Status of the ALICE Fixed Target project

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The ALICE Fixed Target project

- ❑ Fixed-target setup in ALICE (c.m.s energy $\sqrt{s}$ = 115 GeV for p beam and $\sqrt{s_{NN}}$ = 72 GeV for Pb beam)
  - ➢ Proton(/Pb) beam halo channelled with a bent crystal on a retractable solid target (C, W, Ti…) in ALICE
  - ➢ Backward c.m.s rapidity coverage with forward detectors in the lab thanks to the boost
    - ❖ Access to high Feynman-x_F domain (partons with $x_2 \rightarrow 1$ in the target)
  - ➢ Target versatility from light to heavy target
  - ➢ Outstanding luminosities as large as in the collider case
  - ➢ Target location identified between ~ [485;525] cm upstream of IP2 (ALICE A side)

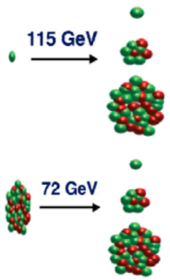
Energy range

7 TeV proton beam on a fixed target

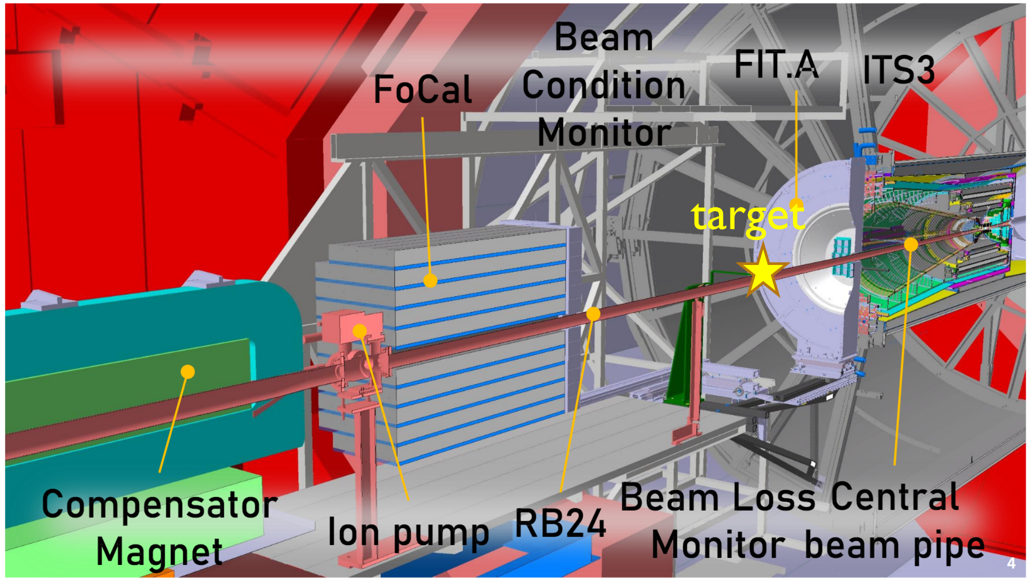
c.m.s. energy: $\sqrt{s} = \sqrt{2m_N E_p} \approx 115\,\mathrm{GeV}$	**Rapidity shift:**
Boost: $\gamma = \sqrt{s}/(2m_N) \approx 60$	$y_{c.m.s.} = 0 \rightarrow y_{lab} = 4.8$

2.76 TeV Pb beam on a fixed target

c.m.s. energy: $\sqrt{s_{NN}} = \sqrt{2m_N E_{Pb}} \approx 72\,\mathrm{GeV}$	**Rapidity shift:**
Boost: $\gamma \approx 40$	$y_{c.m.s.} = 0 \rightarrow y_{lab} = 4.3$



ALICE (A-side) in Run4



The ALICE Fixed Target project

- Two main physics goals identified with an unpolarized fixed-target set-up (see Phys. Rept. 911 (2021) 1-83):

  - Advance our understanding of the large-x gluon, antiquark and heavy-quark content in the nucleon and nucleus (structure of nucleon and nuclei at large-x, gluon EMC effect in nuclei, intrinsic charm in nucleon)

    - Observables: Drell-Yan, antiproton, D mesons…
    - Working on the consolidation of the physics case for the proton beam

      → work still needed to demonstrate the feasibility of Pb beam extraction with bent crystal

  - Study heavy-ion collisions between SPS and RHIC energies towards large rapidities (longitudinal expansion of QGP formation, collectivity in small systems with heavy quarks, factorization of CNM effects)

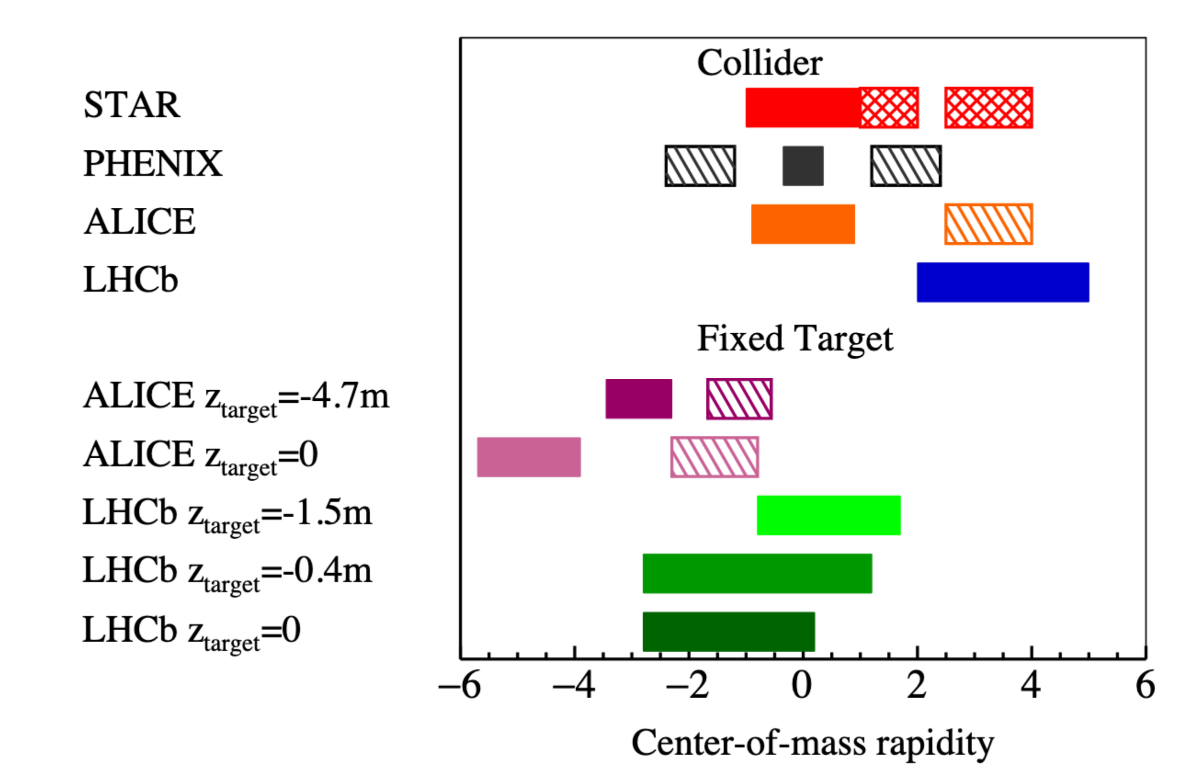
    - Observables: identified particles flow, flow decorrelation, heavy flavour R_{AA} and v_2, Drell-Yan

Main strengths of the ALICE detector in fixed-target mode

- ❑ Large rapidity coverage

  - ➢ ALICE muon arm (+ future MFT) access the mid- to backward- rapidity region ($y_{c.m.s}$<0)
    - ❖ Quarkonium detection down to zero p_T
    - ❖ Rejection of background from π and K decays thanks to the absorber : asset for Drell-Yan studies at low energy

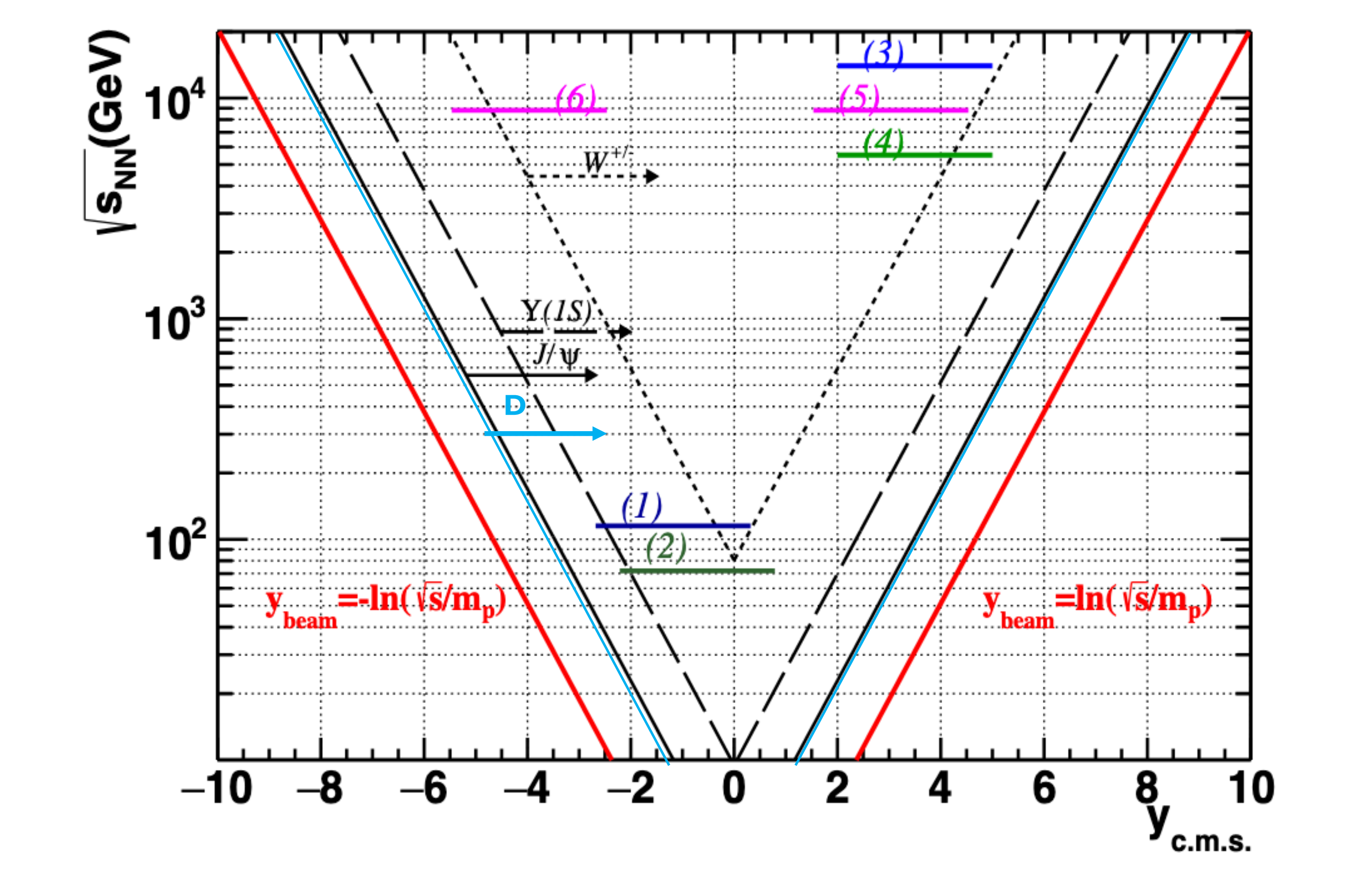
  - ➢ ALICE central barrel probes very backward region (unique wrt to LHCb)
    - ❖ Excellent PID capabilities, particle detection and identification down to low p_T
    - ❖ Caveat: For Z_{target} << 0, ALICE central barrel coverage shifts toward mid-rapidity



Main strengths of the ALICE detector in fixed-target mode

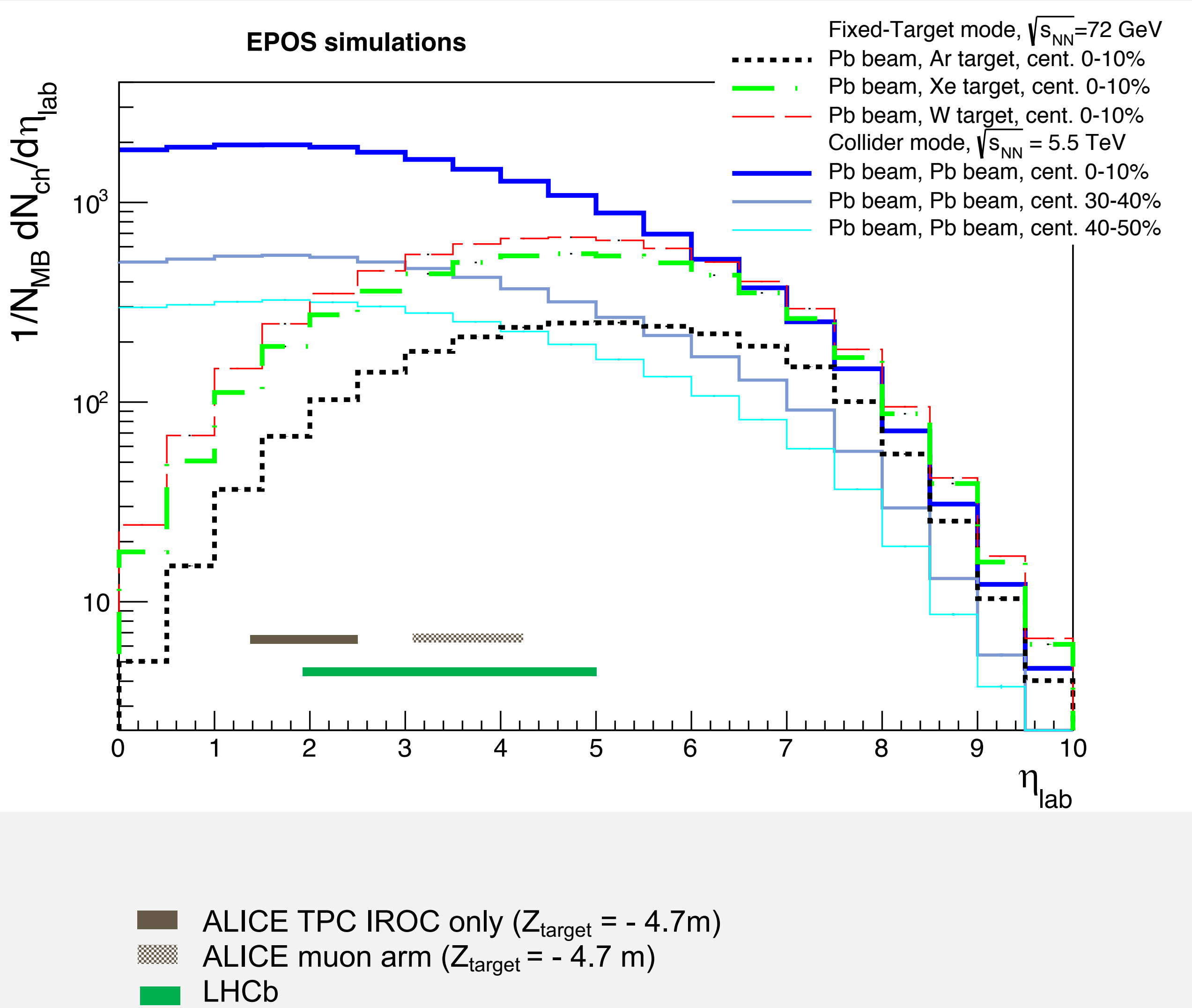
- ❑ Large rapidity coverage

- ➢ End of phase space slightly outside LHCb acceptance for J/ψ and D mesons



(1) pp and pA collisions in fixed target mode (LHCb)
(2) PbA collisions in fixed target mode (LHCb)

Main strengths of the ALICE detector in fixed-target mode



- ALICE can operate with good performance in a high multiplicity environment
- Multiplicities in A–A collisions in FT mode always smaller than the multiplicity in Pb–Pb collisions (centrality 0-10%) in collider mode at $\sqrt{s_{NN}}$ = 5.5 TeV, in the ALICE acceptance
- Multiplicities in most central fixed target Pb–Xe / Pb–W collisions above multiplicity in Pb–Pb collider events for η_{lab} > 2 (centrality 40-50%) , η_{lab} > 3.5 (centrality 30-40%)
- Access to most central fixed FT A–A collisions should be possible with ALICE (if reasonable interaction rate)
- ALICE could potentially devote significant data taking time to a FT programme with the proton beam
  - → Large integrated luminosities
  - → Several target types
- Possibility for low magnetic field runs (0.2T in L3)

Recent news

- ❑ Consolidation of the physics case with the proton beam
- ❑ Ongoing simulations for several probes with realistic TPC performance for displaced vertex (Run 3 software)
- ❑ New studies for the crystal location upstream of ALICE → See talk from M. Patecki
- ❑ New design of the target to comply with the motion of the ITS during EYETS and impact on future FOCAL detector
- ❑ Starting to work on the writing of the Letter Of Intent of the project

→ focussing on few observables with the proton beam : antiproton, D mesons…

See talk from C. Van Hulse

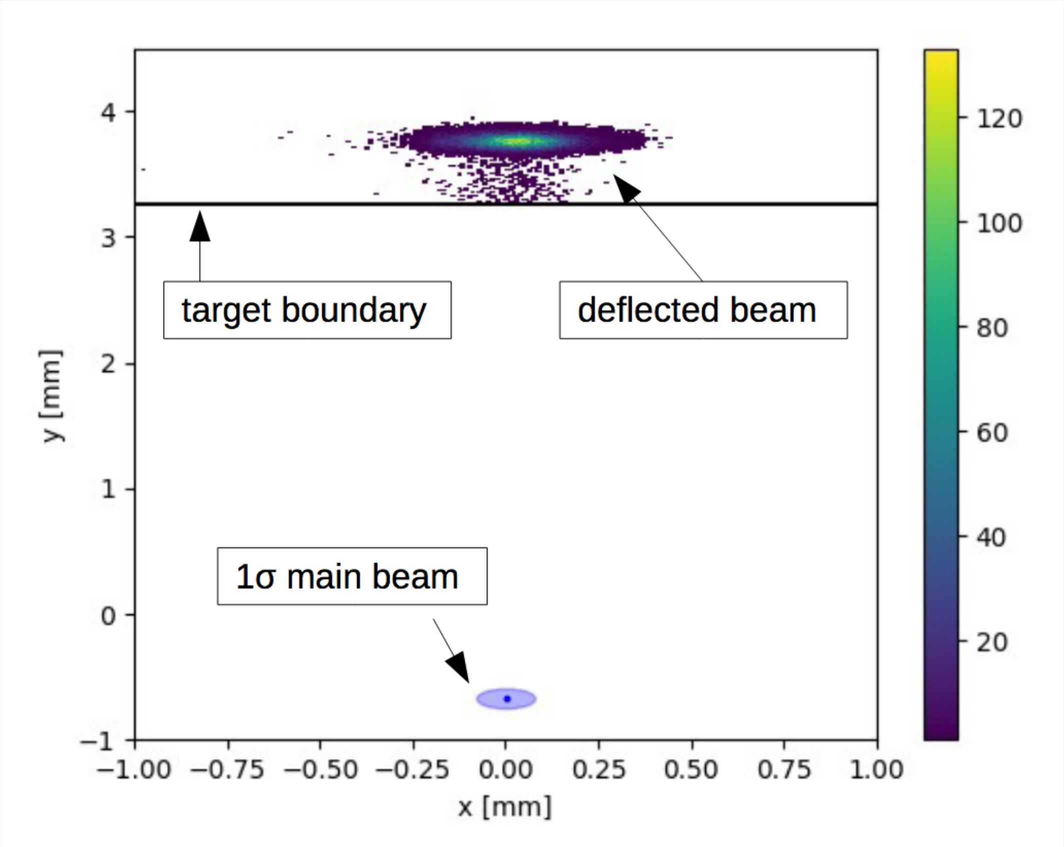
See talk from R. Haque

IMPLEMENTATION AND ACHIEVABLE LUMINOSITIES

Fixed-Target implementation in ALICE

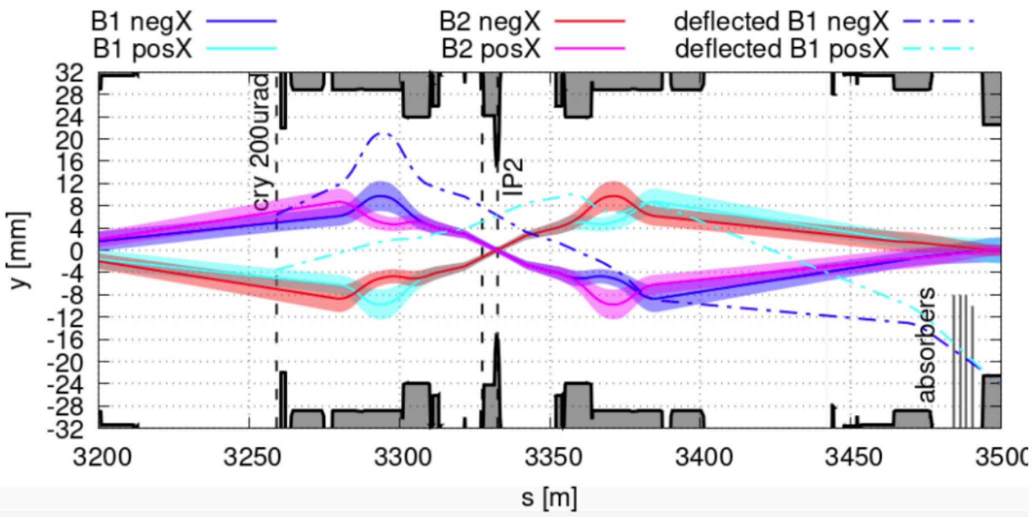
Work from M. Patecki

- ❑ **Beam splitted thanks to a bent crystal + a solid target inside ALICE :**
  - ➢ Halo particles deflected by a bent crystal (~100 m upstream ALICE) sent onto an internal solid target in the ALICE cavern
  - ➢ Particles not interacting with the target need to be absorbed
- ❑ Optimization of the crystal location to maximize the number of particles on target
- ❑ Investigation of the available space upstream of ALICE for possible crystal location
- ❑ Computation of loss maps
- ❑ Positionning of the absorbers downstream to absorb the non-interacting halo

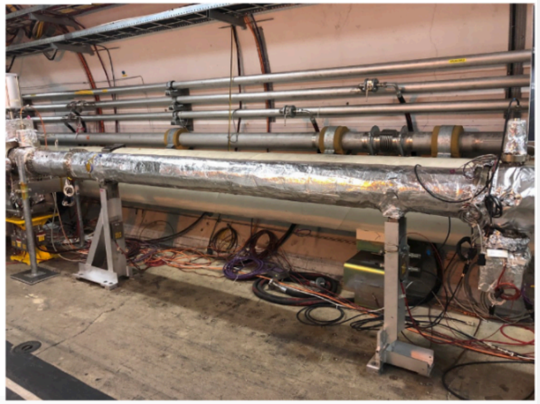


New studies for the crystal location

- Proton beam collimation studies performed (loss maps, positioning of crystal system and of absorbers) and integration studies
- Best performance and easier integration: $z_{crystal} = 3259$ m
- Deflected halo nicely collimated, at least 4 mm away from the main beam at target position (for safety reason)
- Beam optics require adjustment of phase advance to get higher number of Protons on Target (PoT)
- Expected PoT in Run 4: 10^6 p/s as a minimal limit in parasitic mode, equivalent to, for 1cm target length:
  - L = 1.1/pb/year in pC
  - L = 0.6/pb/year in pTi and pW
  - Ongoing studies to increase PoT
- Lead beam studies about to start



space availability at z = 3259 m



M. Patecki, ICFA HB2021 proceedings

Work from M. Patecki

See talk from M. Patecki

Achievable luminosities considering ALICE detector rate limitations

Phys. Rep. 911 (2021) 1-83

Target			ALICE proton beam ($\sqrt{s_{NN}}$ = 115 GeV) $\mathcal{L}$ [$cm^{-2} s^{-1}$]	σ_{inel}	Inel rate [kHz]	$\int \mathcal{L}$	Pb beam ($\sqrt{s_{NN}}$ = 72 GeV) $\mathcal{L}$ [$cm^{-2} s^{-1}$]	σ_{inel}	Inel rate [kHz]	$\int \mathcal{L}$
Internal gas target	Gas-Jet	$H^{\uparrow}$	4.3×10^{30}	39 mb	168	43 pb^{-1}	5.6×10^{26}	1.8 b	1	0.56 nb^{-1}
		H_2	2.6×10^{31}	39 mb	1000	0.26 fb^{-1}	2.8×10^{28}	1.8 b	50	28 nb^{-1}
		$D^{\uparrow}$	4.3×10^{30}	72 mb	309	43 pb^{-1}	5.6×10^{26}	2.2 b	1.2	0.56 nb^{-1}
		$^3He^{\uparrow}$	8.5×10^{30}	117 mb	1000	85 pb^{-1}	2.0×10^{28}	2.5 b	50	20 nb^{-1}
		Xe	7.7×10^{29}	1.3 b	1000	7.7 pb^{-1}	8.1×10^{27}	6.2 b	50	8.1 nb^{-1}
Beam splitting	Unpol-arised solid target	C (658 μm)	3.7×10^{30}	271 mb	1000	37 pb^{-1}	–	–	–	–
		C (5 mm)	–	–	–	–	5.6×10^{27}	3.3 b	18	5.6 nb^{-1}
		Ti (515 μm)	1.4×10^{30}	694 mb	1000	14 pb^{-1}	–	–	–	–
		Ti (5 mm)	–	–	–	–	2.8×10^{27}	4.7 b	13	2.8 nb^{-1}
		W (184 μm)	5.9×10^{29}	1.7b	1000	5.9 pb^{-1}	–	–	-	–
		W (5 mm)	–	–	–	–	3.1×10^{27}	6.9 b	21	3.1 nb^{-1}

Assumptions:

	proton beam	lead beam
Number of bunches in the LHC	2808	592
Number of particles per bunch	1.15×10^{11}	7×10^7
LHC Revolution frequency [Hz]		11245
Particle flux in the LHC [s^{-1}]	3.63×10^{18}	4.66×10^{14}
LHC yearly running time [s]	10^7	10^6
Nominal energy of the beam [TeV]	7	2.76
Fill duration considered [h]	10	5
Usable particle flux in the halo (when relevant) [s^{-1}]	5×10^8	10^5

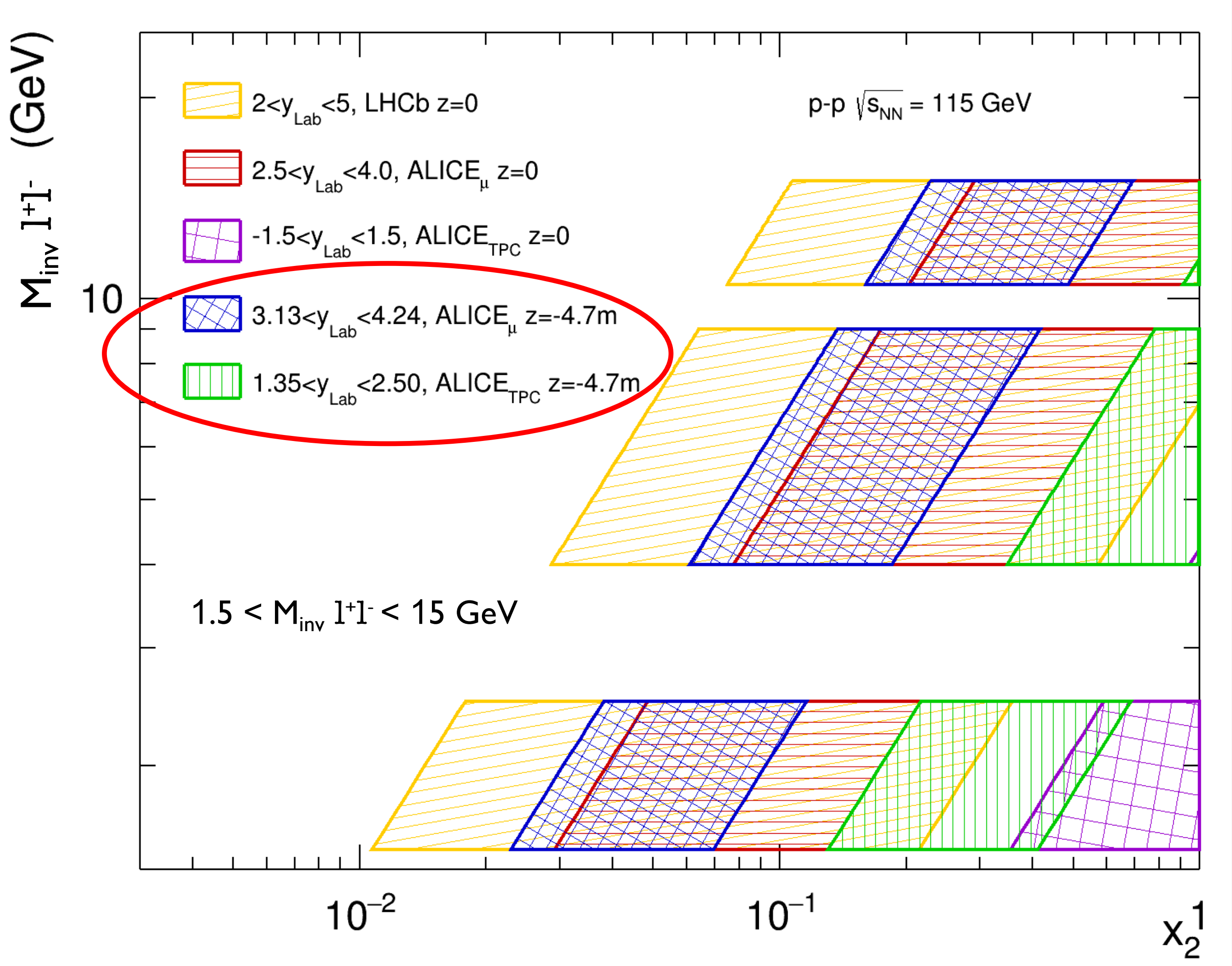
- ALICE runs the full year in fixed target mode
- Maximum readout rate considered 1MHz in pp/pA collisions and 50kHz in PbA

- Proton flux to be (re)considered from recent studies: 10^6 p/s
- Decrease of the flux can be compensated by increasing the target thickness
  eg: pC ($\Phi = 10^6$ p/s, length = 1cm, L_{int} = 1.1pb^{-1}), pTi/pW ($\Phi = 10^6$ p/s, length = 1cm, $L_{int} \sim 0.6\ pb^{-1}$),
- Extraction of Pb beam with bent crystal needs further studies (crystal location (primary/secondary/tertiary halo), composition in terms of species of the channelled ion beam…) Phys. Lett. B703 (2011) 547–551 (UA9 studies with Pb beam)

PHYSICS CASE

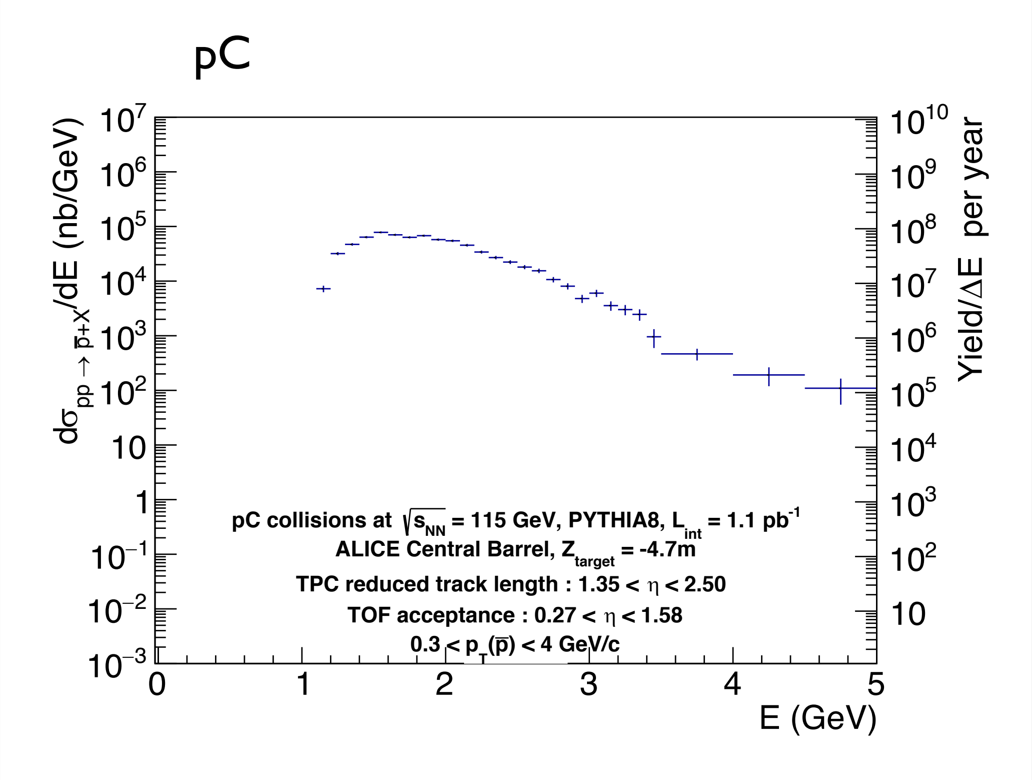
High-x physics: Drell-Yan to probe the nucleon structure

- ❑ DY measurement can constrain the valence and light sea quark PDFs at large-x
- ❑ Measurement of DY pairs in the ALICE central barrel would allow measurement up to $x_2 \rightarrow 1$ for intermediate mass Drell-Yan pairs
- ❑ Same reach in pA with Drell-Yan to constrain valence and see quark nPDFs



Antiproton production for CR physics

- ❑ Antiproton production in pH, pA collisions : important input for astrophysics (Dark Matter searches)
- ❑ Constrain models for secondary antiproton production in interstellar medium and be able to confirm excess in data (AMS)
  - ➢ **p/^{4}He/^{12}C/^{14}N/^{16}O/… (cosmic ray) + H (at rest) → antiproton of large E**
  - ➢ Equivalent to: **p (7 TeV beam) + p/^{4}He/^{12}C/^{14}N/^{16}O/… (at rest) → antiproton of small E**
  - ➢ Complementary measurement with respect to LHCb



- ❑ Minimum bias pp collisions scaled to pC
- ❑ "ALICE-like" detector performances (central barrel)
- ❑ Z_{target} = - 4.7m
- ❑ Yearly luminosity : $L_{int} = 1.1 pb^{-1}$:

➡ ALICE CB is accessing the very low energy domain for antiproton production
Large yearly yields expected

See talk from C.Van Hulse

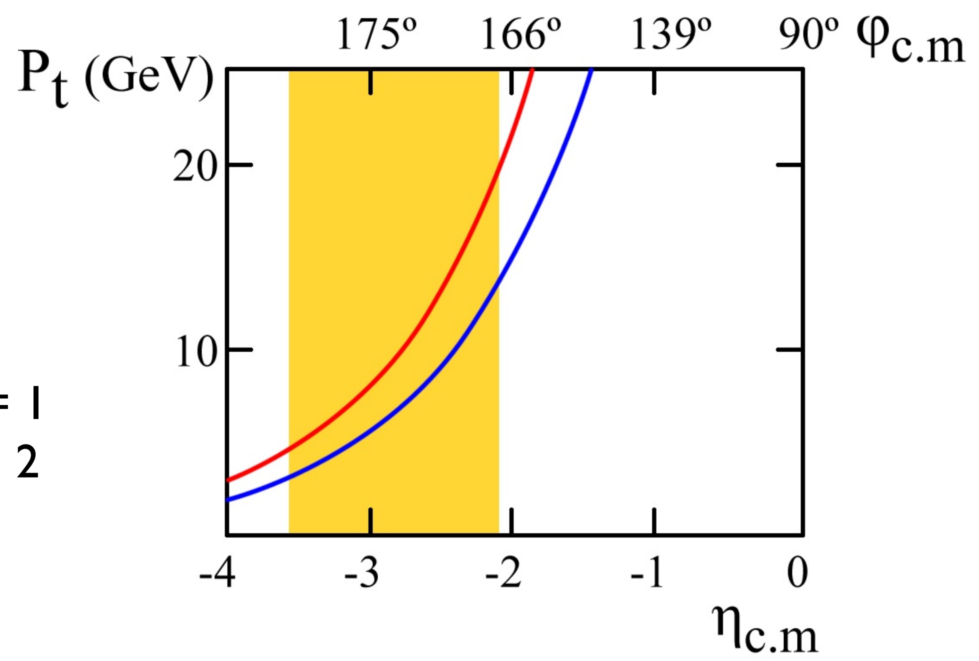
Antiproton subthreshold production in pA collisions

Work from A. Kurepin

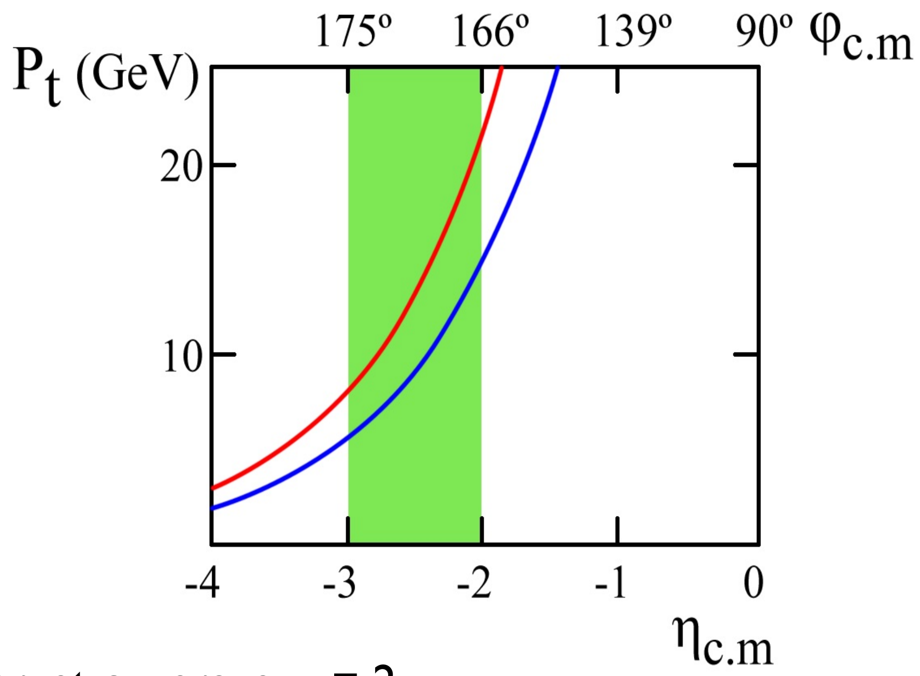
- Measure the cross section for antiproton production in pA fixed target collisions in a kinematically forbidden region
- Estimate the subthreshold production of superheavy particles (~ 10 TeV) with LHC Pb-Pb collisions and search for new physics
- Measurements from 3-20 GeV/c possible in the TPC

x > 1 kinematically forbidden region

Blue line x = 1
Red line x = 2



Target coverage, x =1

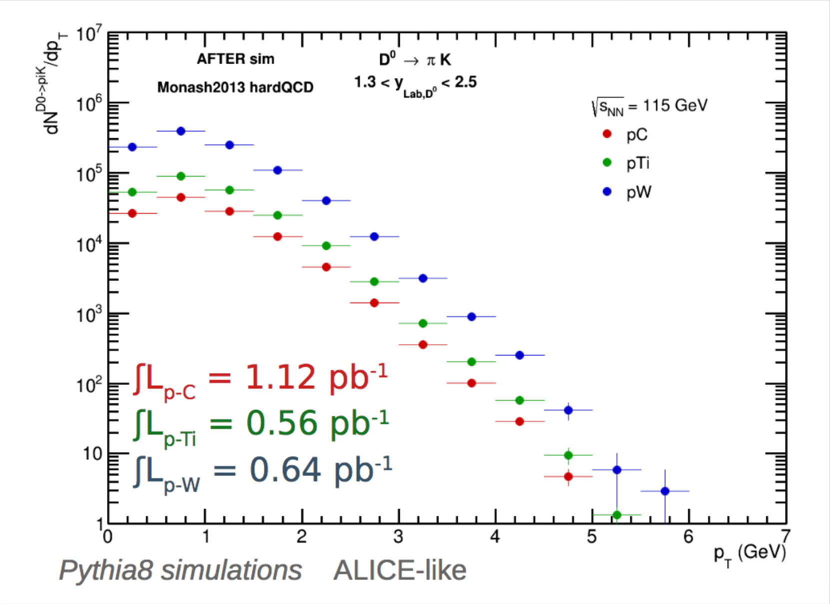


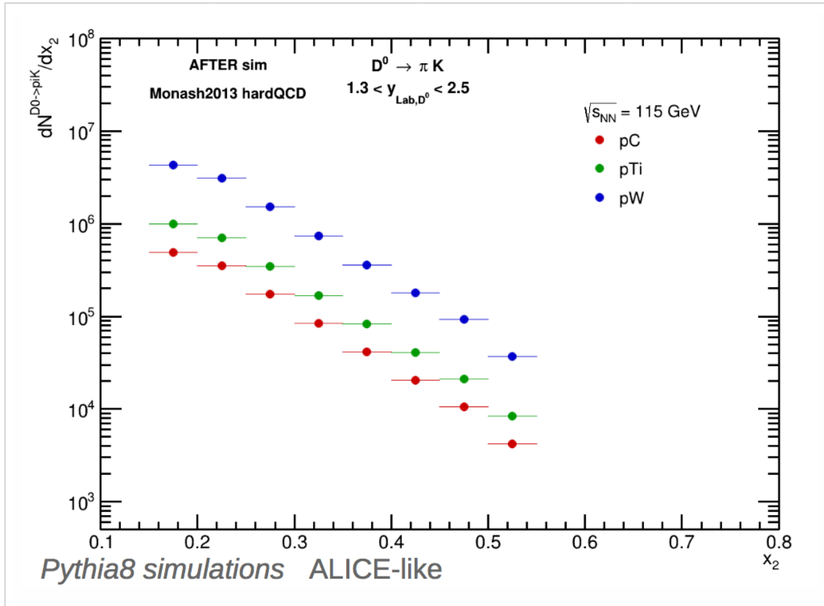
Target coverage, x = 2

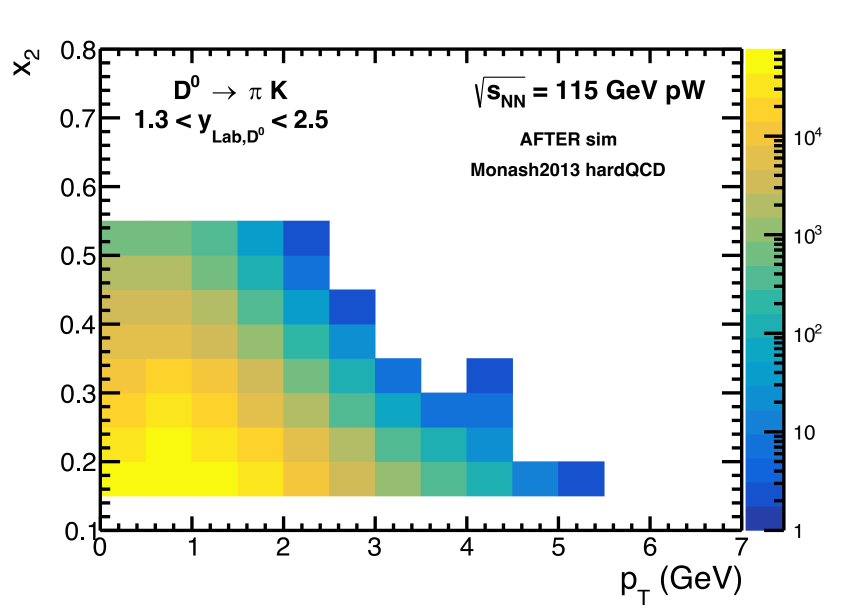
Heavy flavour production in pA collisions

Work from B. Trzeciak

- Study large-x gluon nPDFs [assuming modification of nPDF is the dominant Cold Nuclear Matter effect, also need pH reference]
- Intrinsic Charm in light nucleus ? [Phys. Lett. B. 783 (2018) 287-293](#)
- Target Z = - 4.7m, 1 cm long solid target (C, Ti, W), $-3.5 < y^{D}_{CMS} < -2.3$
- $D^0 \rightarrow \pi^+K^-$, BR = 3.89%, AxEff = 2%
- Precise measurement up to p_T ~ 4 GeV/c, x_2 coverage 0.15 – 0.55 [Note for y_{lab}=1.3, $y_{c.m.s}$ = -3.5, x_2 ~ 0.74]



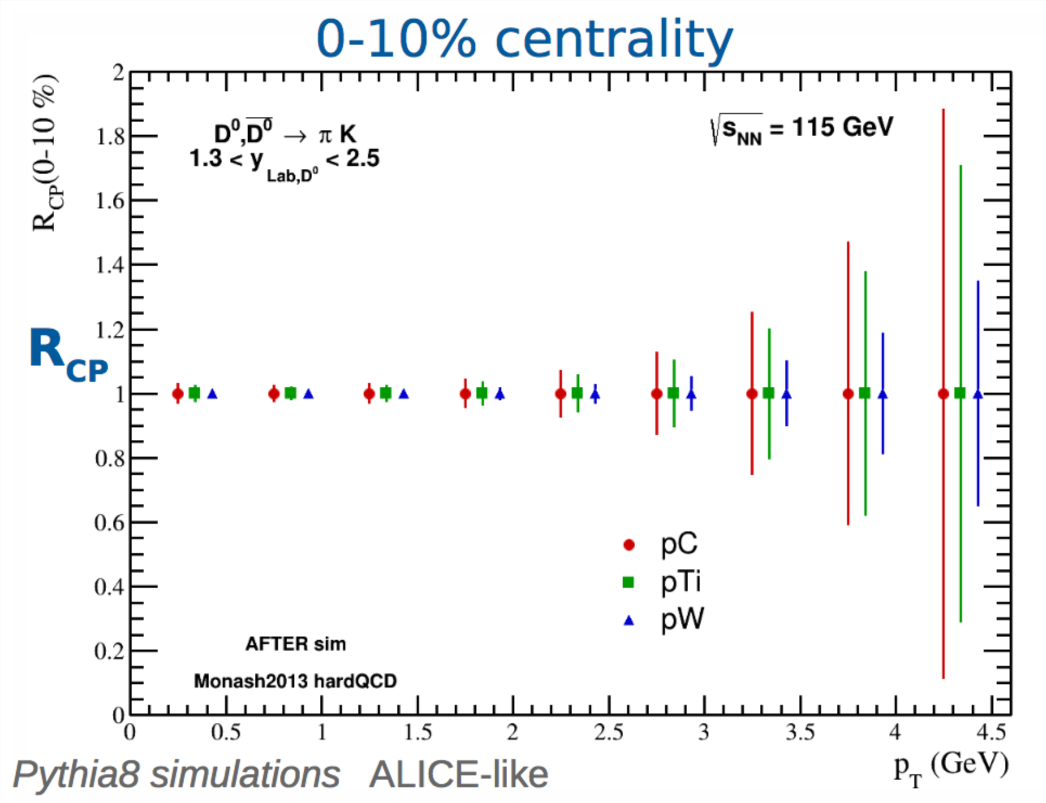




D^0 meson R_{CP} in pA collisions

Work from B. Trzeciak

- Study of CNM effects and collectivity in small systems with simultaneous measurements of D meson R_{CP} and v_2 in different systems
- Target z = - 4.7m, 1 cm long solid target (C, Ti, W), $-3.5 < y^D_{CMS} < -2.3$, $D^0 \rightarrow \pi^+K^-$, BR = 3.89%, AxEff = 2%
- Central bin : 0-10%, peripheral bin : 60-100%,



For 0-10% centrality

$\int L_{p\text{-}C} \approx 92\ nb^{-1}$

$\int L_{p\text{-}Ti} \approx 43\ nb^{-1}$

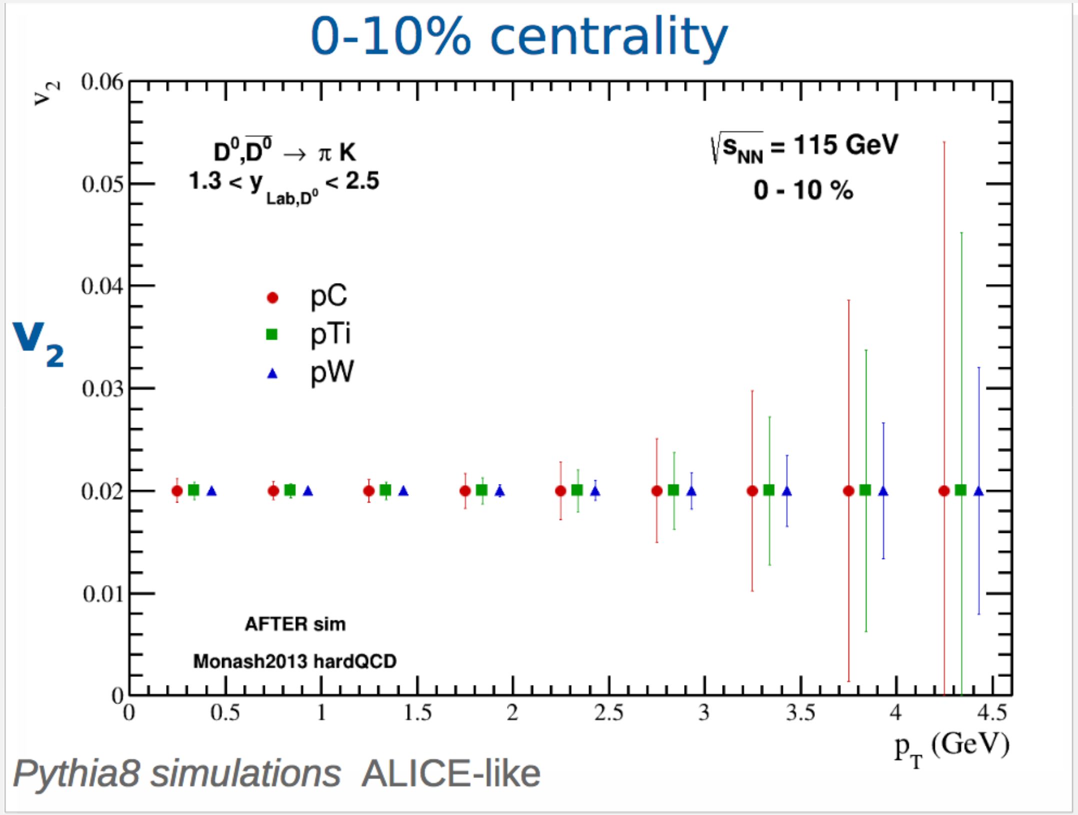
$\int L_{p\text{-}W} \approx 47\ nb^{-1}$

- Precise R_{CP} measurement up to 3 GeV/c
- Similar precision expected in 10-20, 20-40% centrality intervals

D^0 meson v_2 in pA collisions (centrality 0-10%)

Work from B. Trzeciak

- Study of CNM effects and collectivity in small systems with simultaneous measurements of D meson R_{CP} and v_2 in different systems
- Target z = - 4.7m, 1 cm long solid target (C, Ti, W), $-3.5 < y^D_{CMS} < -2.3$, $D^0 \rightarrow \pi^+K^-$, BR = 3.89%, AxEff = 2%
- Event plane resolution 0.2



- Precise flow measurements up to $p_T \sim 3$ GeV/c

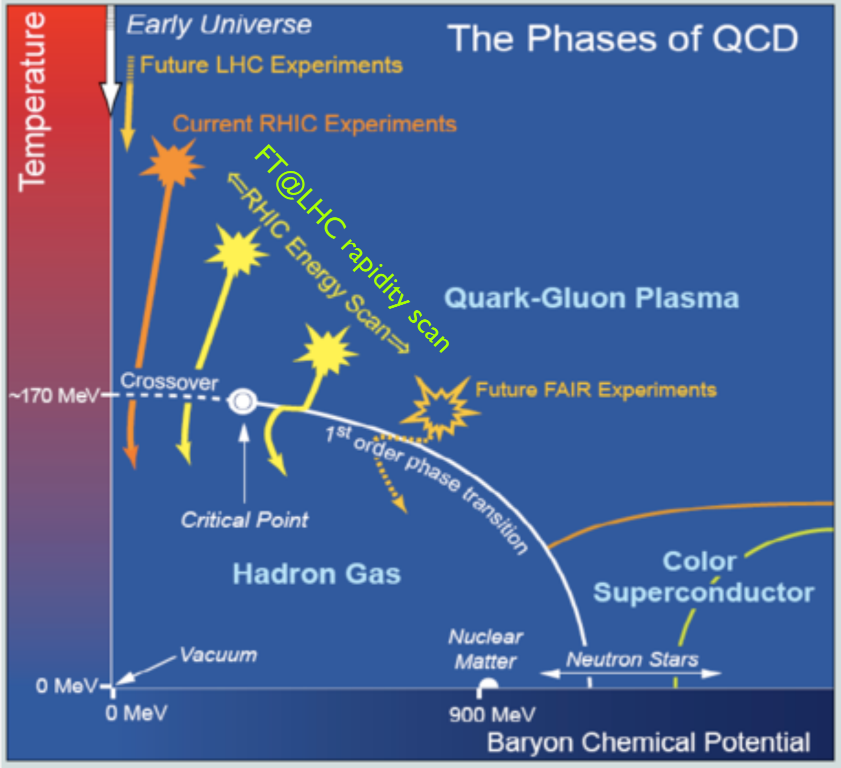
Heavy Ion physics case : rapidity scan to search for QCD critical point

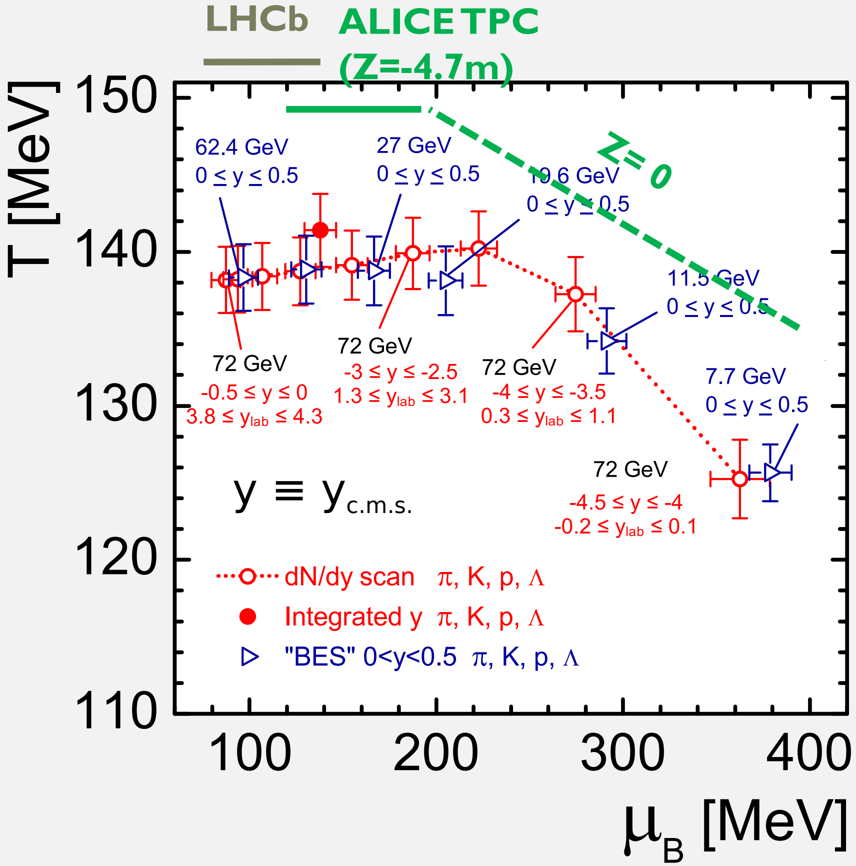
- **Advance the understanding of hadronic matter properties under extreme conditions (QGP) and explore the phase diagramme of nuclear matter thanks to a rapidity scan down to the target rapidity**

- Systematic studies of the medium properties with three experimental degrees of freedom : rapidity scan, different colliding systems, centrality dependence

- Rapidity scan at 72 GeV with FT@LHC can complement the RHIC beam energy scan from 62.4 GeV down to 7.7 GeV (at y_{cms} ~ 0)

- A novel way to search for the QCD critical point and probe the nature of the phase transition to confined partons

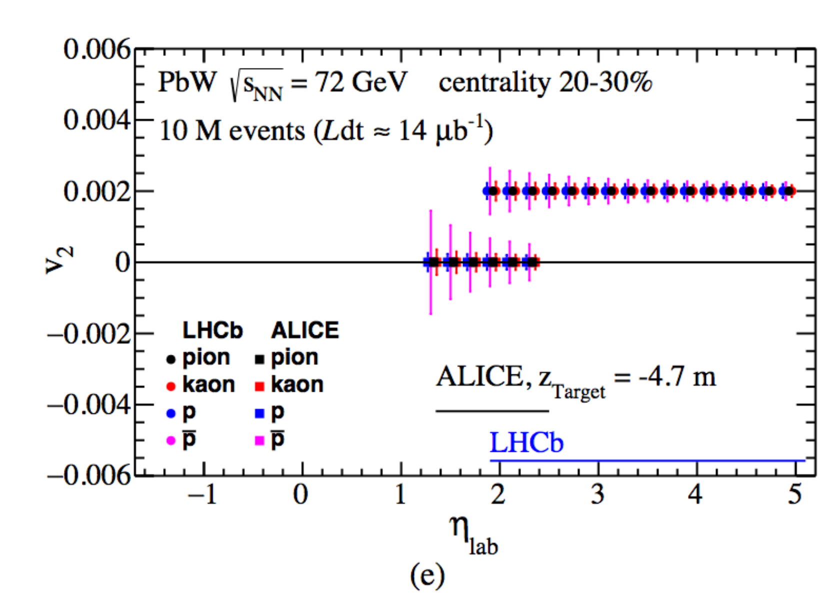




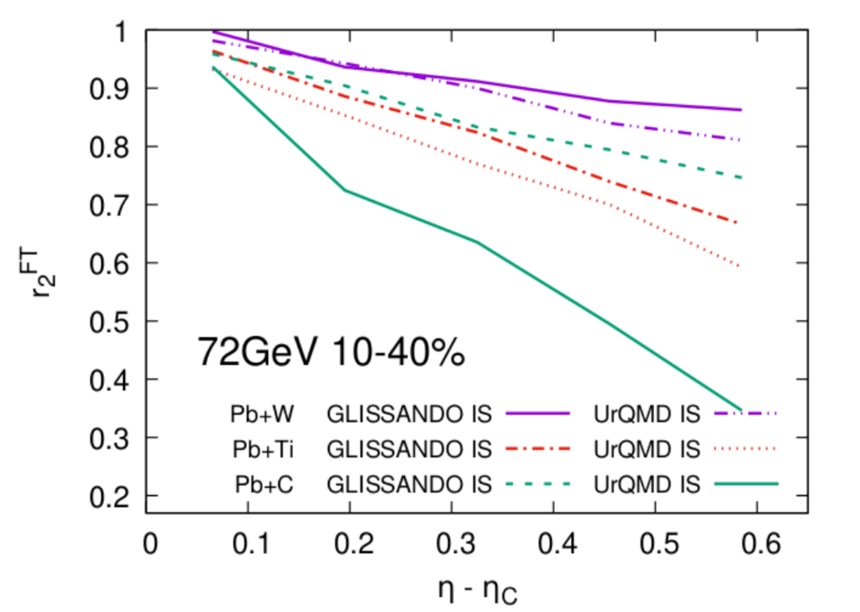
V. Begun, D. Kikola, V. Vovchenko, D. Wielanek, PRC 98 (2018) 034905

Heavy Ion physics case

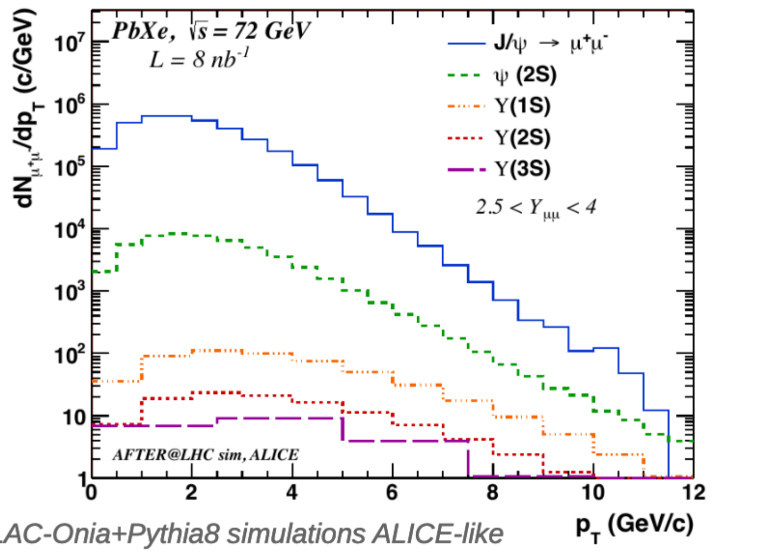
- ❑ **QGP macroscopic properties : temperature dependence of η/s of the created matter**



- ❑ **Study the longitudinal dynamics of HI collisions → information on the initial stages of the collision**



- ❑ **Quarkonium suppression in medium**



HELAC-Onia+Pythia8 simulations ALICE-like

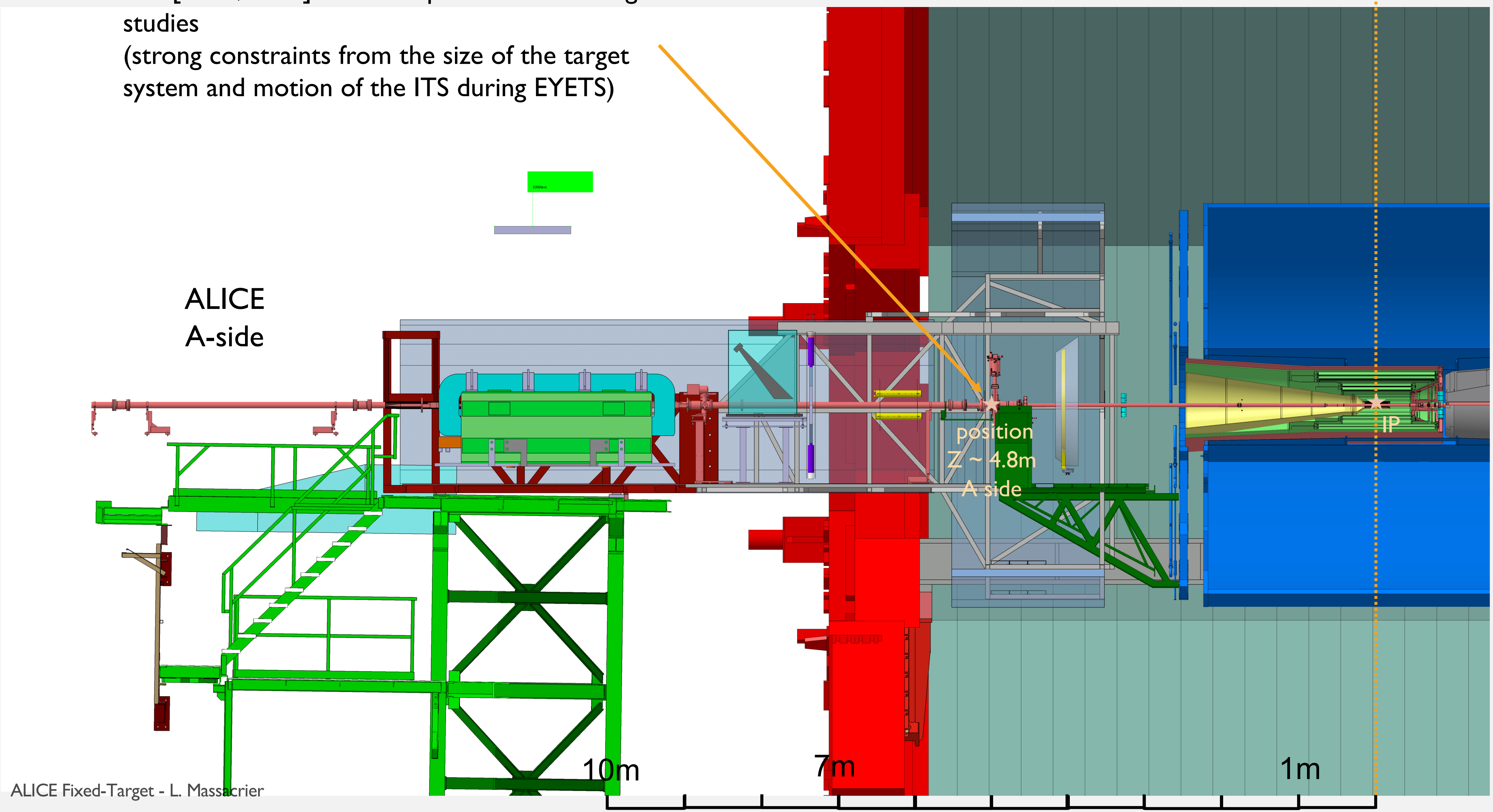
For an overview **See talk from B. Trzeciak**

INTEGRATION

Possible target location

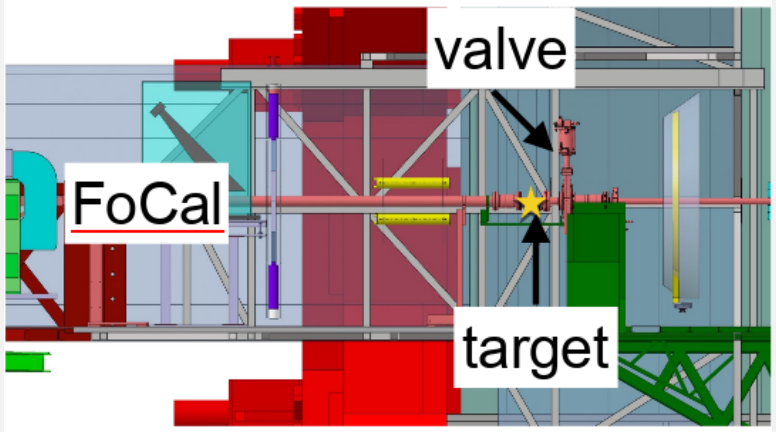
Z ~ [-5.25; -4.85] : favored position from integration studies
(strong constraints from the size of the target system and motion of the ITS during EYETS)

ALICE
A-side

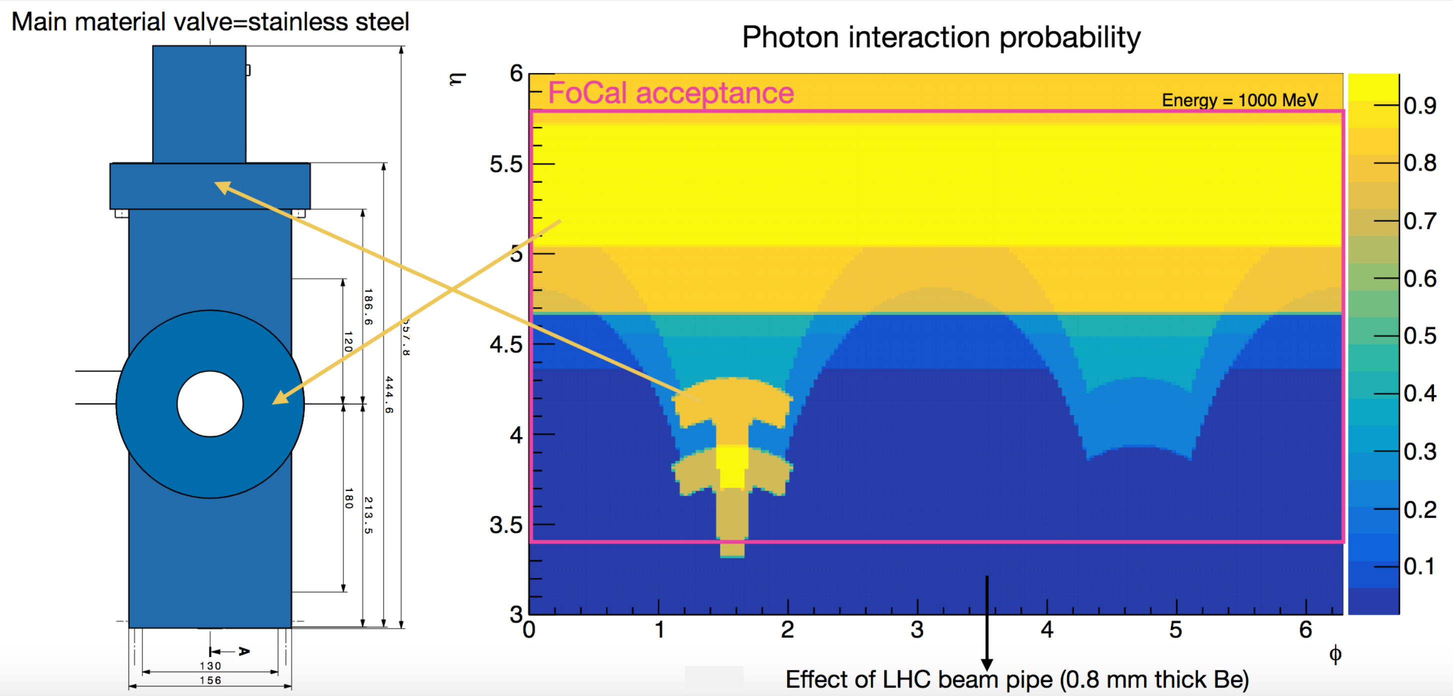


Integration constraints and impact of the fixed target setup on FOCAL

- Integration constraints :
  - Need to isolate the pipe region where the target will be located
  - Take into account ITS removal constraints during winter shutdown
  - Need pumping system because of target outgassing and bake-out device
  - RF shielding probably needed (need further impedance studies)
  - Avoid shadow to FOCAL detector (LOI presented to LHCC in Jun. 2020) CERN-LHCC-2020-009



Work from C. Van Hulse

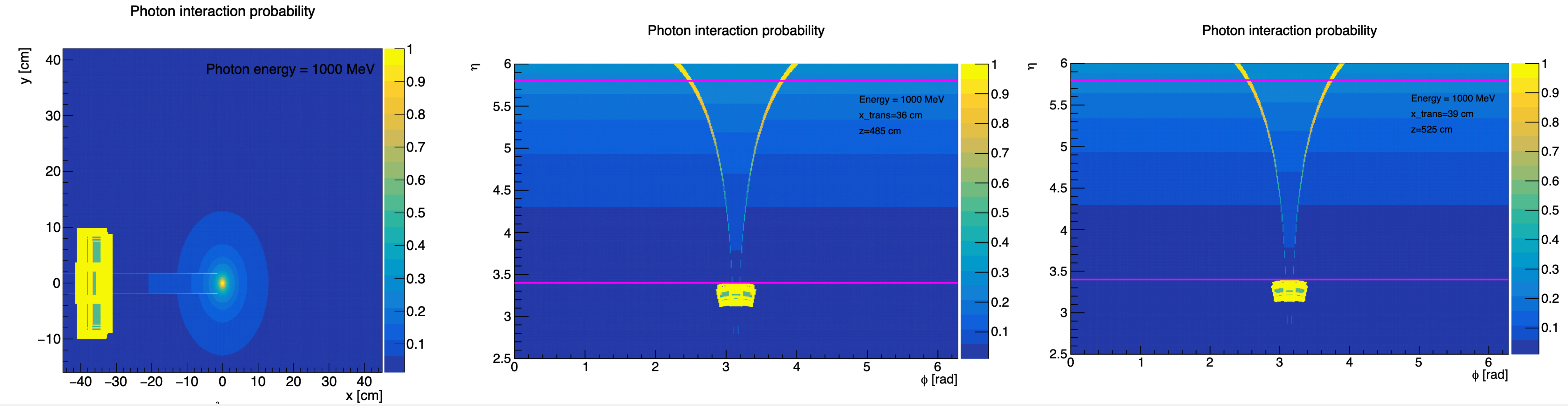


Current valve in the acceptance of FOCAL detector with strong impact on photon interaction probability

Integration constraints and impact of the fixed target setup on FOCAL

Work from C.Van Hulse

- ❑ Proposed solution : target system connected to main LHC beam pipe via a transverse beam pipe, and vacuum valve moved on the transverse pipe
- ❑ Vacuum valve (for target system vacuum isolation when target is not used) better placed at 36 cm (for Z_{target} = -4.85m) or at 39 cm (for Z_{target} = -5.25m) from the beam pipe, in the transverse plane, to reduce the material budget in front of FOCAL



Optimization of the target design

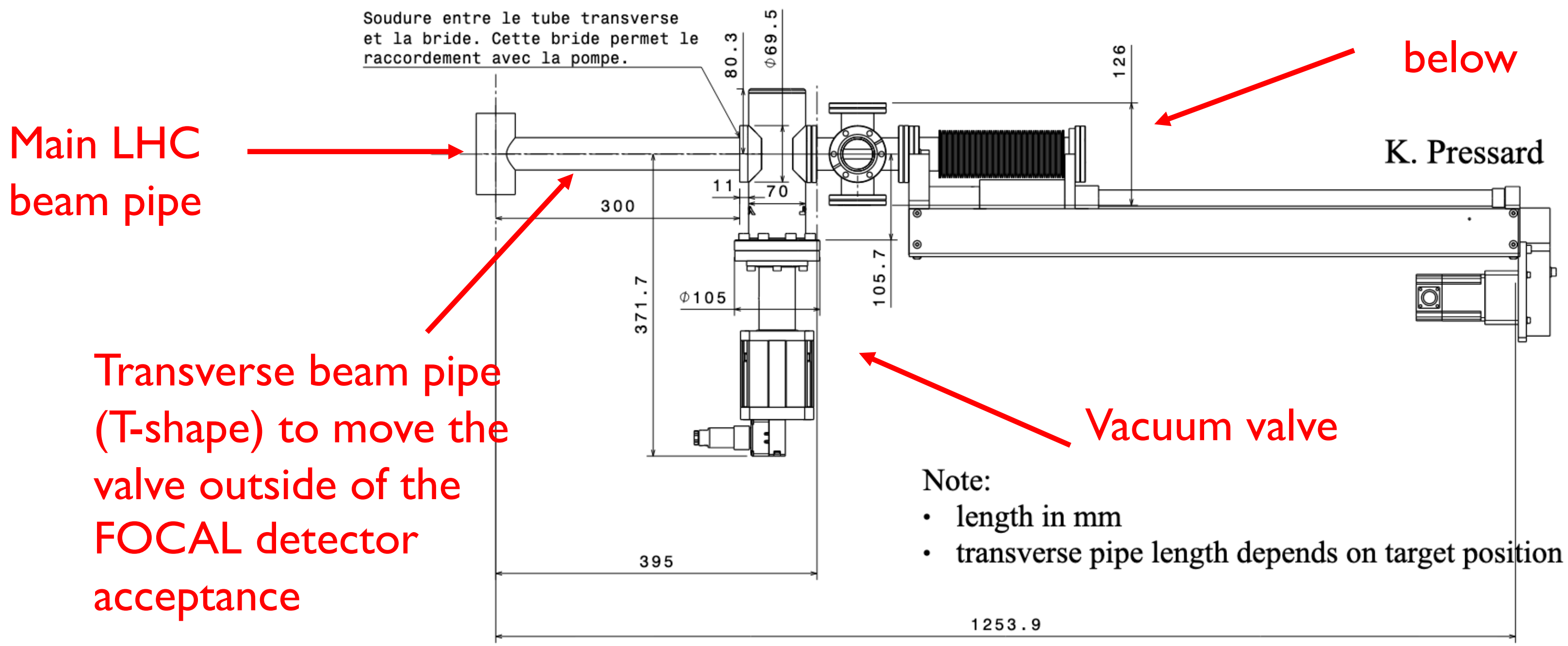
Work from K. Pressard

Target system

- step motor to achieve a better movement resolution
- retractable target with linear motion
- target actuator lies in a vacuum chamber and moves thanks to a step motor that compresses a bellow
- vacuum valve closed when target is fully retracted
- target, crosses and bellow can be removed during EYETS

One valve solution

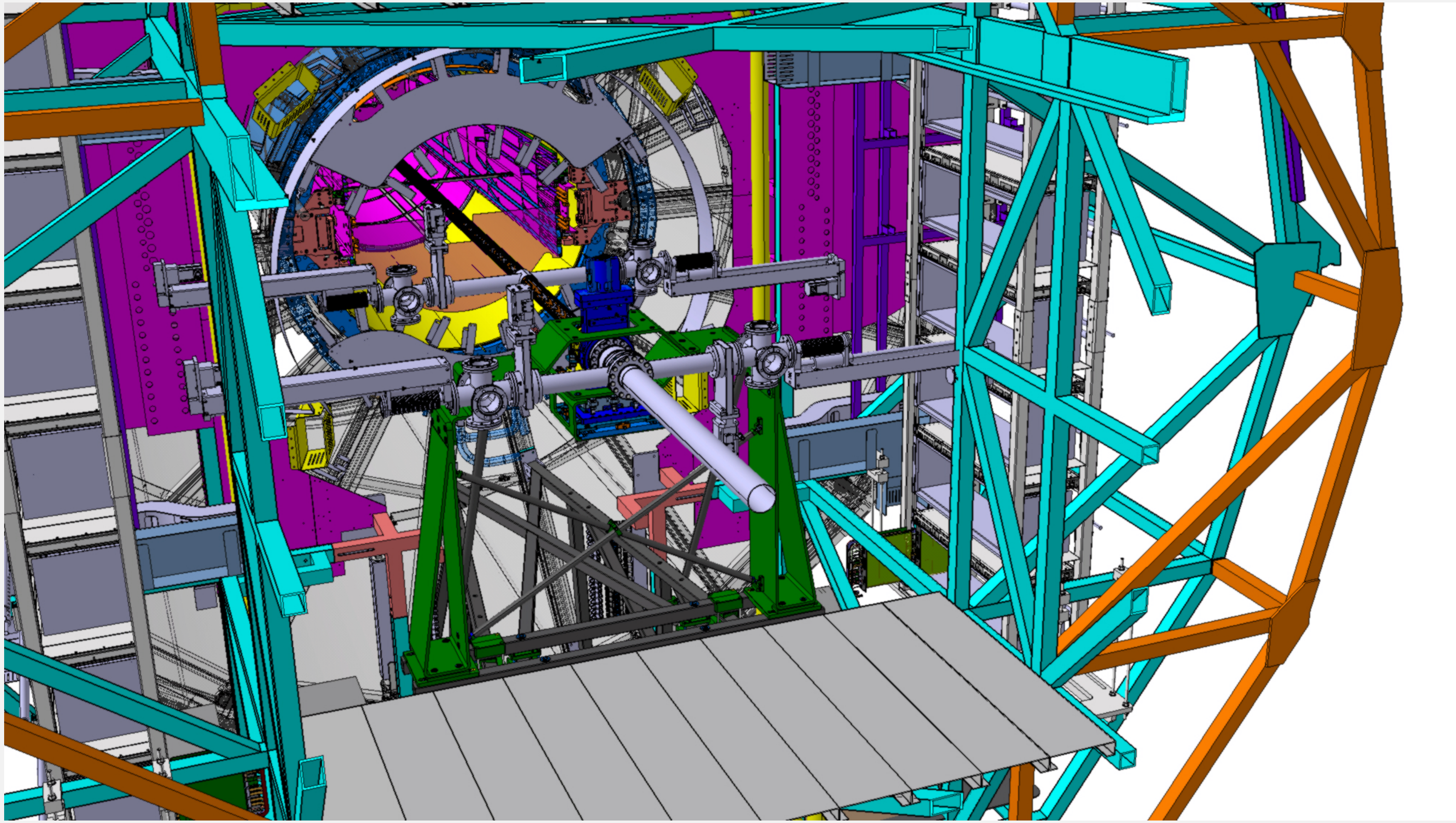
- vacuum related task must be performed in the cavern
- pumps switch on before opening the valve
- moving speed: 10 mm/s
- accuracy: 10 µm
- estimated cost: 17 kEuros (without vacuum eq.)



Note:

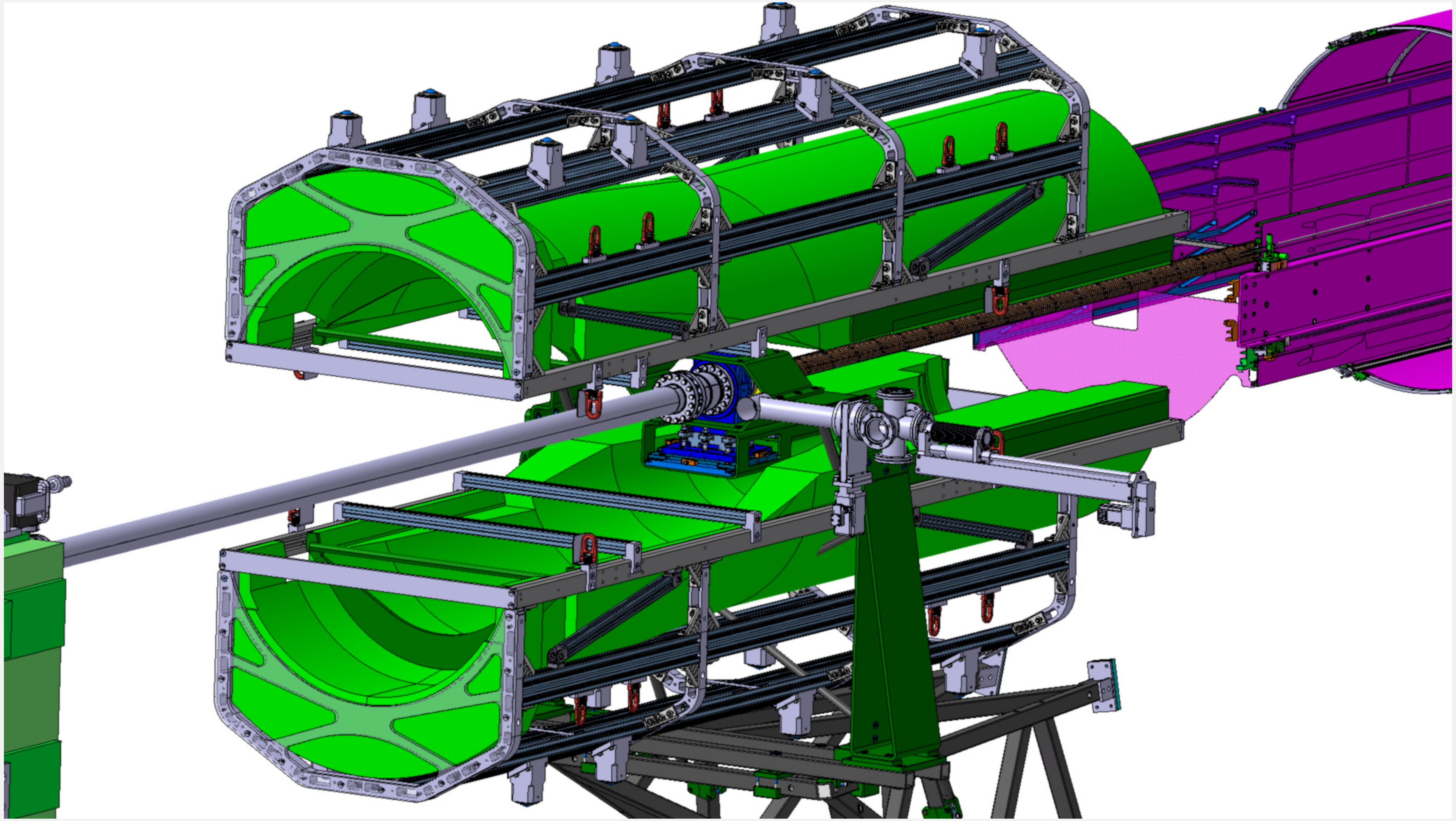
- length in mm
- transverse pipe length depends on target position

Integration of the target in the ALICE mini-frame



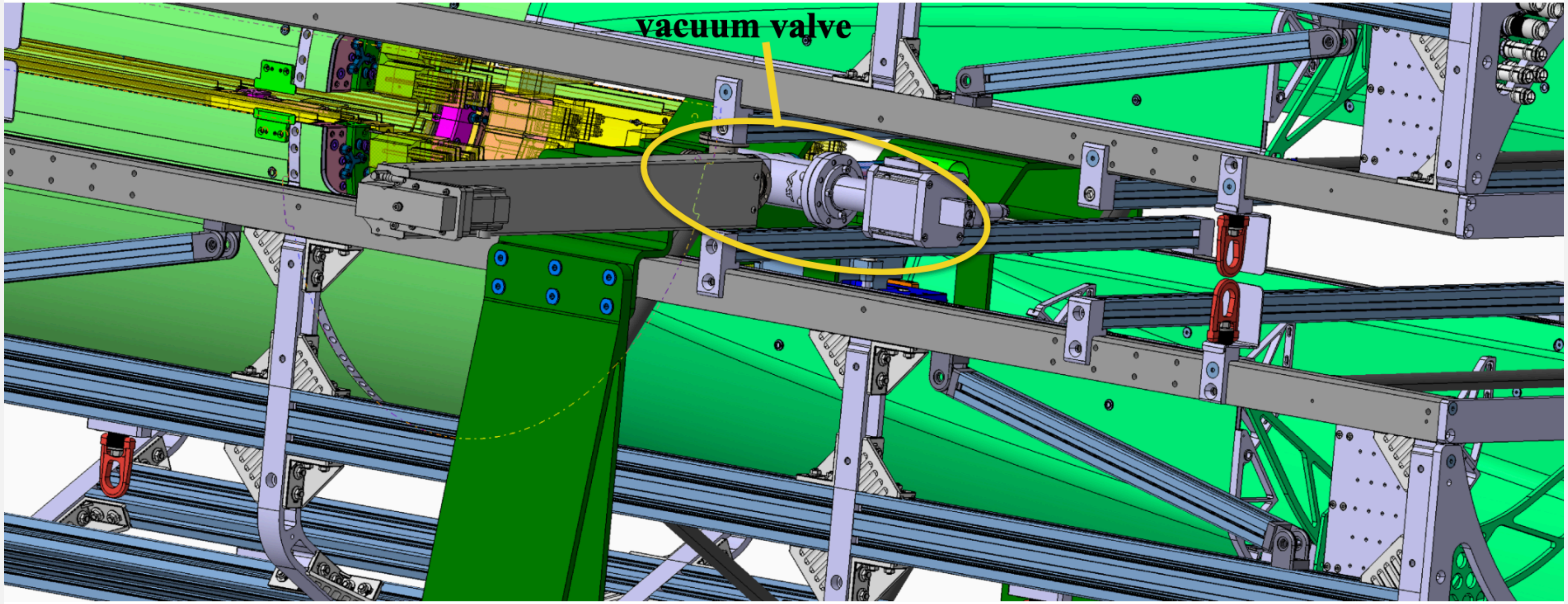
mini-frame structure

Integration of the target in the ALICE mini-frame



ITS support in open position at Z ~ -5m, to allow for interventions on the ITS during EYETS
→ Need positionning of the target system along the horizonthal plane

Integration of the target in the ALICE mini-frame



- Possible ITS movements during EYETS with ITS support (in open position in light green) around the beam pipe: target system needs to be in horizontal plane (target system vacuum valve in yellow circle)
- Conflict with service in mini-frame if target system is too long and with FoCal if T-shape too short
- Ongoing integration studies (in contact with Corrado Gargiulo):
  - valve size reduced
  - two target positions z = 485 and 505 mm considered with different T-shape lengths

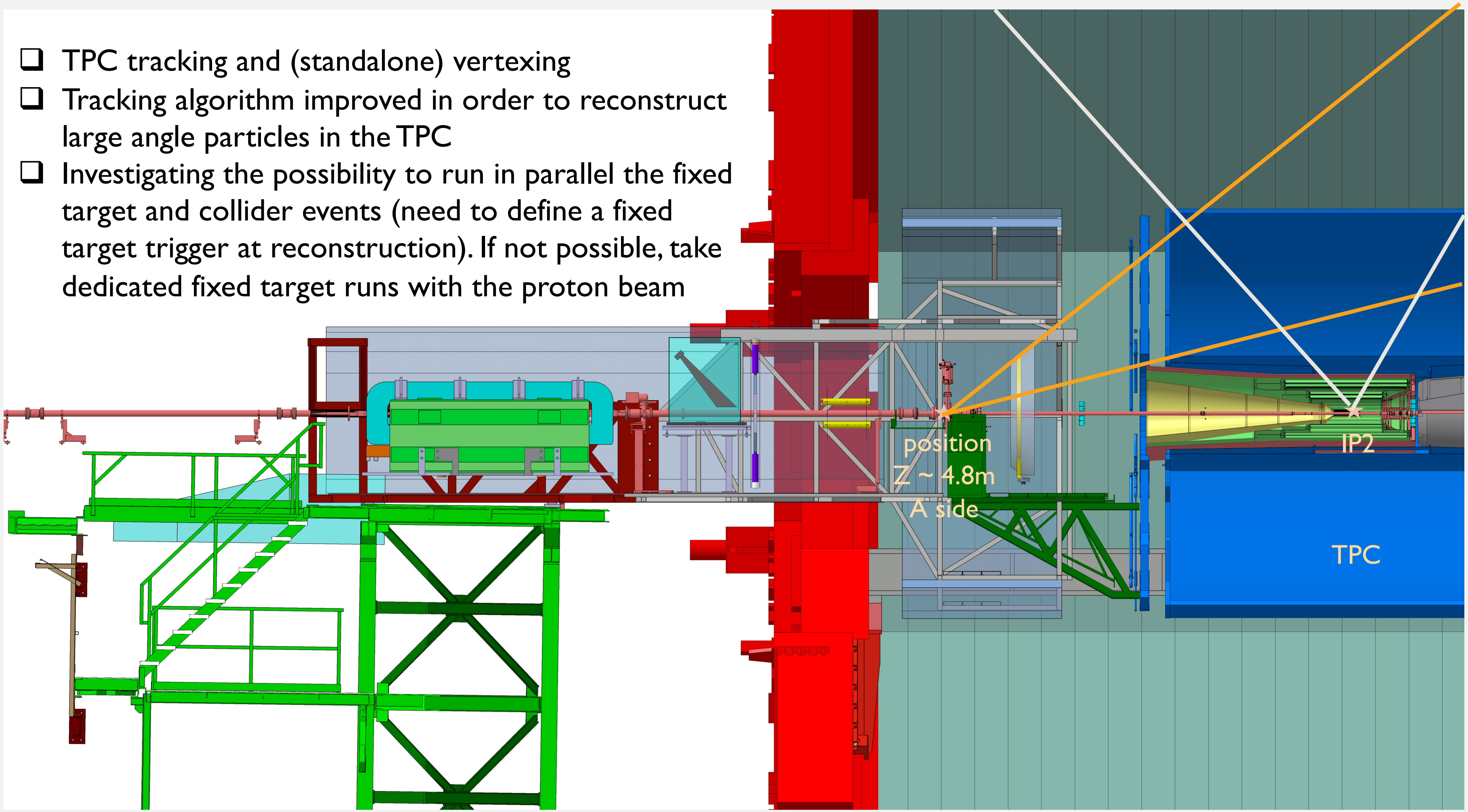
Work from K. Pressard, C. Gargiulo

Orientation of the vacuum valve also matters

TPC PERFORMANCE IN FIXED-TARGET MODE

Evaluation of the TPC performance in FT mode

- TPC tracking and (standalone) vertexing
- Tracking algorithm improved in order to reconstruct large angle particles in the TPC
- Investigating the possibility to run in parallel the fixed target and collider events (need to define a fixed target trigger at reconstruction). If not possible, take dedicated fixed target runs with the proton beam



Tracks produced in FT events

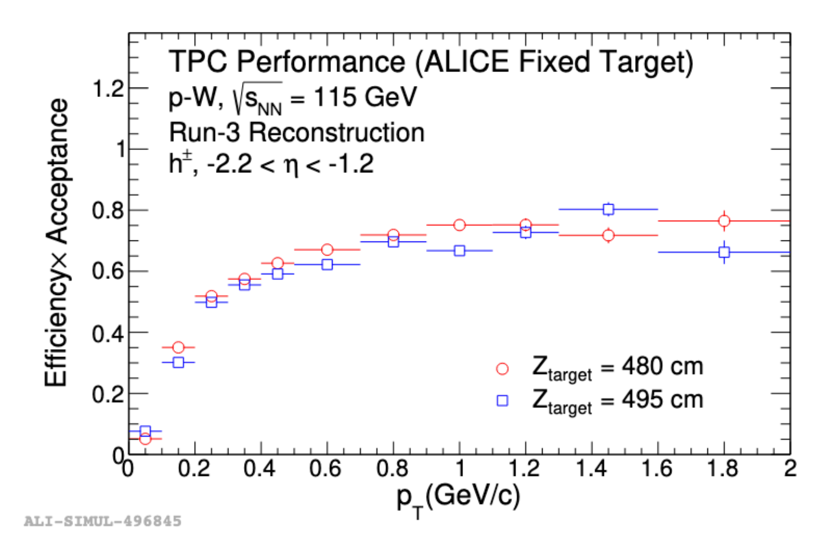
Tracks produced in collider events

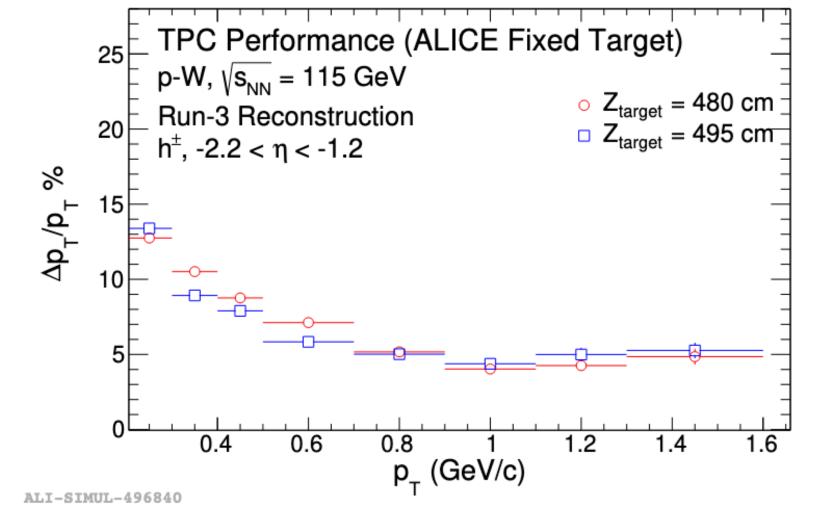
What is the TPC response to inclined FT tracks?
$-2.5 \leq \eta \leq -1.0$

See talk from R. Haque

Realistic simulations for charged particles with the TPC

Work from R. Haque





[Int.J.Mod.Phys.A 29 (2014) 1430044]

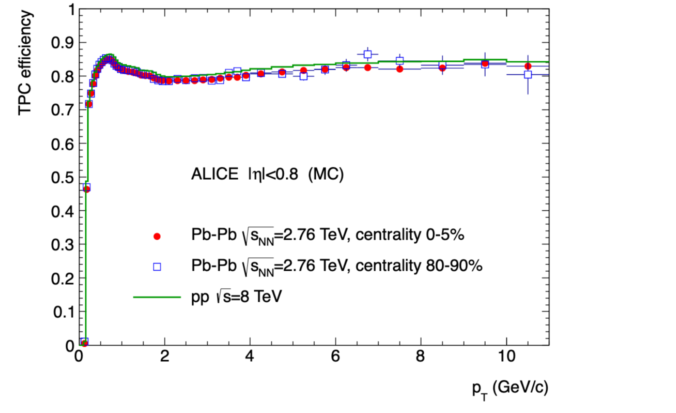
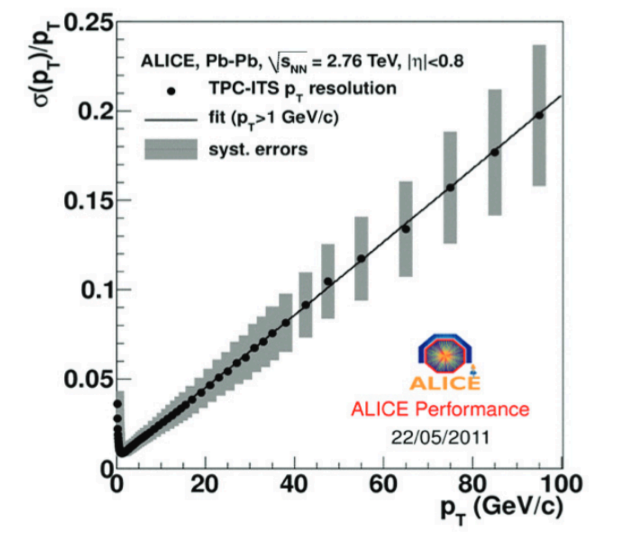


Fig. 19: TPC track finding efficiency for primary particles in pp and Pb–Pb collisions (simulation). The efficiency does not depend on the detector occupancy.

[Physics Procedia 37 (2012) 434 – 441]



See talk from R. Haque

- ➢ Charged particles : efficiency and p_T resolution sufficent for analysis
- ➢ **Λ**: efficiency and p_T resolution sufficent for analysis (without extra vertex detector)
- ➢ D^0: TPC vertex resolution not sufficient to use secondary vertex method for analysis. Investigating combinatorial background method, reduced target size and constraints on beam spot position for tracking

Conclusion

- Consolidation of the physics case with the proton beam : large-x physics (focus on antiproton, D meson, Drell-Yan) and « QGP-like» features in small systems (collectivity for HF)

- New results from fast simulations with realistic TPC performance

- Implementation of the fixed target in ALICE:
  - Optimization of the crystal location/integration. New evaluation of particle flux on target
  - Integration solutions proposed to comply with FOCAL and ITS motion constraints during EYETS

- Next steps:
  - Crystal channeling: additional collimators, impedance, Pb beam channeling
  - Target system: integration in mini-frame, thermal study, impedance/vacuum study, geometry and motion system
  - Physics performance with realistic detector conditions and impact on theory
  - LOI in ALICE (2022) → Aim for installation during LS3

BACKUP

Fast simulations for Λ

new

Observations:

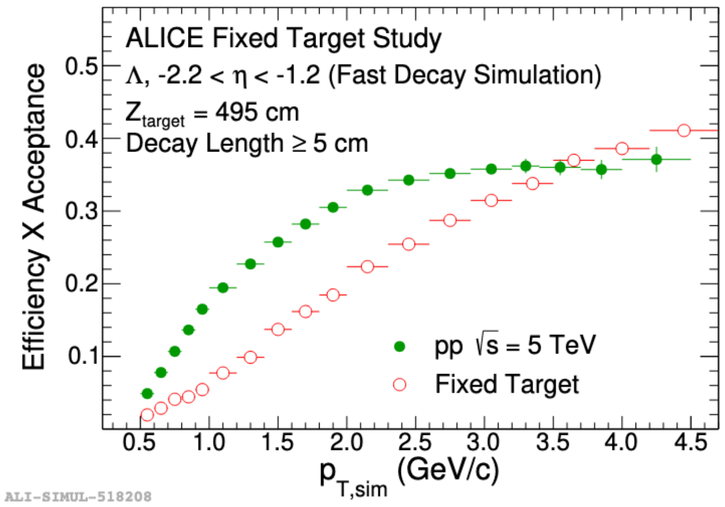
Tracking Efficieny for Λ:

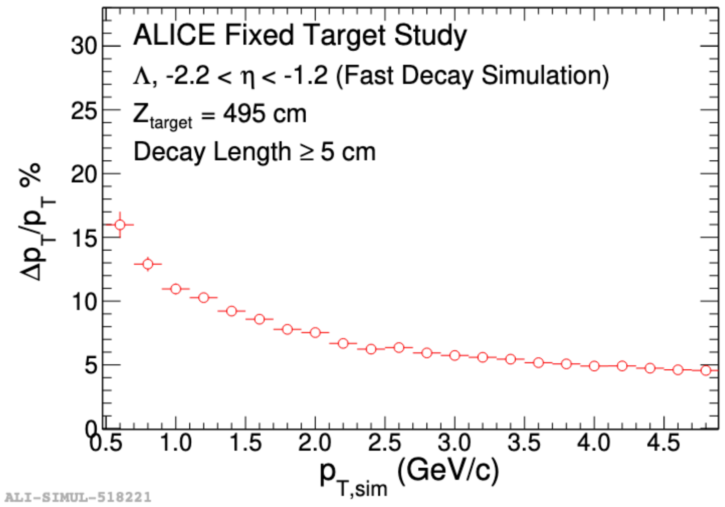
- ★ Efficiency X Acceptance shown for DL ≥ 5cm, and M_{inv} cut: $M_{\mathrm{pdg}} \pm 10$MeV.
- ★ Efficiency is lower than Λ from collider events. → But sufficient for analysis.

p_{T} Resolution of Λ:

- ★ p_{T} resolution estimated from Λ reconstructed with smeared daughters.
- ★ Pt resolution sufficient for analysis,
  → without any dedicated tracker for FT.
- ★ Caveats: The Λ efficiency should also depend on resolution of Sec. (V0-)Vertex, purity/mis-identification of daughters (π and p) → has not been estimated!

Note: Primary V_Z resolution = 2.4 cm for FT.





Work from R. Haque, presented at the ALICE upgrade week: https://indico.cern.ch/event/1142976/

Fast simulations for D^0

new

Observations:

Tracking Efficieny of D^0 with DL cut:

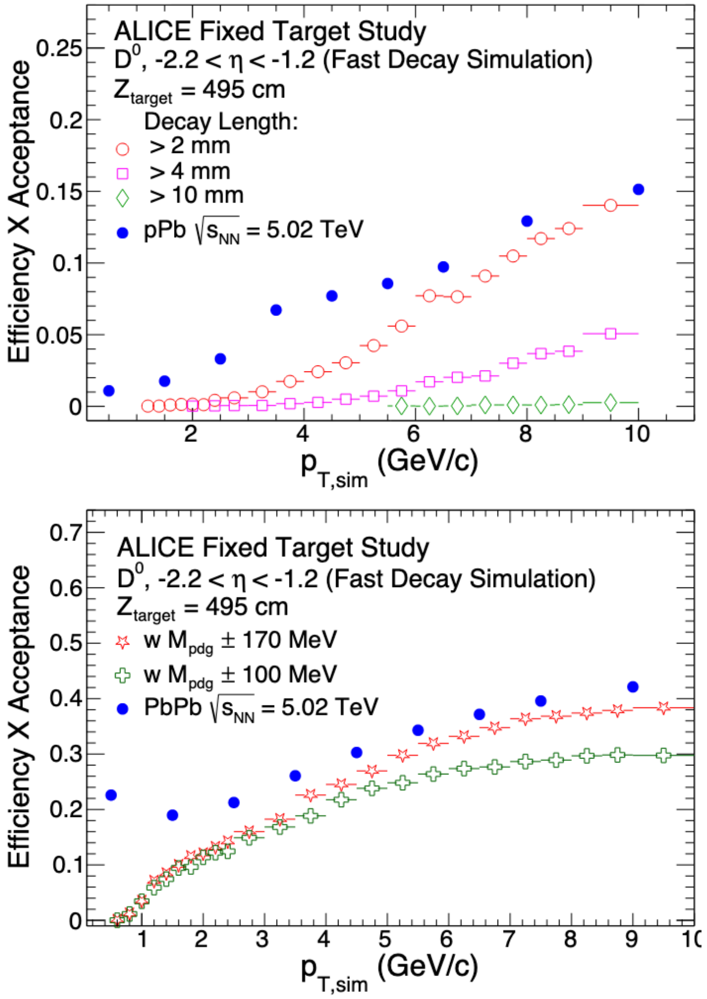
- ★ Top Fig: EfficiencyXAcceptance shown for varying DL cuts (w/o M_{inv} cut).
- ★ Most of D^0 decays withing target (thickness ~1cm).
- ★ Conclusion: sec. vertex method not feasible for $D^0 \rightarrow$ use combinatorial method.

Tracking Efficieny of D^0 w/o DL cut:

- ★ EfficiencyXAcceptance is sufficient for analysis.
- ★ Combinatorial background study for S/B (with bulk π,K from models) → ongoing!
- ★ Caveats: The D^0 results should also depend on on the purity/mis-identification of daughter π and $K \rightarrow$ not estimated!

Note: Primary V_z resolution = 2.4 cm for FT.

ALICE Efficiency: JHEP 2019(2019)92; JHEP 01(2022)174



Work from R. Haque, presented at the ALICE upgrade week: https://indico.cern.ch/event/1142976/

Realistic simulations for charged particles with the TPC

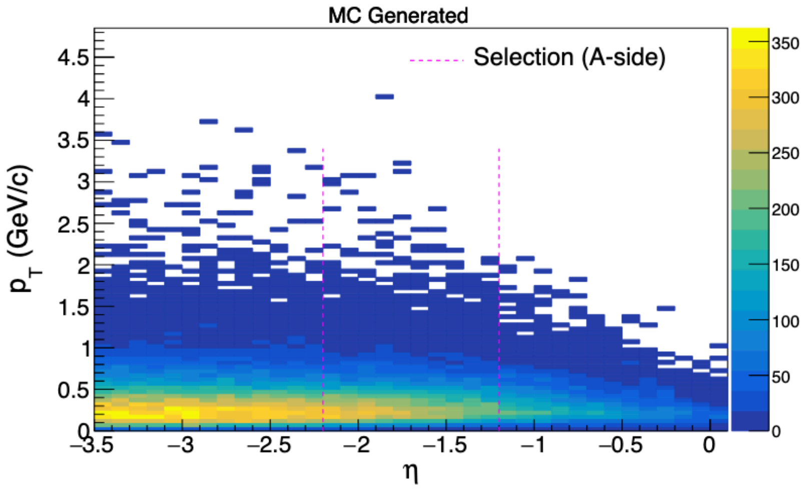
new

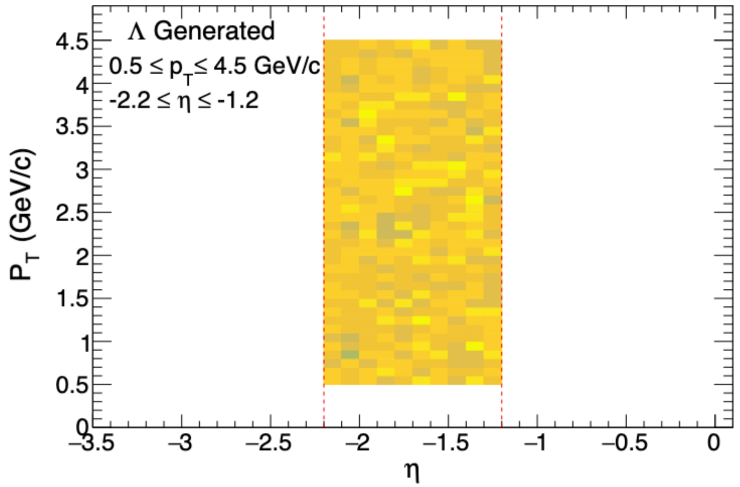
For Charged particles:

- System: proton on Tungsten (W).
- Energy: $\sqrt{s_{\mathrm{NN}}} = 115$ GeV/c.
- Generator: HIJING (w. Run-2 software).
- Reconstruction: with O2 (Run-3 software).
- No. of Events: $\sim$5000 events.
- Particles: $h^{\pm}$ (-2.2 $\leq \eta \leq$ -1.2).

For Λ and D^0 particles:

- Fast Decay simulation $\rightarrow$ we can decide if wee need full O^2 simulation for Λ and D^0.
- Generated Λ and D^0: Flat in p_{T} with -2.2 $\leq \eta \leq$ -1.2 and $0 \leq \phi \leq 2\pi$.
- No. of Fast sim particle: $\sim$200K (per set).
- Decayed with TGenPhaseSpace (Root class).
- Topological cuts: Decay length, M_{inv}.
- Sec.Vertex resolution not simulated.



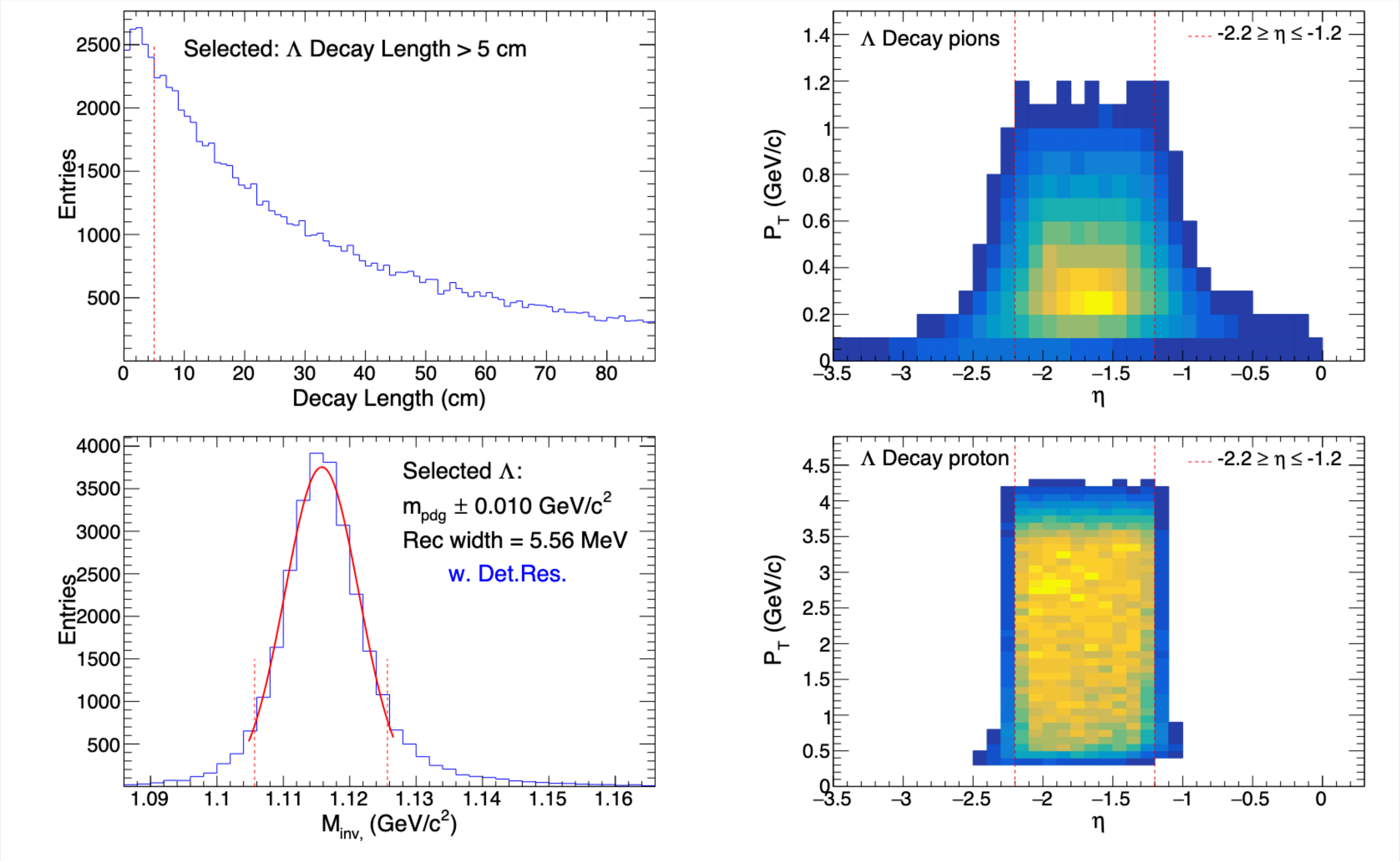


Work from R. Haque, presented at the ALICE upgrade week: https://indico.cern.ch/event/1142976/

Fast simulations for Λ

new

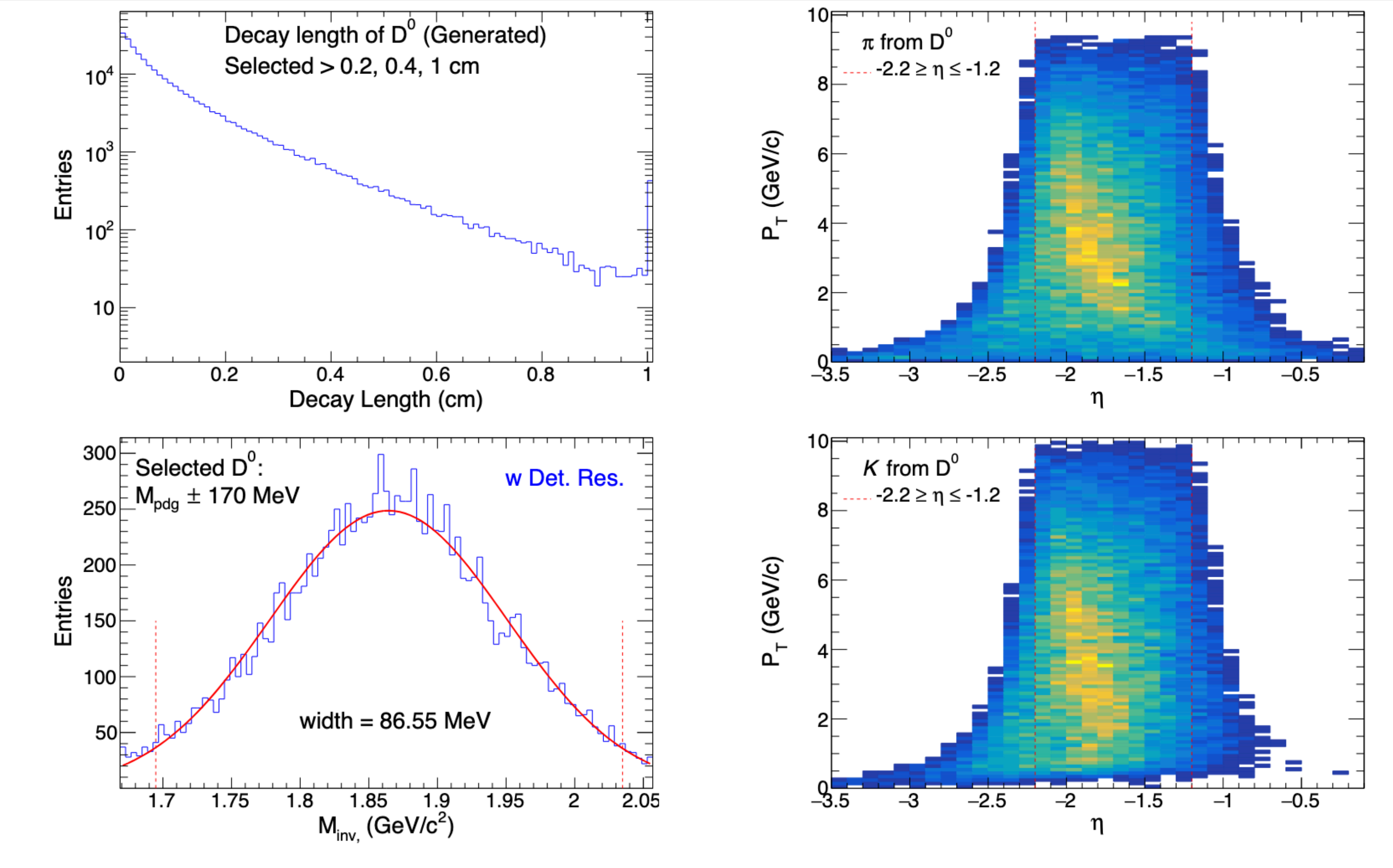
- Using inputs from realistic charged particle simulations with the TPC
- QA plots of the kinematics of the Λ and Λ decays



Work from R. Haque, presented at the ALICE upgrade week: https://indico.cern.ch/event/1142976/

Fast simulations for D^0

new



Work from R. Haque, presented at the ALICE upgrade week: https://indico.cern.ch/event/1142976/

Fast simulations for Λ

new

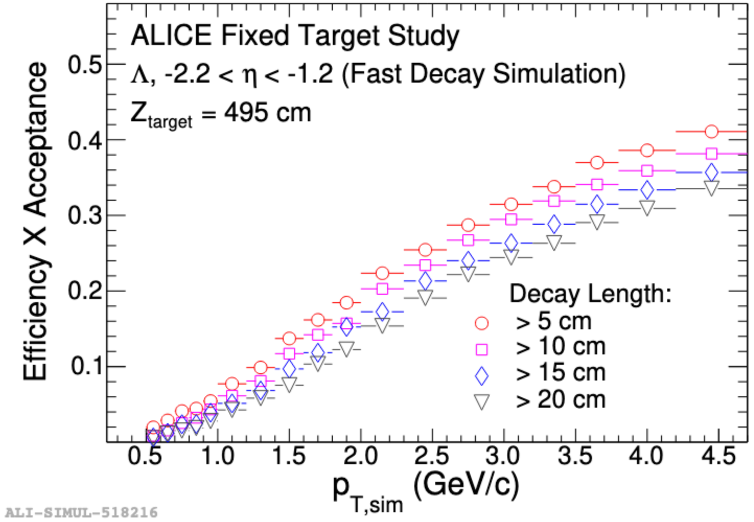
Observations:
Tracking Efficieny for Λ:

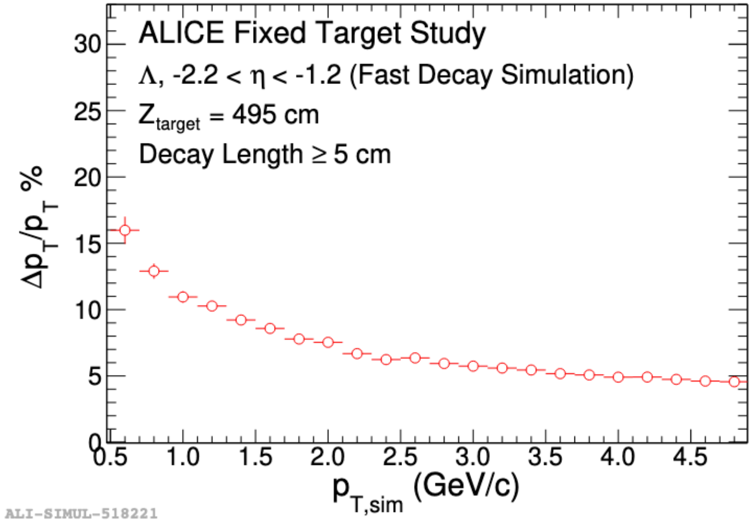
- ★ Efficiency X Acceptance decreases with increasing decay length cut.
- ★ With larger decay length cuts, efficiency decreases. → Still sufficient for analysis.

p_T Resolution of Λ:

- ★ p_T resolution does not depend on decay length cut, → only depends on N_{cls}.
- ★ Pt resolution sufficient for analysis, → without any dedicated tracker for FT.
- ★ Caveats: The Λ efficiency should also depend on resolution of Sec. (V0-)Vertex, purity/mis-identification of daughters (π and p) → has not been estimated!

Note: Primary V_z resolution = 2.4 cm for FT.

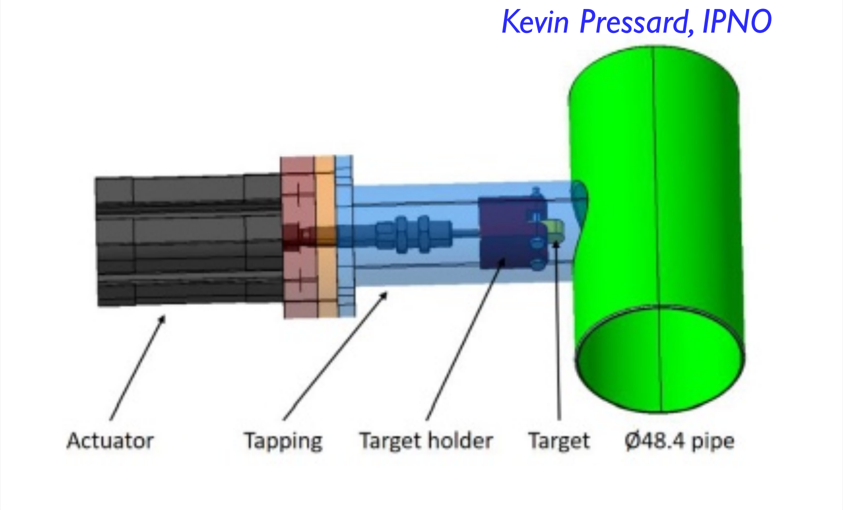




Work from R. Haque, presented at the ALICE upgrade week: https://indico.cern.ch/event/1142976/

Target requirements

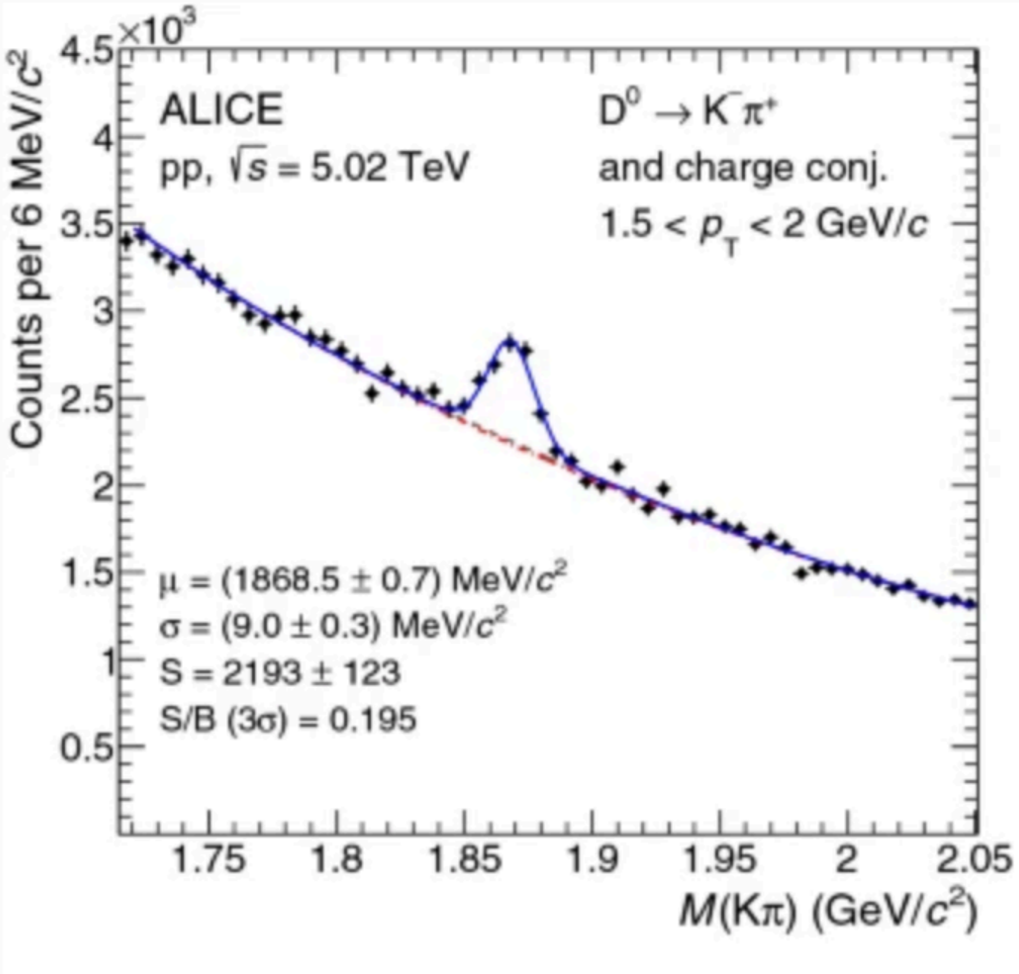
- Some target requirements to conduct the full heavy-ion programme foreseen:
  - Have a reference system, ie. a target with lowest possible atomic number (ideally pH):
    - ✓ Solid H probably not compatible with LHC vacuum
    - ✓ Lighter target that could be envisonned is probably Beryllium (Z = 4)
  - Have good target versatily : take data with different target species / be able to change frequently the target
  - Have target with large atomic numbers
    - ✓ W might be possible if cooled
    - ✓ Pb probably not usable because of too low melting temperature
  - Other possible target species: Ca, C, Os, Ir, Ti, Ni, Cu
- Target holder and other elements : stainless steel
- Retractable target : active position at 8 mm from the beam axis, parking position out of the beam pipe



D meson in pp collider events

https://link.springer.com/article/10.1140/epjc/s10052-019-6873-6

Fig. 1



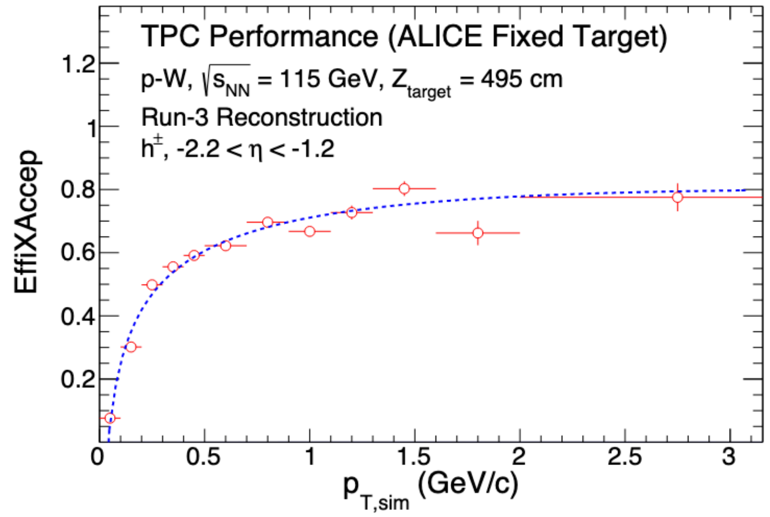
Realistic simulations for charged particles, Λ and D^0 with the TPC

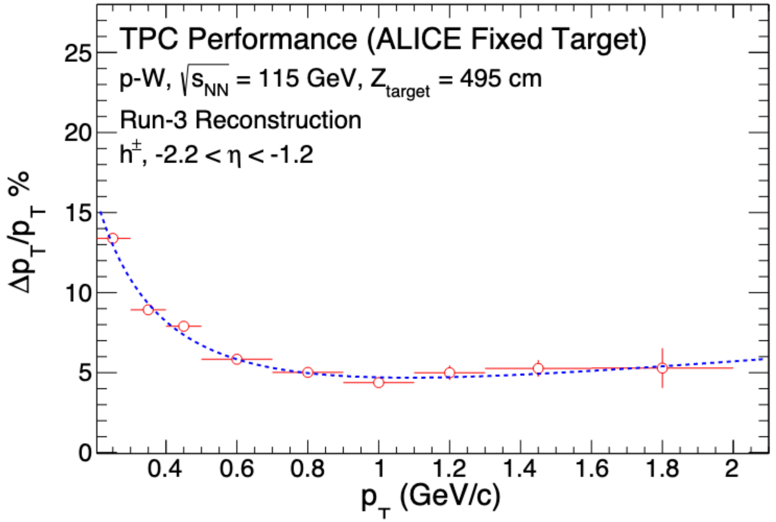
Observations:
Tracking Efficieny for charged tracks:

- ★ Efficiency X Acceptance shown for Target positions = 495 cm.
- ★ Efficiency is similar for two positions.
- ★ Fit with PolN and Log function $\rightarrow$ for continuous value for Fast decay sim.

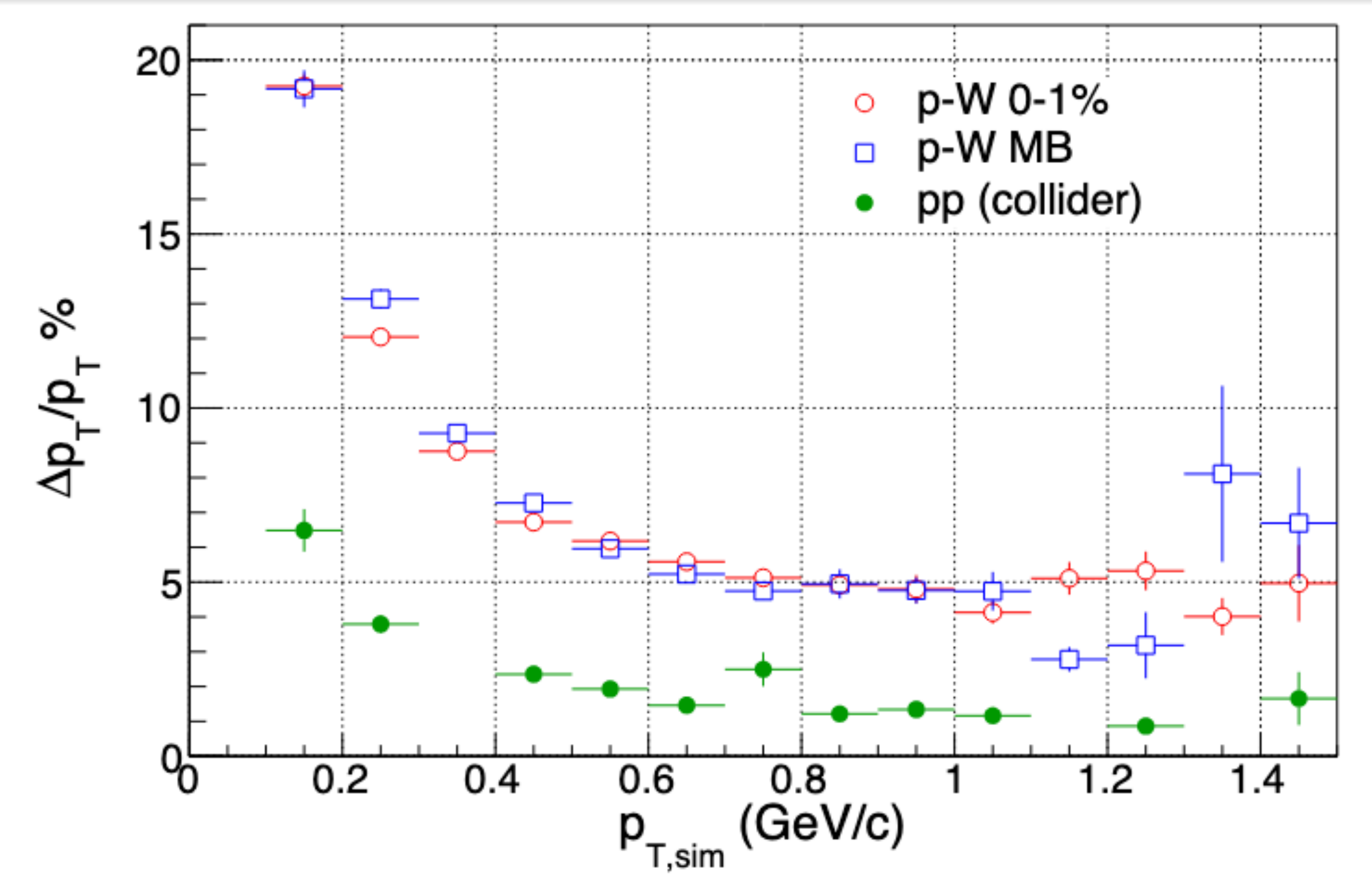
p_{T} Resolution of charged tracks:

- ★ p_{T} resolution estimated with $N_{cls} \geq 70$.
- ★ p_{T} resolution does not depend on target position.
- ★ p_{T} resolution is smaller than collider tracks. $\rightarrow$ collider tracks has higher N_{cls}.
- ★ Fit with PolN and exp function $\rightarrow$ for continuous value for Fast decay sim.





Charged particles p_T resolution in the TPC



TPC efficiency for collider events

https://arxiv.org/pdf/1402.4476.pdf

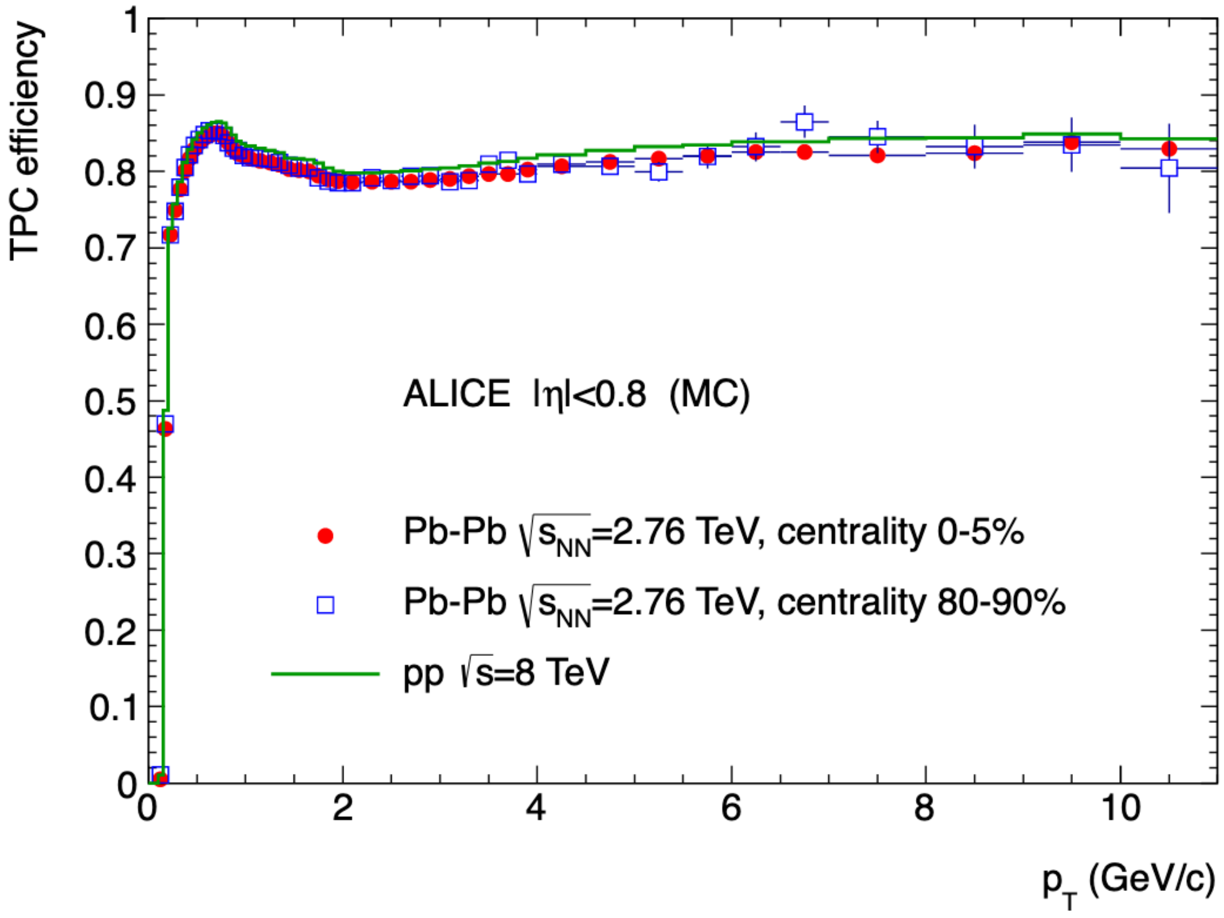


Fig. 19: TPC track finding efficiency for primary particles in pp and Pb–Pb collisions (simulation). The efficiency does not depend on the detector occupancy.