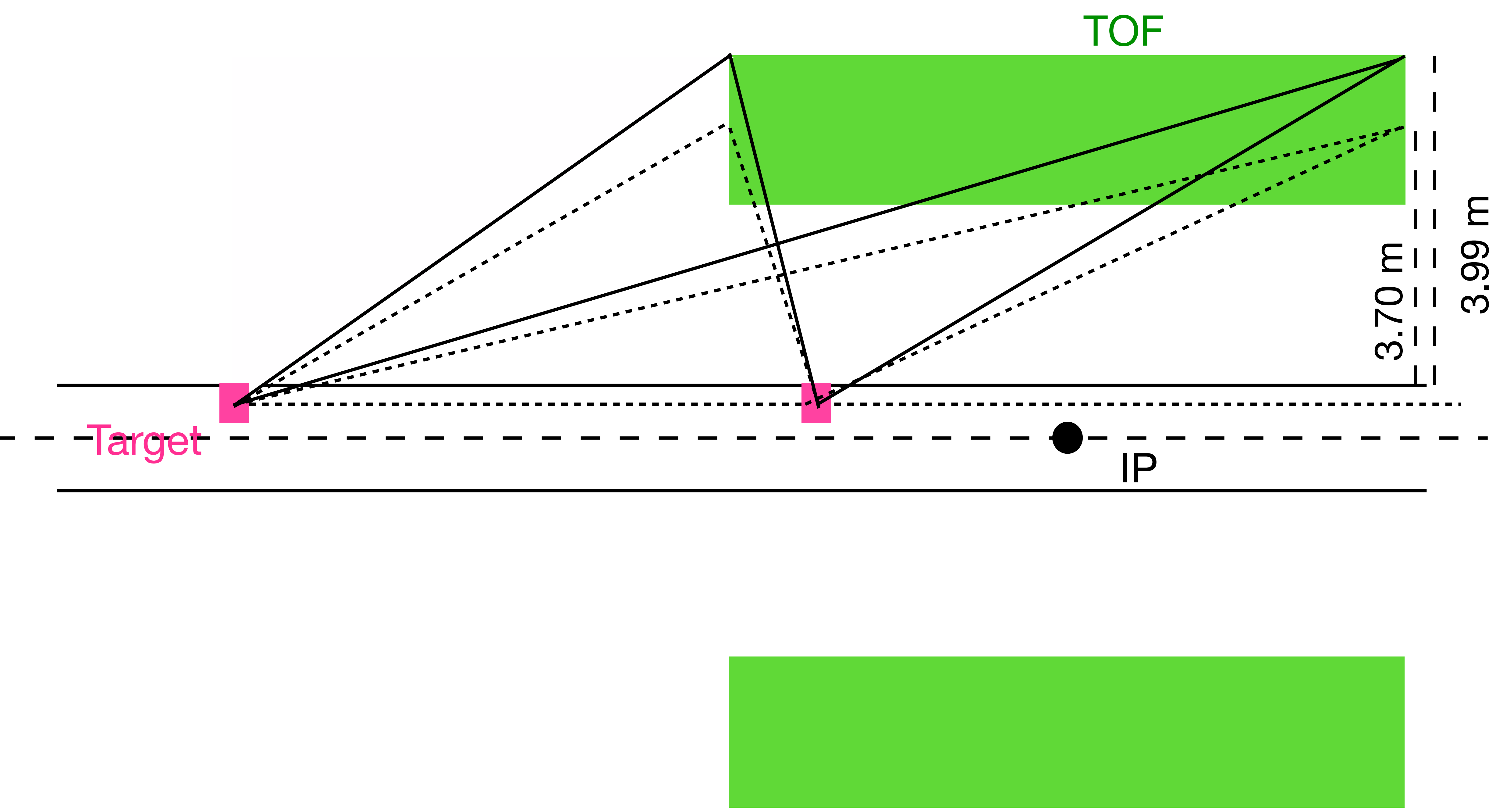


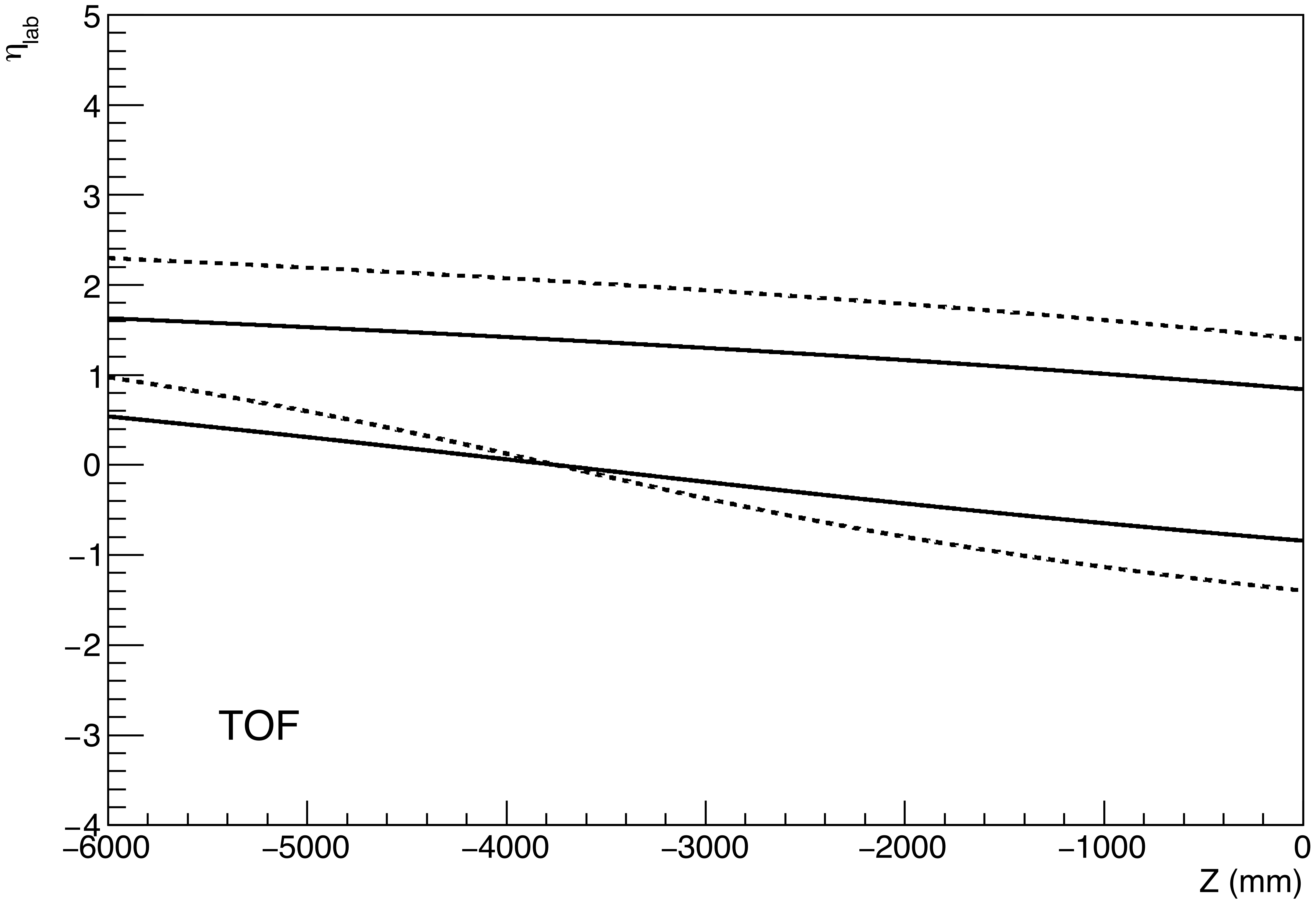


At z=495 cm, $1.33<\eta<2.40$

Optimised acceptance via full simulation, see Rihan's talk: $1.2<\eta<2.2$

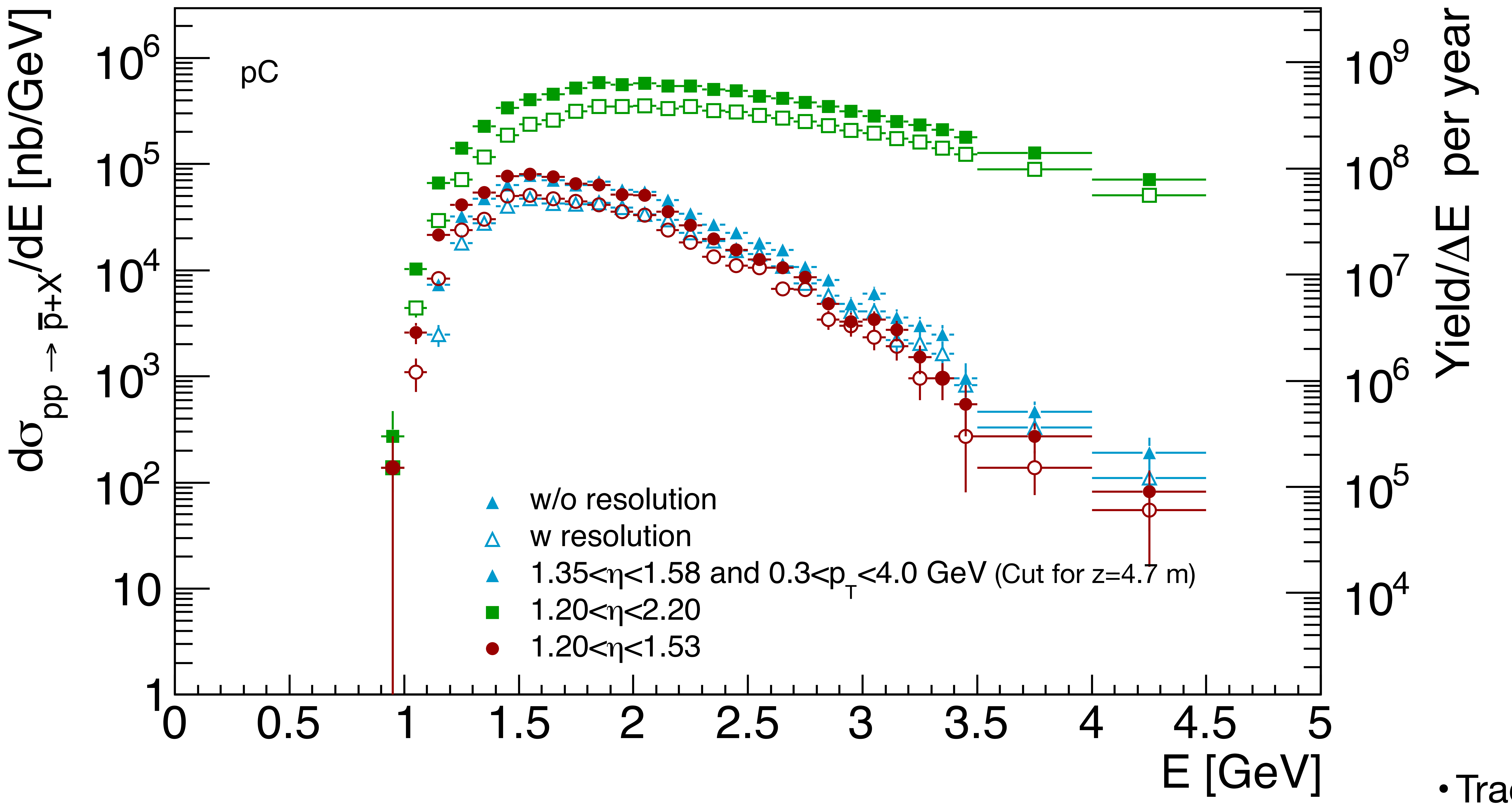
TOF acceptance





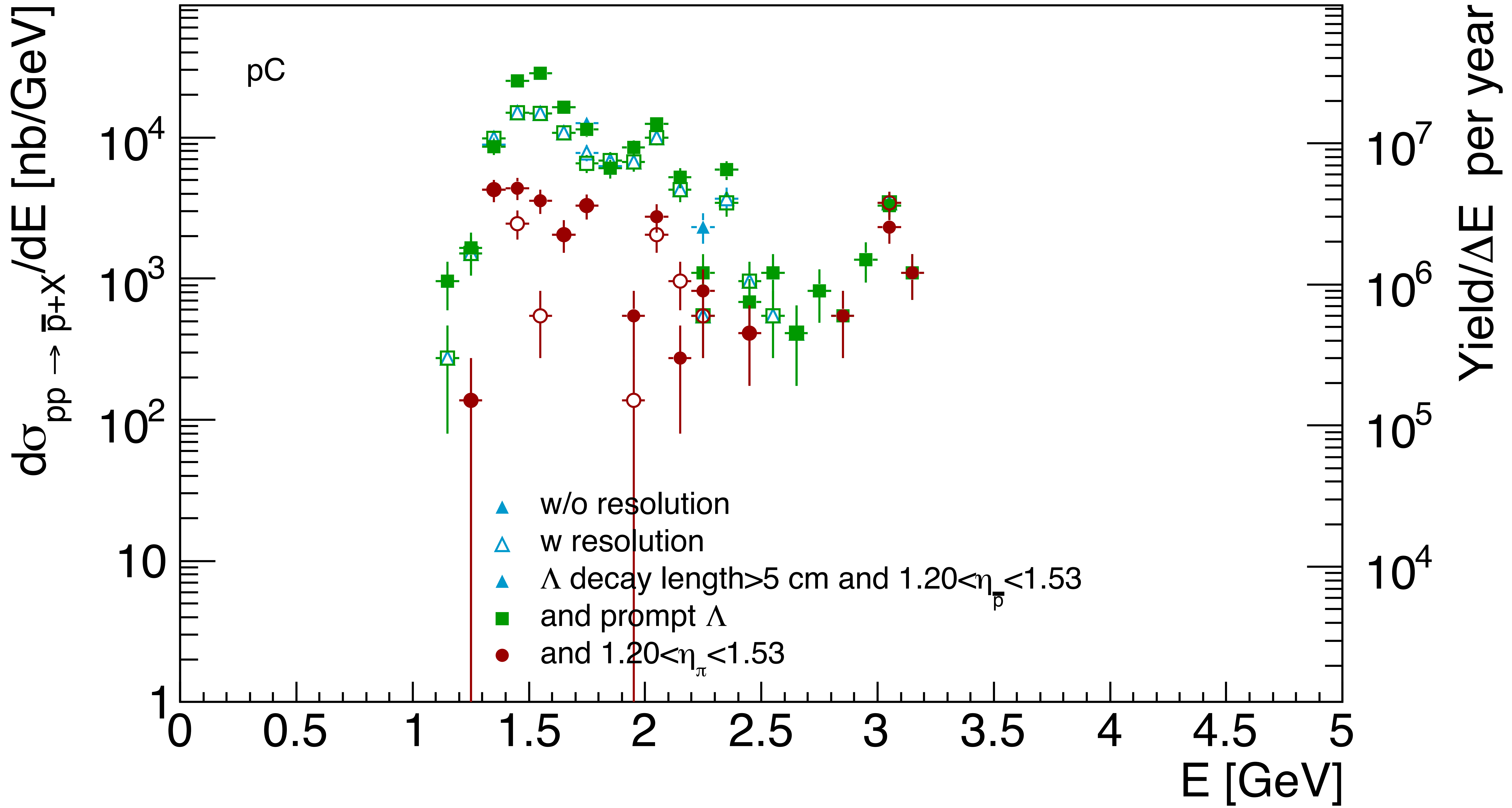
At z=495 cm, $0.30<\eta<1.53$

Anti-proton production



- Tracking efficiency results in 40% reduction of yield

Anti-protons from (prompt) anti-lambda production



- requirement on pion detection results in 80% reduction of yield

Anti-deuteron and anti-helium production

- Anti-deuteron production in cosmic rays:

  important contribution is expected from the nuclear interactions of primary cosmic rays with intergalactic matter.

Anti-deuteron and anti-helium production

- Anti-deuteron production in cosmic rays:

  important contribution is expected from the nuclear interactions of primary cosmic rays with intergalactic matter.

- Production of deuteron in cosmic rays:
  - Interaction of cosmic rays nuclei with interstellar matter
  - p+p -> d π^+
  - production via coalescence:

    Free (anti-)nucleons created in the interaction of cosmic rays with interstellar matter lie sufficiently close in phase-space to form (anti-)deuterons → only mechanism for formation of secondary anti-deuterons

Anti-deuteron and anti-helium production

- Anti-deuteron production in cosmic rays:

  important contribution is expected from the nuclear interactions of primary cosmic rays with intergalactic matter.

- Production of deuteron in cosmic rays:
  - Interaction of cosmic rays nuclei with interstellar matter
  - p+p -> d π^+
  - production via coalescence:

    Free (anti-)nucleons created in the interaction of cosmic rays with interstellar matter lie sufficiently close in phase-space to form (anti-)deuterons → only mechanism for formation of secondary anti-deuterons

- Various dark-matter models predict high enhancement of anti-deuterons at low kinetic energy

Anti-deuteron and anti-helium production

- Anti-deuteron production in cosmic rays:

  important contribution is expected from the nuclear interactions of primary cosmic rays with intergalactic matter.

- Production of deuteron in cosmic rays:
  - Interaction of cosmic rays nuclei with interstellar matter
  - p+p -> d π^+
  - production via coalescence:

    Free (anti-)nucleons created in the interaction of cosmic rays with interstellar matter lie sufficiently close in phase-space to form (anti-)deuterons → only mechanism for formation of secondary anti-deuterons

- Various dark-matter models predict high enhancement of anti-deuterons at low kinetic energy
- Similar production mechanism for anti-helium and likewise a promising detection channels for dark matter

Deuteron and Antideuteron Production Simulation in Cosmic-ray Interactions

Phys. Rev. D 98, 023012 2018

Experiment or Laboratory	Reference	Collision	Final states	p_{lab} (GeV/c)	$\sqrt{s}$ (GeV)	Phase Space
ITEP [a]	[22]	p+Be	p	10.1	4.5	$1\leq p \leq 7.5$ GeV/c; $\theta = 3.5$ deg
CERN [a]	[23, 24]	p+p	p, p̄	19.2	6.1	$2\leq p \leq 19$ GeV/c;
		p+Be	p, p̄			$0.72 \leq \theta \leq 6.6$ deg
CERN [a]	[24]	p+p	p	24	6.8	$2\leq p \leq 9$ GeV/c; $\theta = 6.6$ deg
NA61/SHINE	[25]	p+C	p	31	7.7	$0\leq p \leq 25$ GeV/c; $0\leq \theta \leq 20.6$ deg
	[20]	p+p	p, p̄			$p_T \leq 1.5$ GeV/c; $0.1\leq y \leq 2.0$
NA61/SHINE	[20]	p+p	p, p̄	40	8.8	$p_T \leq 1.5$ GeV/c; $0.1\leq y \leq 2.0$
Serpukhov [a]	[26, 27]	p+p	p, p̄	70	11.5	$0.48\leq p_T \leq 4.22$ GeV/c; $\theta_{lab} = 9.2$ deg
	[28]	p+Be	p, p̄			
	[29]	p+Al	p, p̄			
NA61/SHINE	[20]	p+p	p, p̄	80	12.3	$p_T \leq 1.5$ GeV/c; $0.1\leq y \leq 2.0$
CERN-NA49	[19]	p+p	p, p̄	158	17.5	$p_T \leq 1.9$ GeV/c; $x_F \leq 1.0$
	[30]	p+C	p, p̄			
CERN-NA61	[20]	p+p	p, p̄			$p_T \leq 1.5$ GeV/c; $0.1\leq y \leq 2.0$
CERN-SPS [a]	[31, 32]	p+Be	p, p̄	200	19.4	$23\leq p \leq 197$ GeV/c
		p+Al	p, p̄			$\theta_{lab} = 3.6$ mr, $\theta_{lab} = 0$
Fermilab [a]	[33, 34]	p+p	p, p̄	300	23.8	$0.77 \leq p_T \leq 6.91$ GeV/c;
		p+Be	p, p̄			$\theta_{lab} = 4.4$ deg, $\theta_{cm} = 90$ deg
Fermilab [a]	[33, 34]	p+p	p, p̄	400	27.4	$0.77 \leq p_T \leq 6.91$ GeV/c; $\theta_{lab} = 4.4$ deg
		p+Be	p, p̄			
CERN-ISR	[35]	p+p	p, p̄	1078	45.0	$0.1< p_T <4.8$ GeV/c; $0.0\leq y \leq 1.0$
CERN-ISR	[35]	p+p	p, p̄	1498	53.0	$0.1< p_T <4.8$ GeV/c; $0.0\leq y \leq 1.0$
CERN-LHCb	[36]	p+He	p̄	6.5×10^3	110	$0.0\leq p_T \leq 4.0$ GeV/c; $12\leq p \leq 110$
CERN-ALICE	[37]	p+p	p, p̄	4.3×10^5	900	$0.0\leq p_T \leq 2.0$ GeV/c; $-0.5\leq y \leq 0.5$
CERN-ALICE	[37]	p+p	p, p̄	2.6×10^7	7000	$0.0\leq p_T \leq 2.0$ GeV/c; $-0.5\leq y \leq 0.5$

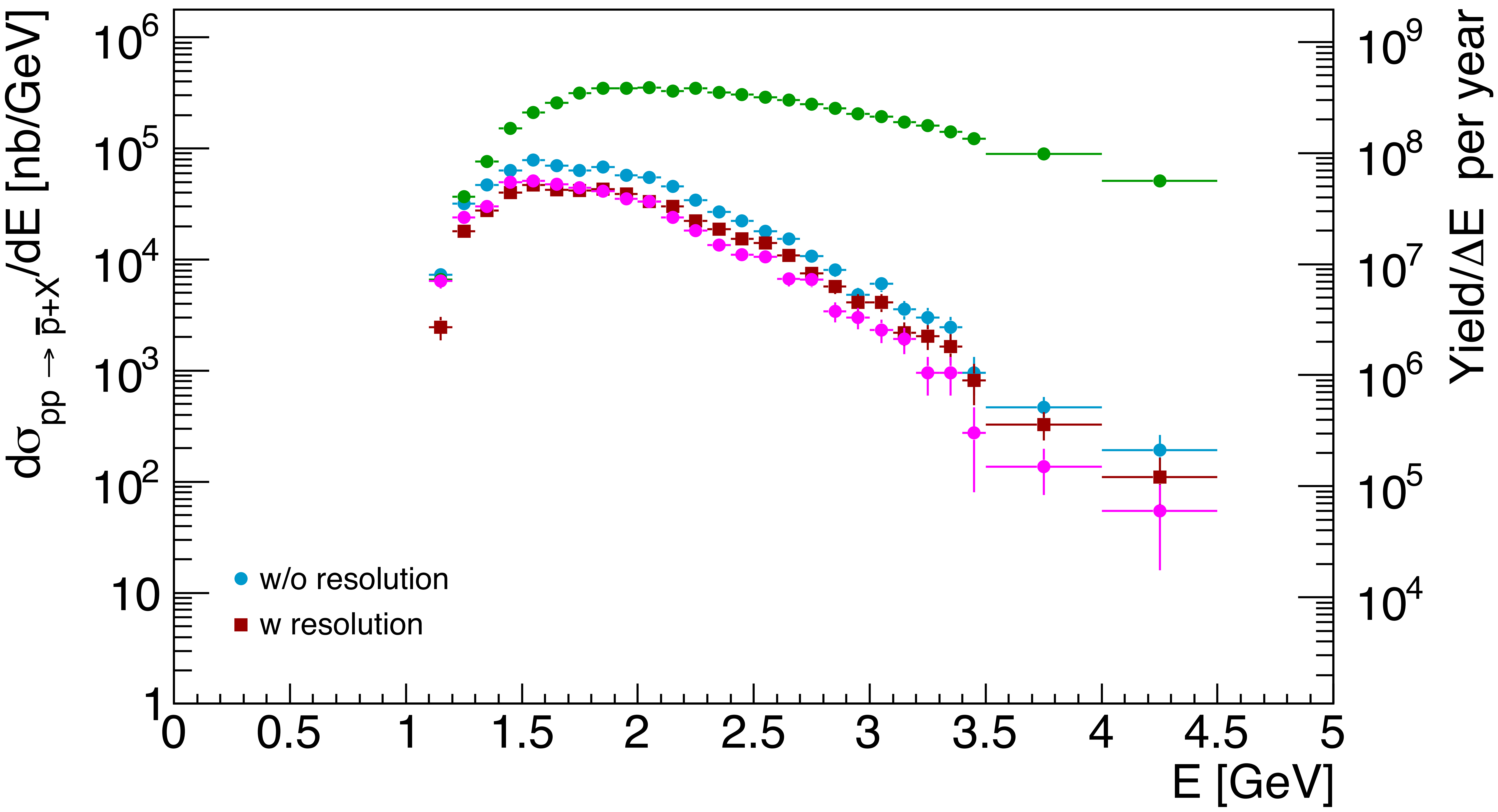
the coalescence momentum depends on the collision energy, and is not constant as previous work suggested

Conclusion and outlook

- Feasibility studies show good capabilities of ALICE FT to perform anti-proton measurements down to low E
- Future studies:
  - Full simulation for anti-proton studies
  - Evaluate best selection for anti-Λ reconstruction
- Extend studies to other anti-particles, such as anti-deuteron and anti-helium

Back up

With pT cut



$d\sigma_{pp \to \bar{p}+X}/dE$ [nb/GeV]
Yield/ΔE per year
E [GeV]
w/o resolution
w resolution
1
10
10^2
10^3
10^4
10^5
10^6
10^4
10^5
10^6
10^7
10^8
10^9
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5