Alice TPC particle identification

on the way to

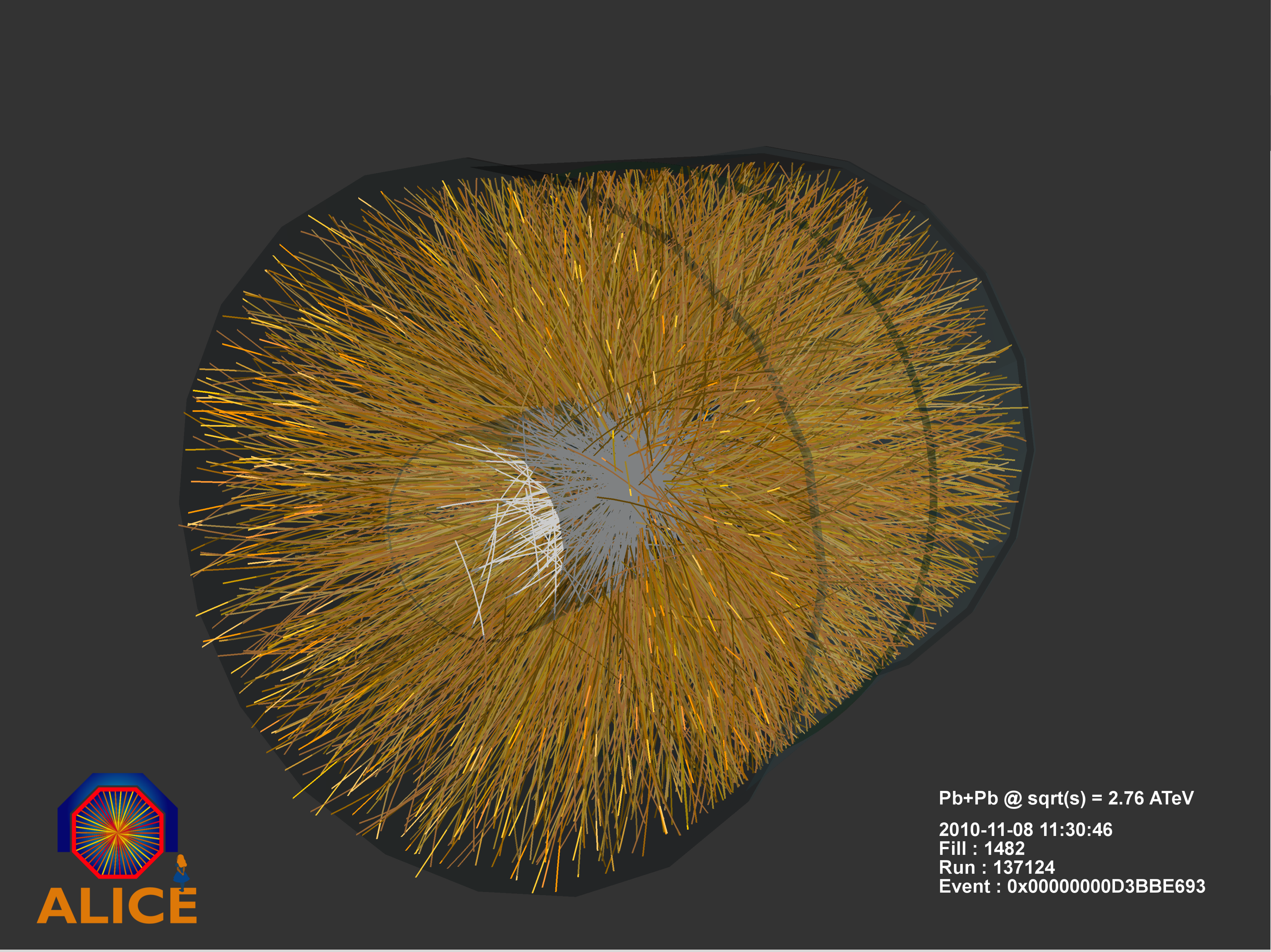
Anti-Nuclei and exotic states

INTERNATIONAL SCHOOL OF NUCLEAR PHYSICS
34th Course
Probing the Extremes of Matter with Heavy Ions
Erice-Sicily: 16 - 24 September 2012

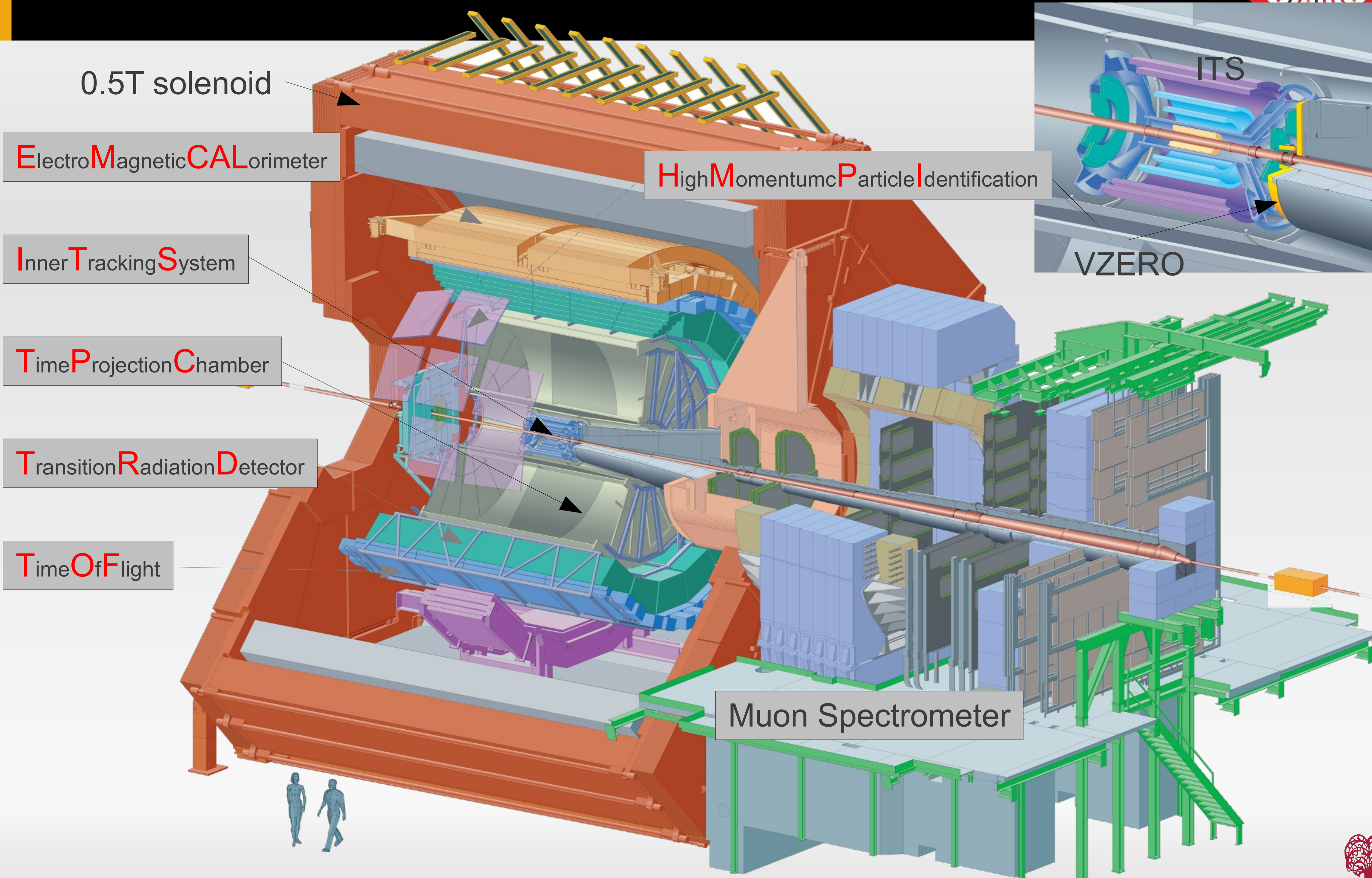
Jens Wiechula
for the ALICE Collaboration

Outline

- The ALICE apparatus
- ALICE TPC performance
- ALICE capability: search for and possible study of bound states involving multi-strange baryons
- Identification of
  - Anti-Alpha
  - Hyperons
  - Baryon bound states
- Summary


Pb+Pb @ sqrt(s) = 2.76 ATeV
2010-11-08 11:30:46
Fill : 1482
Run : 137124
Event : 0x00000000D3BBE693
ALICE

The ALICE apparatus



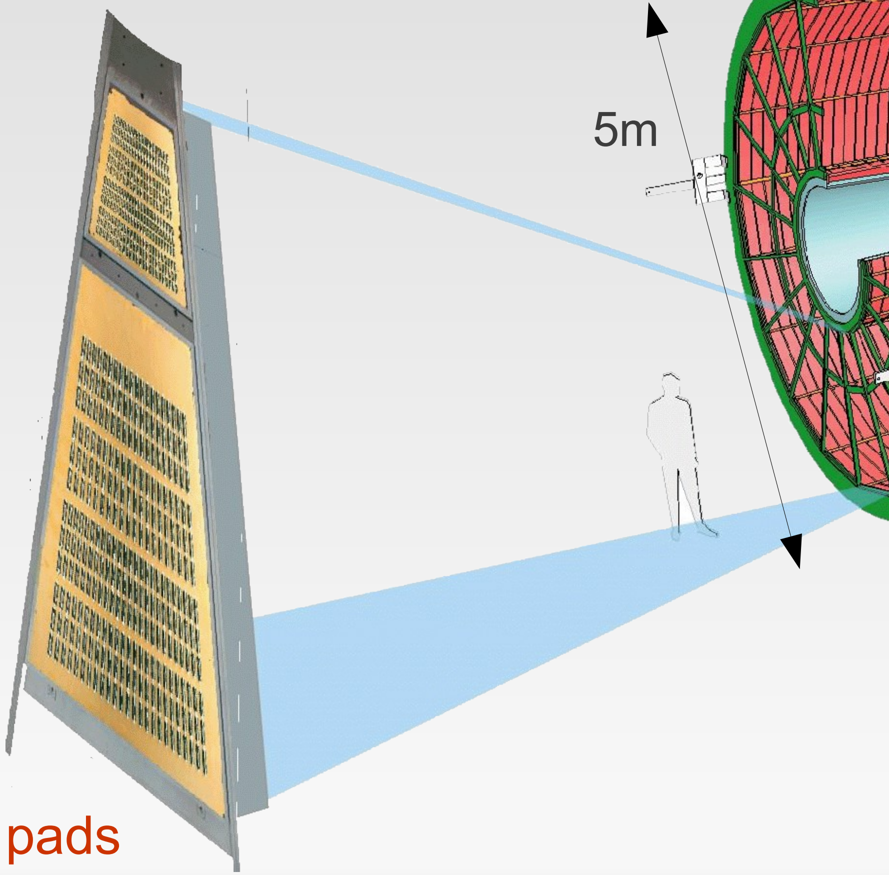
The ALICE Time Projection Chamber
in numbers

Most challenging TPC ever built

2x18 Inner Readout Chambers

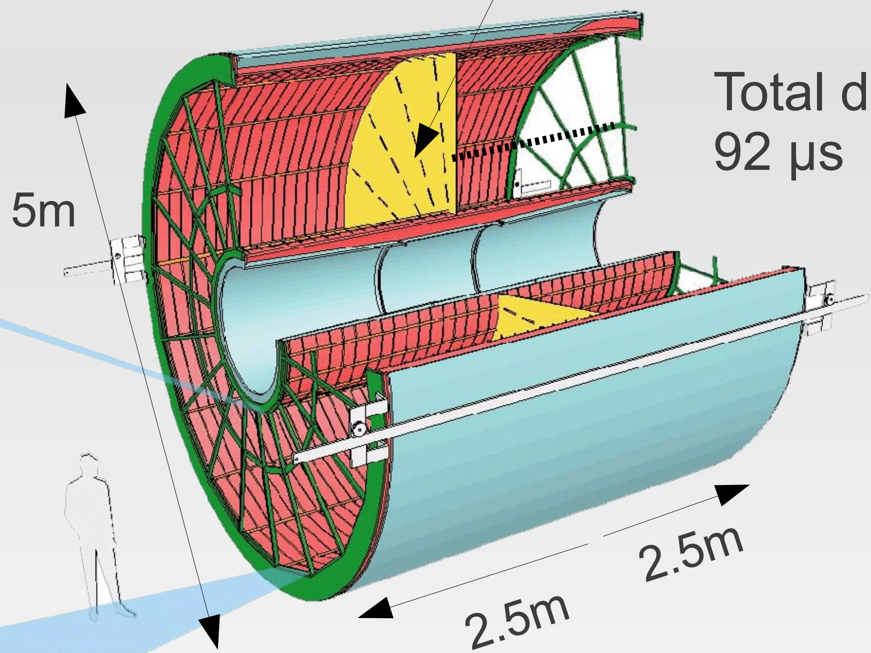
2x18 Outer Readout Chambers

159 pad rows



Central HV electrode
100kV

Total drift time
92 µs



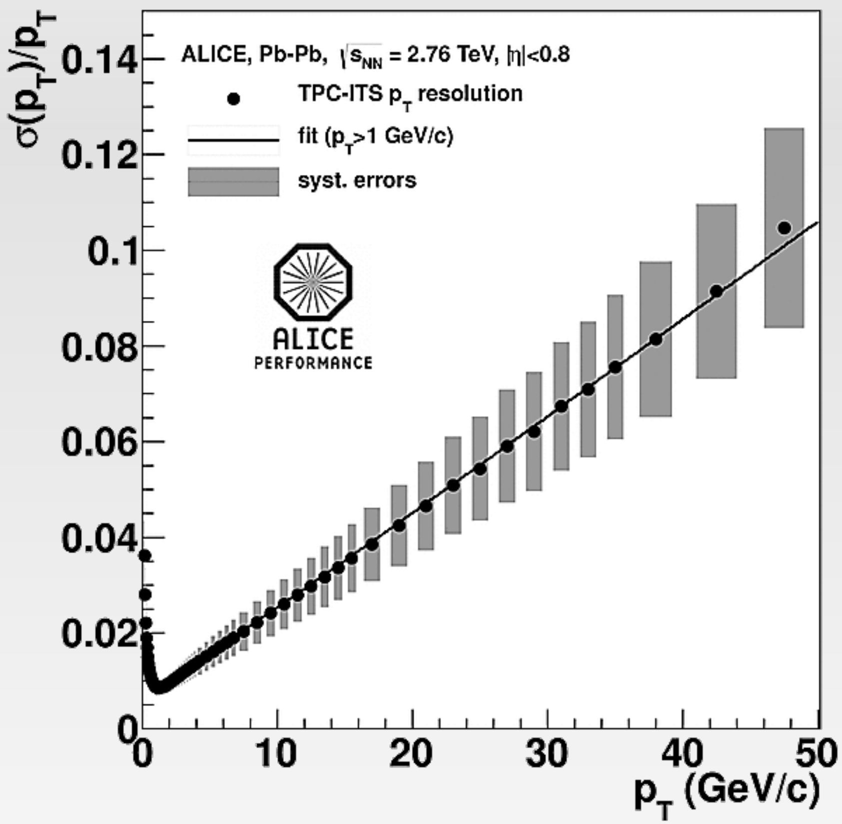
557568 readout pads
1000 samples in time direction

Gas:

- 90 m^3
- Ne-CO_2-N_2 (90 - 10 – 5)
- low diffusion (“cold gas”)
- drift velocity non saturated
  - temp. homogeneity and stability 0.1 K required

The ALICE TPC

Tracking performance



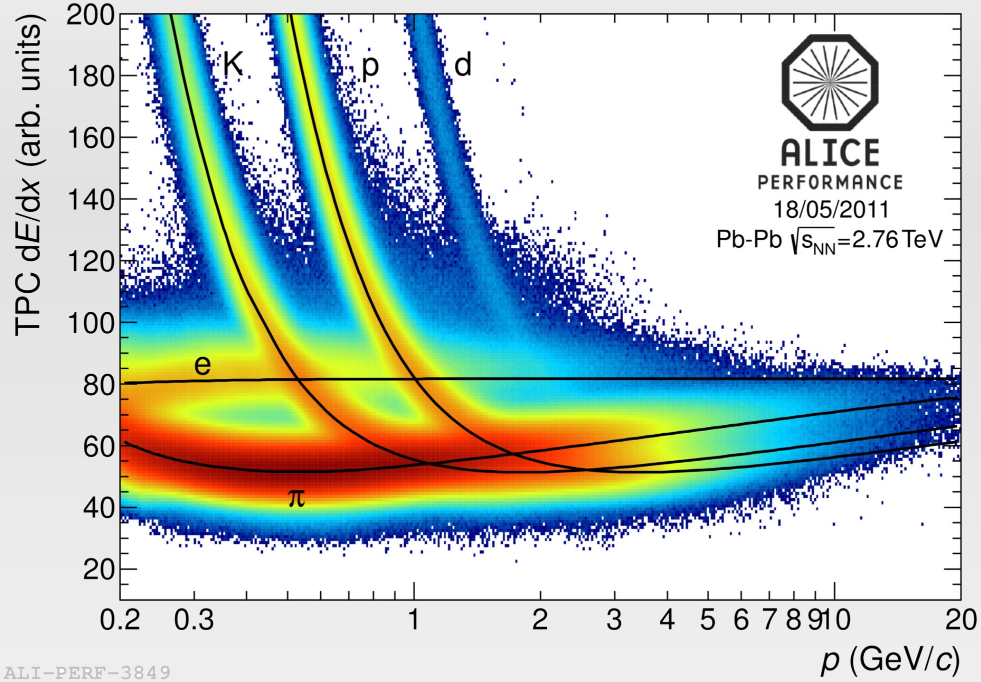
ALI-PERF-16396

Combined tracking TPC-ITS
momentum resolution ~10% at 50 GeV/*c*
(Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV from 2010)

For new productions, the momentum resolution improved to ~ 5% at 50 GeV/*c*, as a result of improved TPC-ITS matching

The ALICE TPC

PID performance

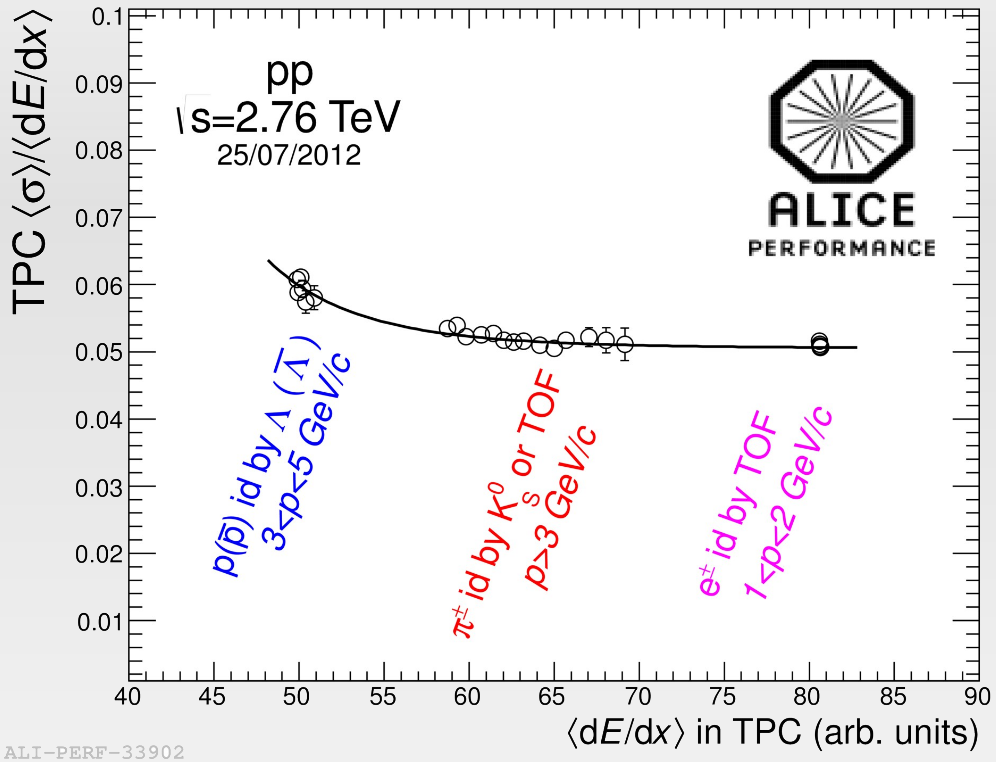


ALI-PERF-3849

- Sophisticated calibration
  - Pad-by-pad (557k channels) gain calibration using the ^{83}Kr decay
  - Keep gain stable within 0.2 %: calibration update every 15 minutes to follow changes of P, T and gas composition

The ALICE TPC

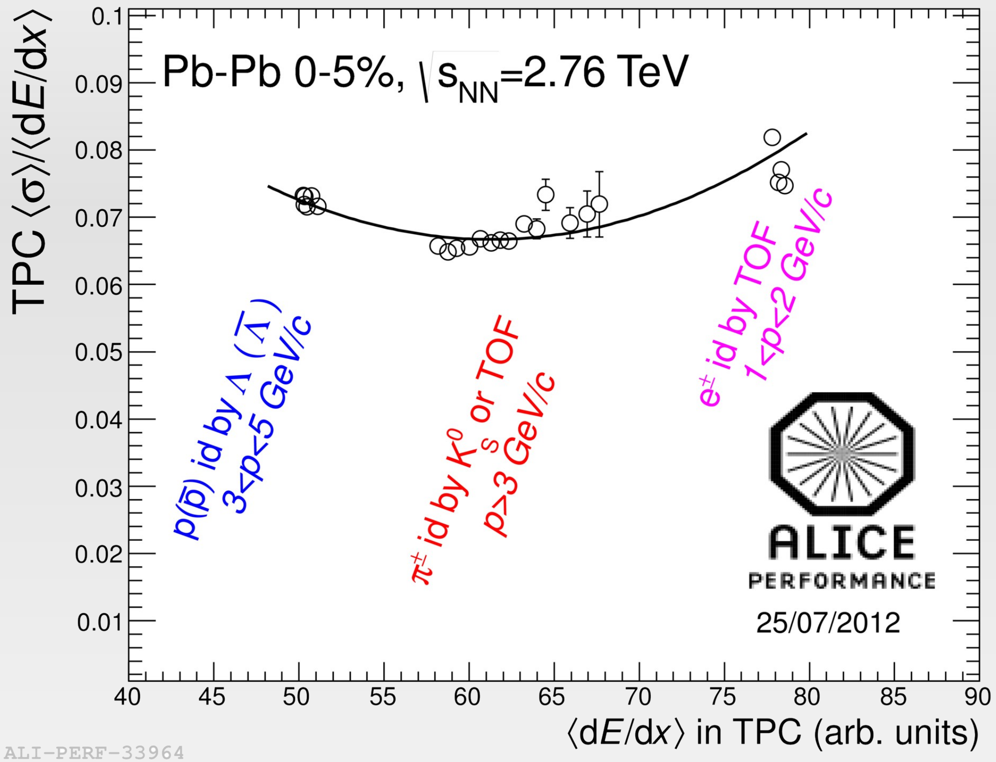
PID performance



- Sophisticated calibration
  - Pad-by-pad (557k channels) gain calibration using the 83Kr decay.
  - Keep gain stable within 0.2 %: calibration update every 15 minutes to follow changes of P, T and gas composition.
- High performance
  - dE/dx resolution close to design values
  - 5.5% at low multiplicity

The ALICE TPC

PID performance

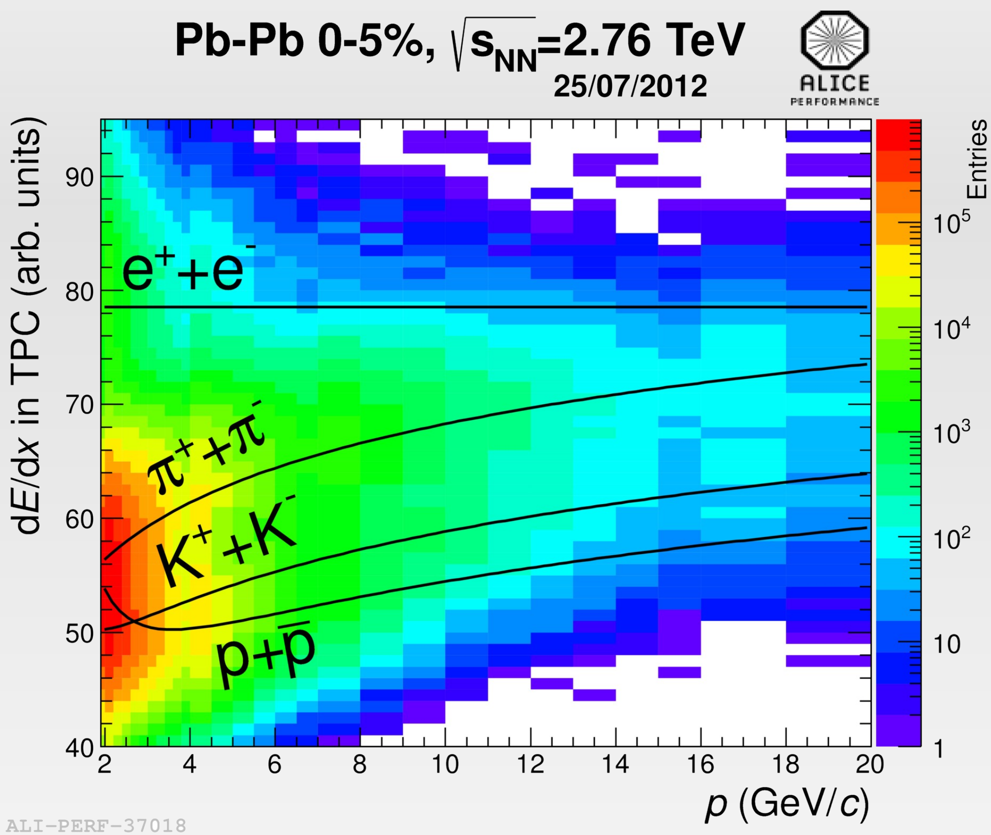


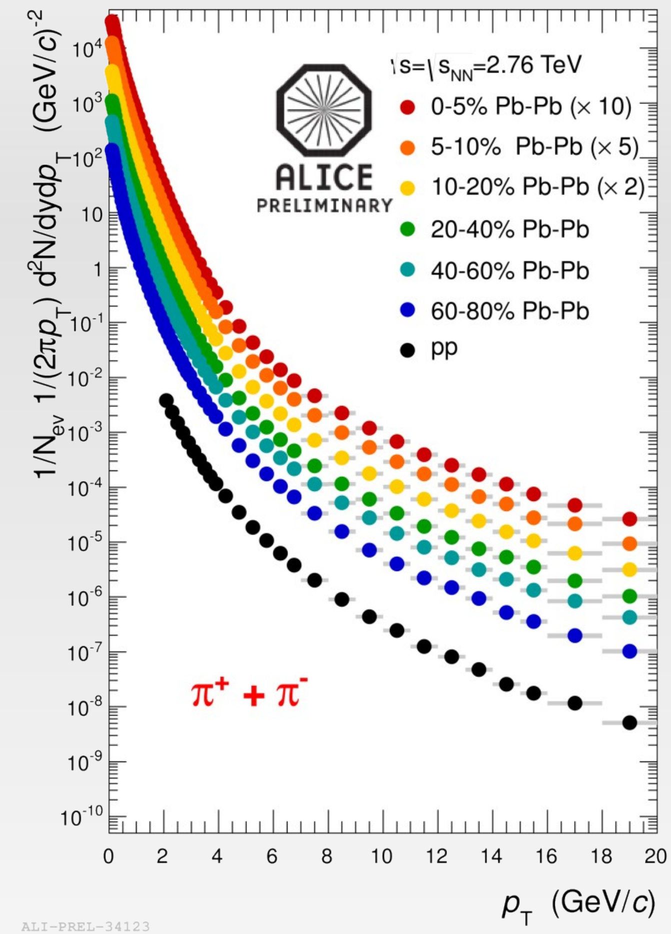
ALI-PERF-33964

- Sophisticated calibration
  - Pad-by-pad (557k channels) gain calibration using the 83Kr decay.
  - Keep gain stable within 0.2 %: calibration update every 15 minutes to follow changes of P, T and gas composition.
- High performance
  - dE/dx resolution close to design values
  - 5.5% at low multiplicity
  - 6.8% at high multiplicity

The ALICE TPC

PID performance





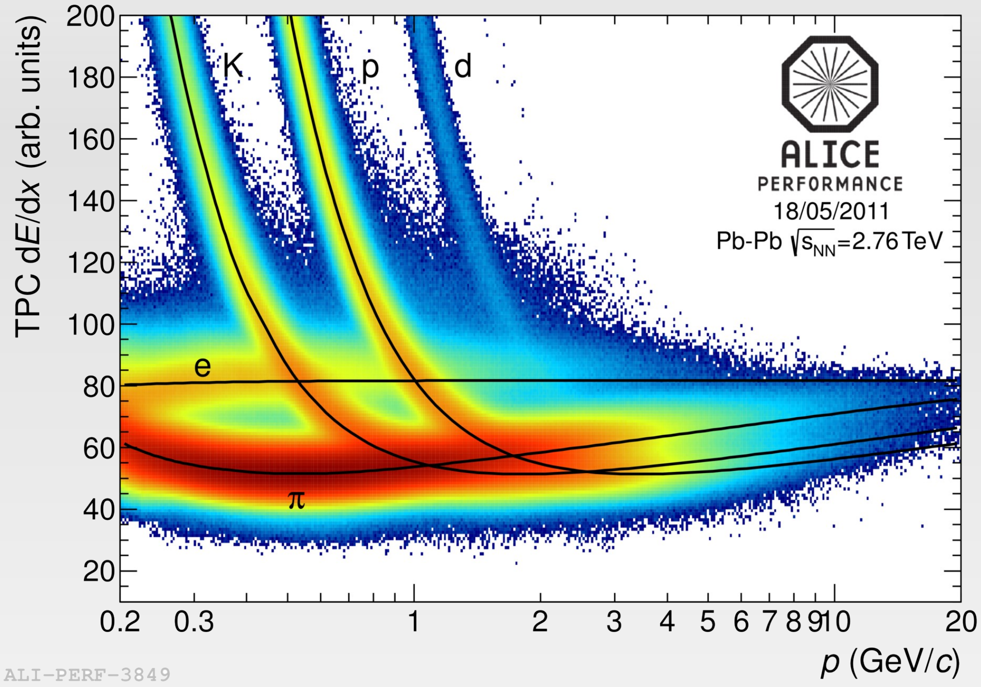
Excelent resolution allows PID in the relativistic rise

Currently up to p_T = 20 GeV/*c*

Planned up p_T = 50 GeV/*c* (mainly statistics limited)

The ALICE TPC

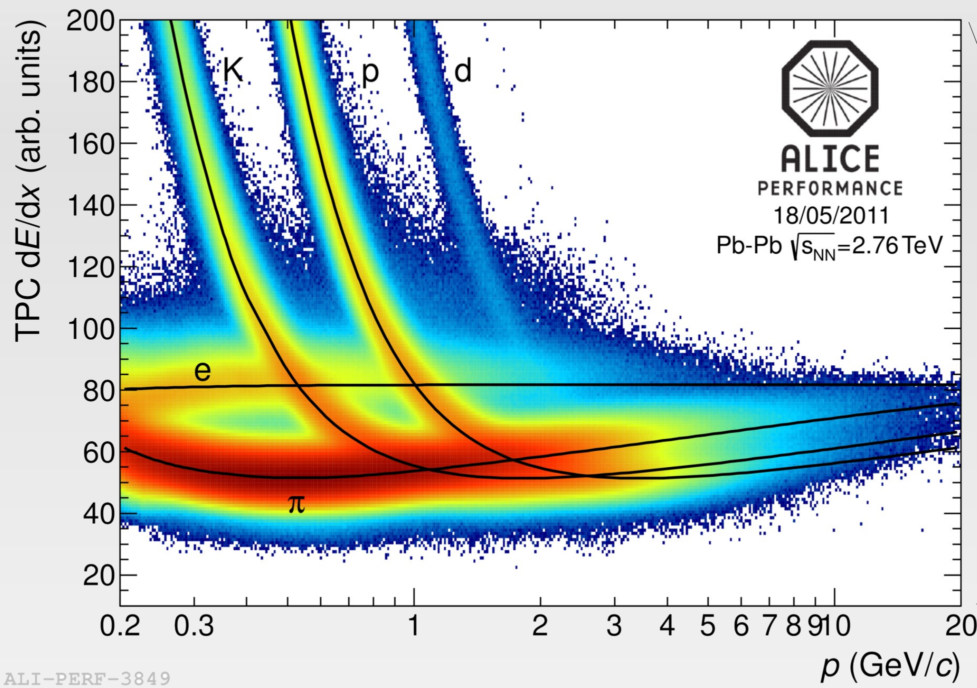
PID performance

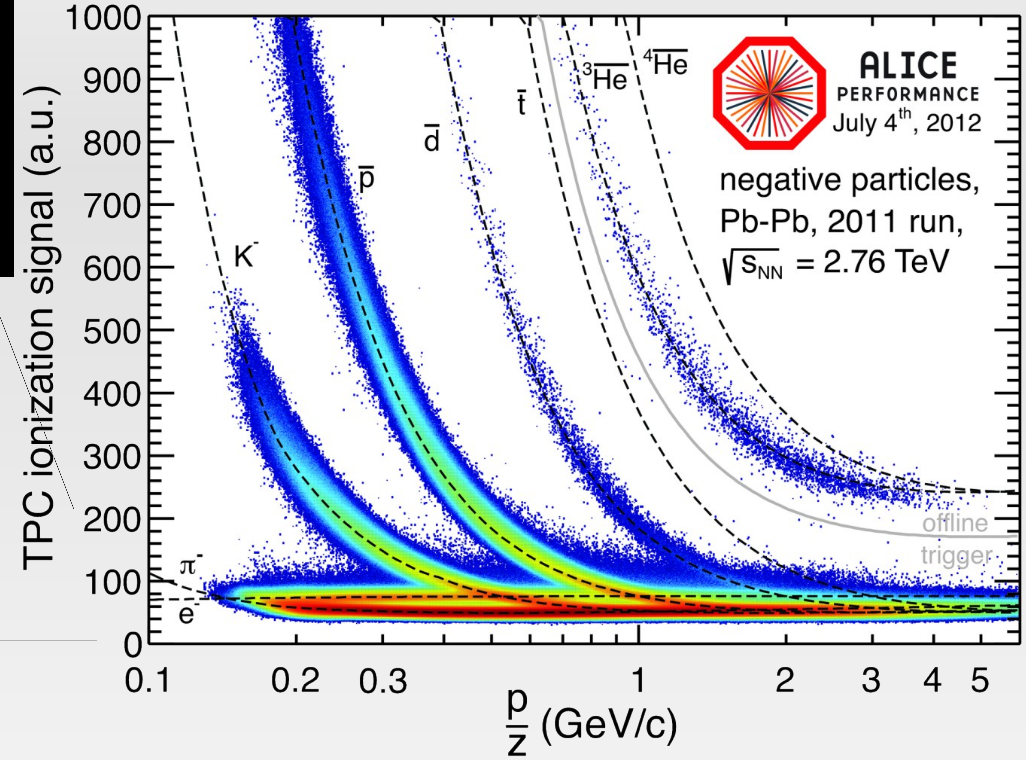


PID to high momenta ...

The ALICE TPC

PID performance





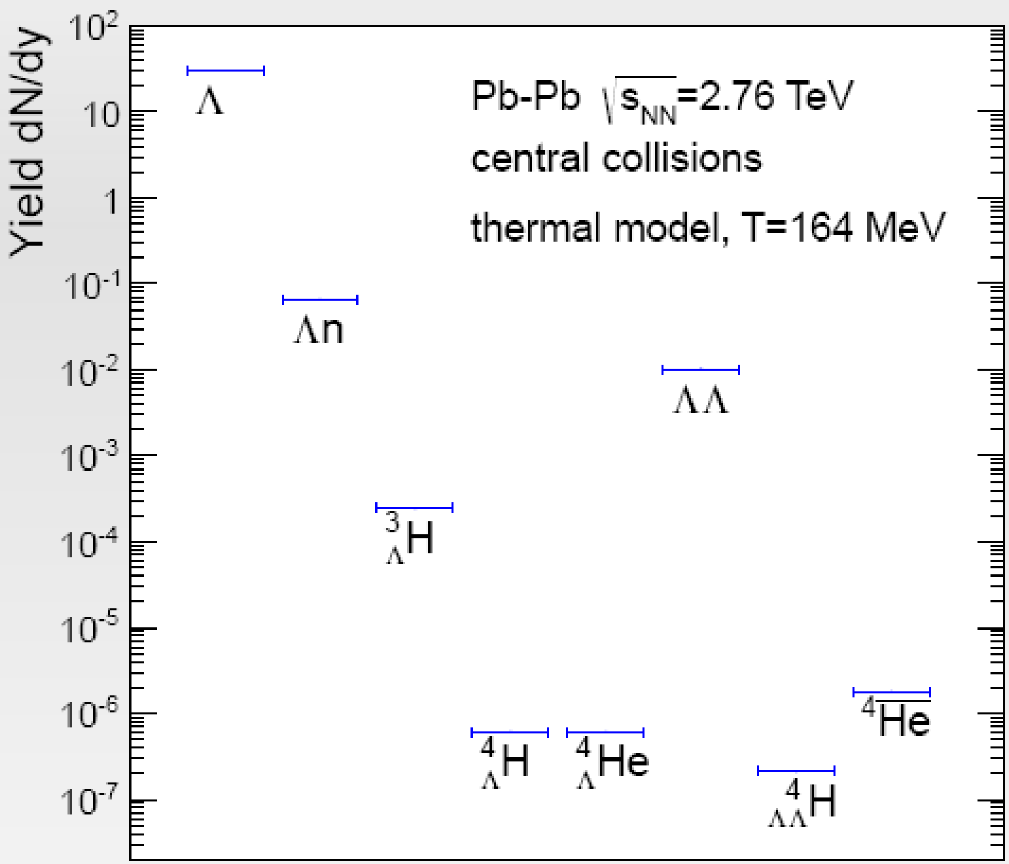
PID to high momenta ... and also high energy loss

Large dynamic range allows identification of

- ^3He, ^4He
- p, d, t to low momenta

Anti-Nuclei and hyper-matter

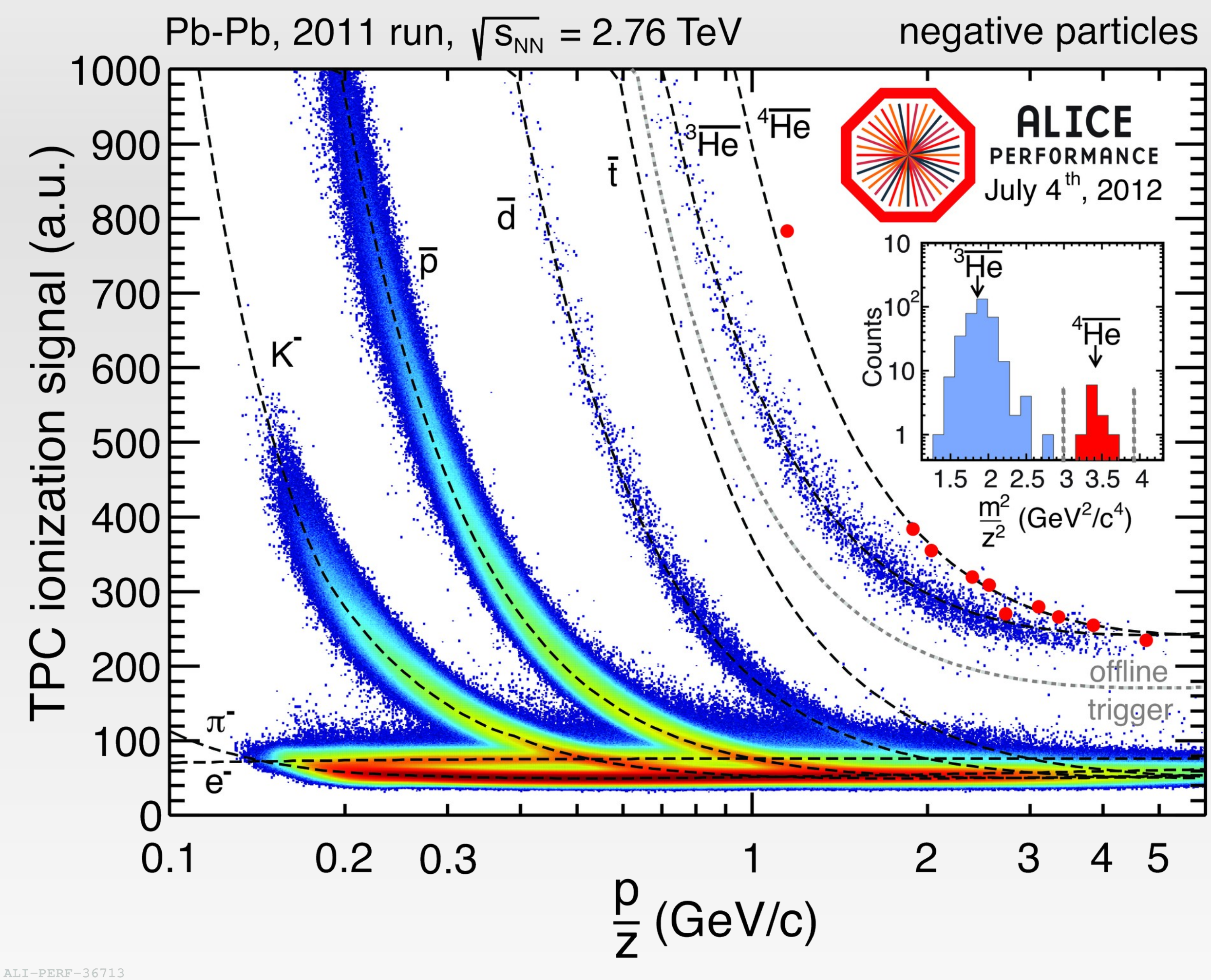
Motivation



A.Andronic, private communication, model described in A. Andronic, P. Braun-Munzinger, J. Stachel, H. Stöcker, PLB 697, 203 (2011) and references therein

- Explore QCD predictions for unusual multi-baryon states
- Search for rarely produced anti- and hyper-matter
- Test thermal model predictions

Anti-Alpha
Candidate Selection



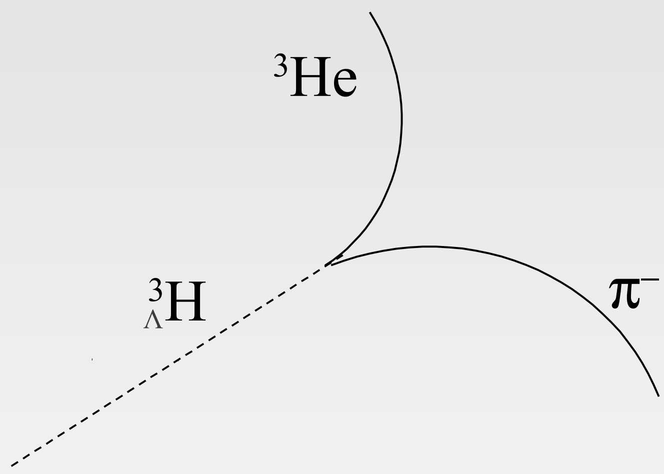
- Combine TPC dE/dx with mass estimate of TOF
- Good Separation of Anti-Alpha from Anti-^{3}He
- 10 Anti-Alpha candidates in full Pb-Pb statistics of 2011

Also measured at RHIC energies (STAR): Nature 473, 353-356 (19 May 2011), arXiv:1103.3312

Hypertriton

Reconstruction

- Use decay topology for identification
- Reduce background by performing PID on the legs



m ($\overline{^3_\Lambda H}$) = 2.991 ± 0.001 ± 0.002 GeV/c^2
decay lenght $c\tau = 5.5^{+2.7}_{-1.4} \pm 0.8$ cm
life time $\tau = 182^{+89}_{-45} \pm 27$ ps

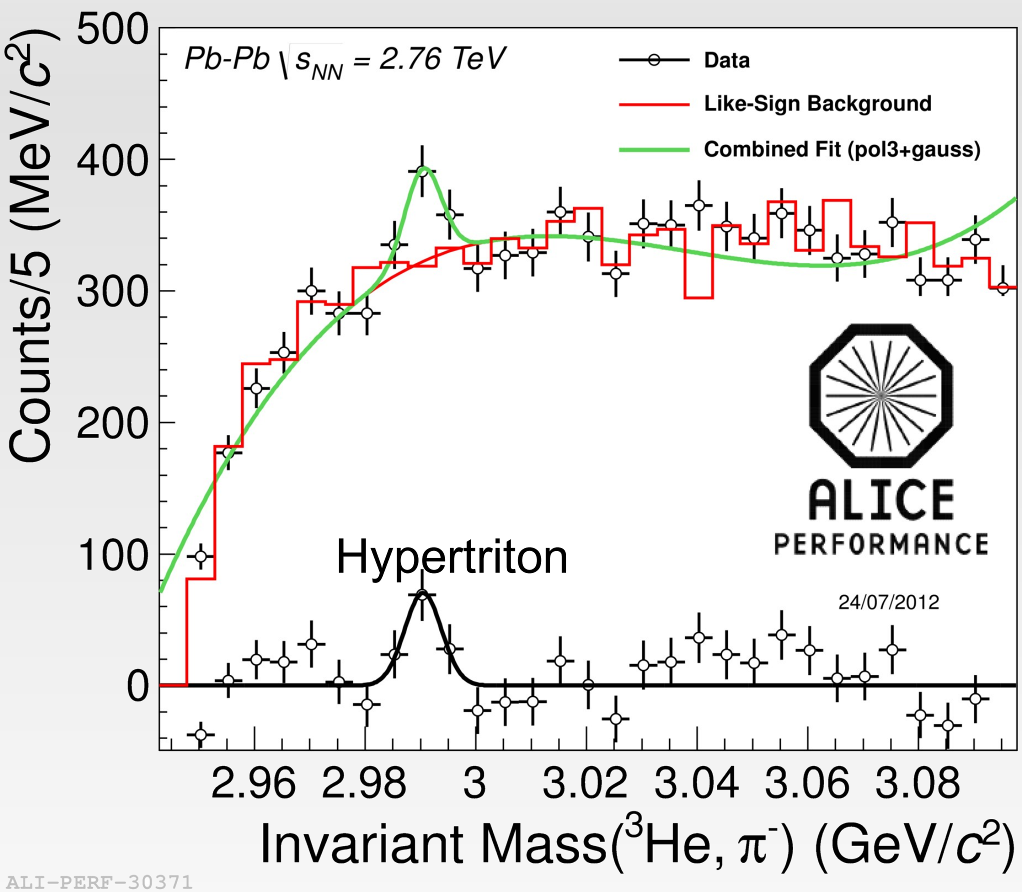
$$\overline{^3_\Lambda H} \longrightarrow \overline{^3He} + \pi^+$$

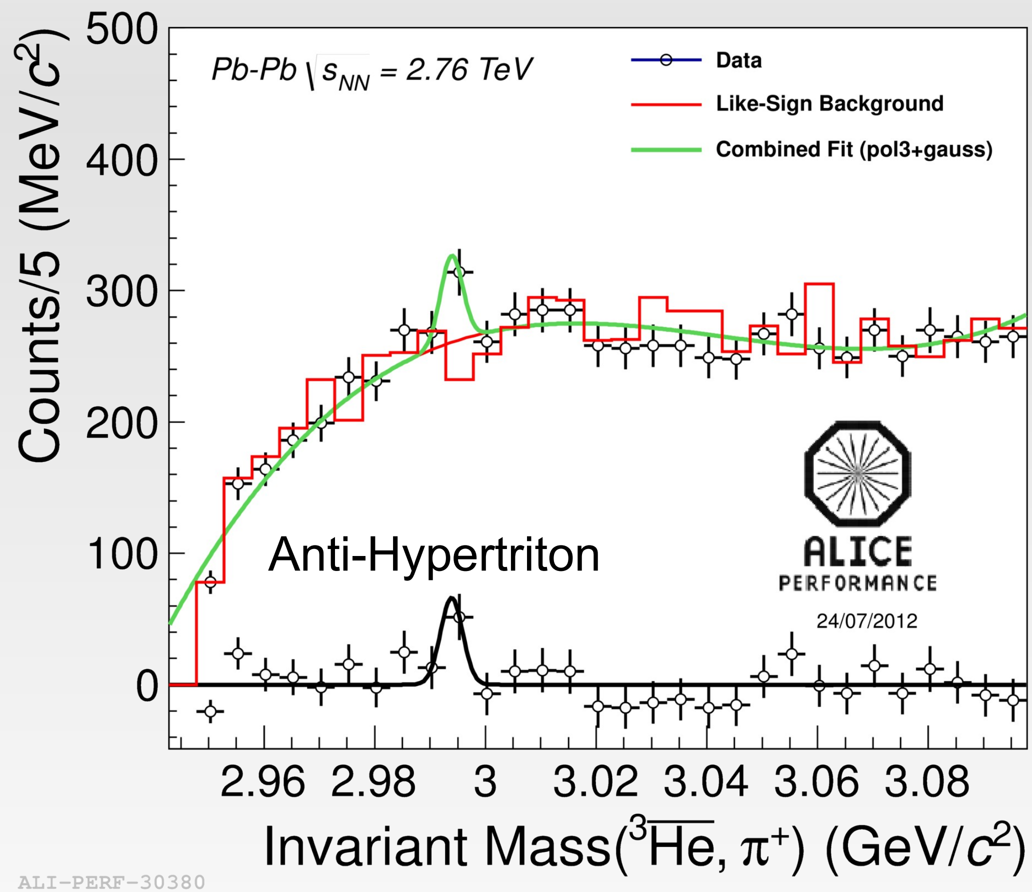
$$^3_\Lambda H \longrightarrow {}^3He + \pi^-$$

Hypertriton

Results

Signal of the hypertriton from the 2011 run
currently working on the extraction of the *p*T spectra





μ = (2.990 ± 0.001) GeV/*c*2
σ = (3.35 ± 0.7)x10^{-3} GeV/*c*2

μ = (2.993 ± 0.001) GeV/*c*2
σ = (2.00 ± 1.2)x10^{-3} GeV/*c*2

Also measured at RHIC energies (STAR): Science 328 (2010) 58, arXiv:1003.2030

Baryon bound states

H-Dibaryon (ΛΛ bound state)

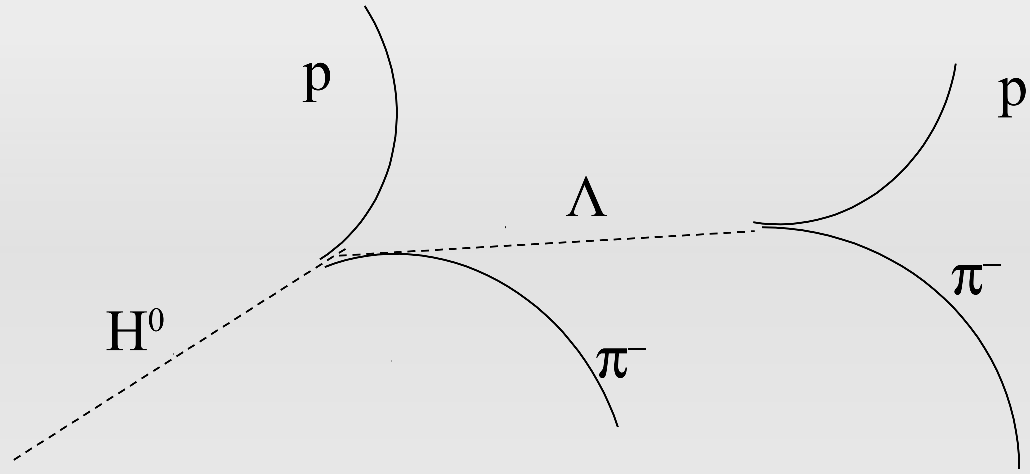
Two cases:

1.) weakly bound

$m^H < \Lambda\Lambda$ threshold

$2.2\ \text{GeV}/c2 < m^H < 2.231\ \text{GeV}/c2$

measurable channel $H^0 \rightarrow \Lambda p \pi$

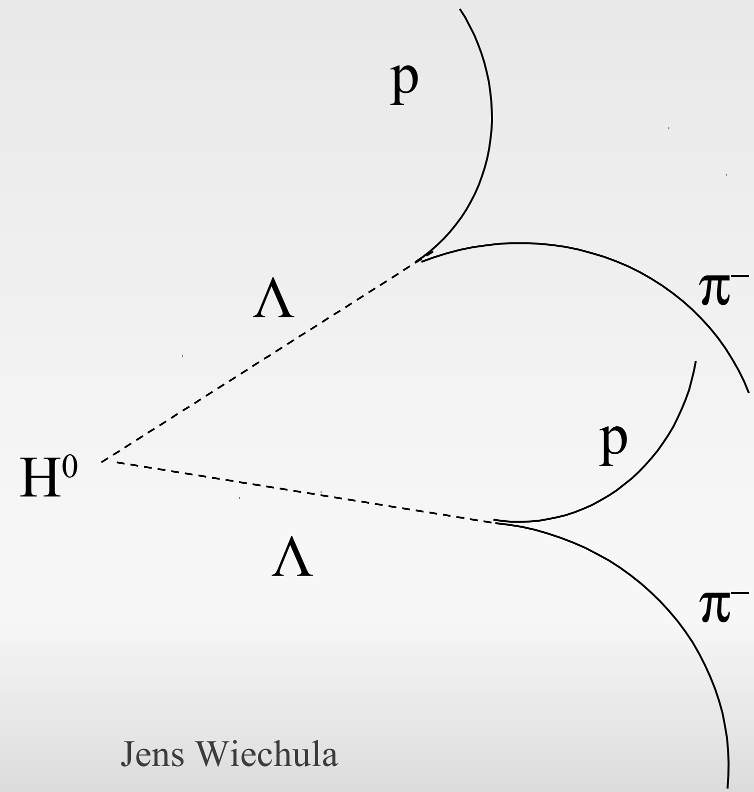


2.) resonant state

$m^H > \Lambda\Lambda$ threshold

$m^H > 2.231\ \text{GeV}/c2$

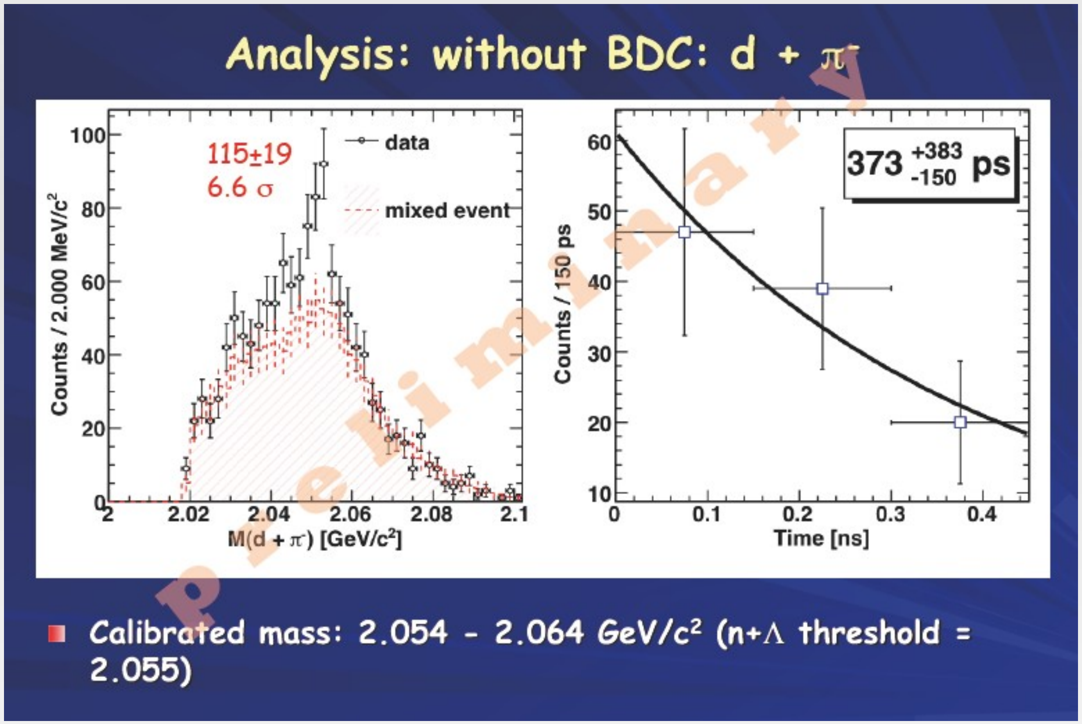
measurable channel $H^0 \rightarrow \Lambda\Lambda$



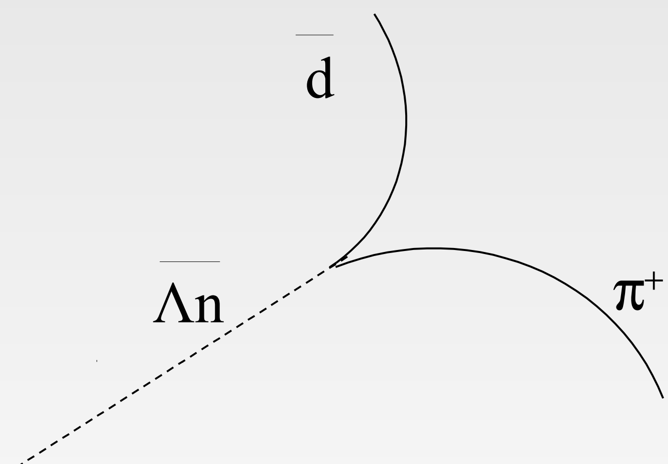
Baryon bound states

Λn bound state

http://www.bnl.gov/hhi/files/talks/TakehikoSaito.pdf, as shown 1.3.2012



HypHI experiment at GSI presented preliminary resluts of a new state:



$m^H = 2.054$ GeV/c2

measurable channel $\overline{\Lambda n} \rightarrow \bar{d}\pi^+$

Baryon bound states

Expected yield in ALICE

- Determine the number of expected particles for the available data using thermal model expectations

Acc. times efficiency
(taken from MC simulations)

Expected yield
(taken thermal Model calculations)

$$N_{\exp}^{BBS} = N_{events} \cdot (A \times \varepsilon) \cdot BR \cdot dN/dy \cdot \Delta y$$

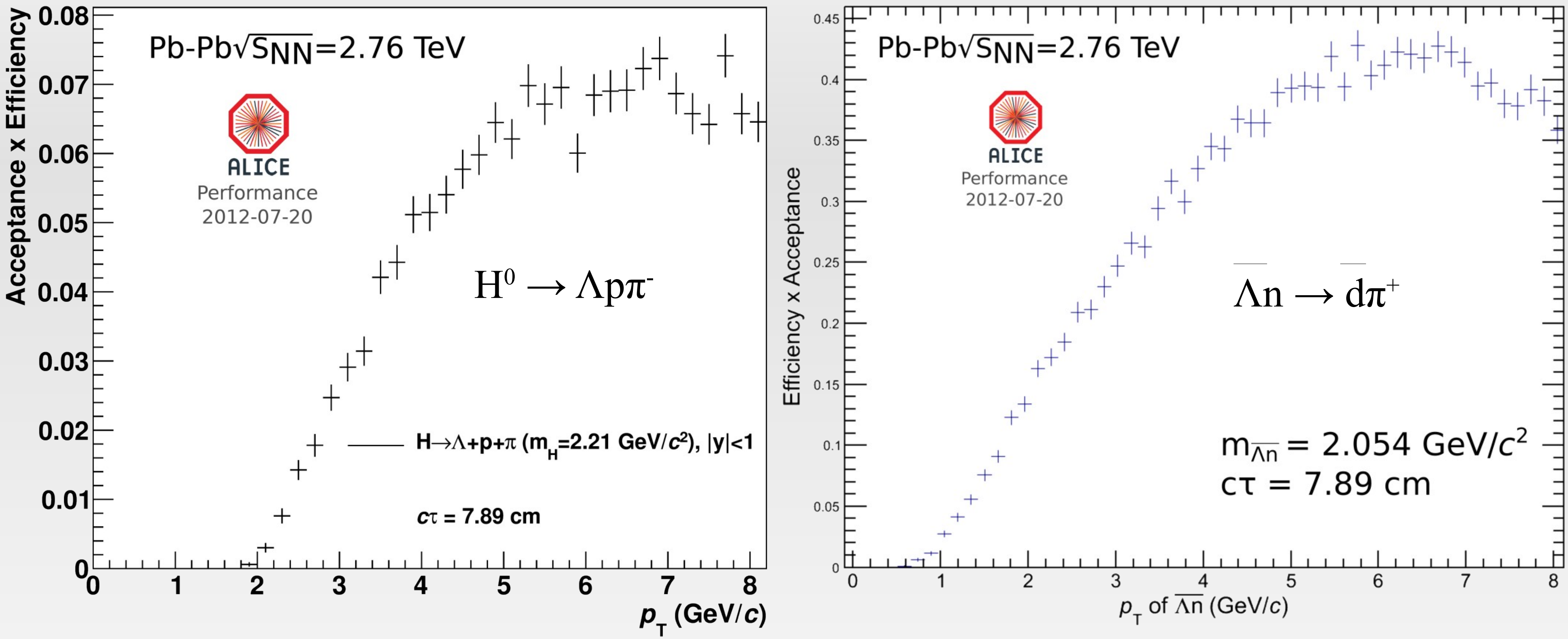
Min. Bias interactions
(13.8 · 10⁶)

Branching ratio
(taken from model calculations)

Detector rapidity (2)

Baryon bound states

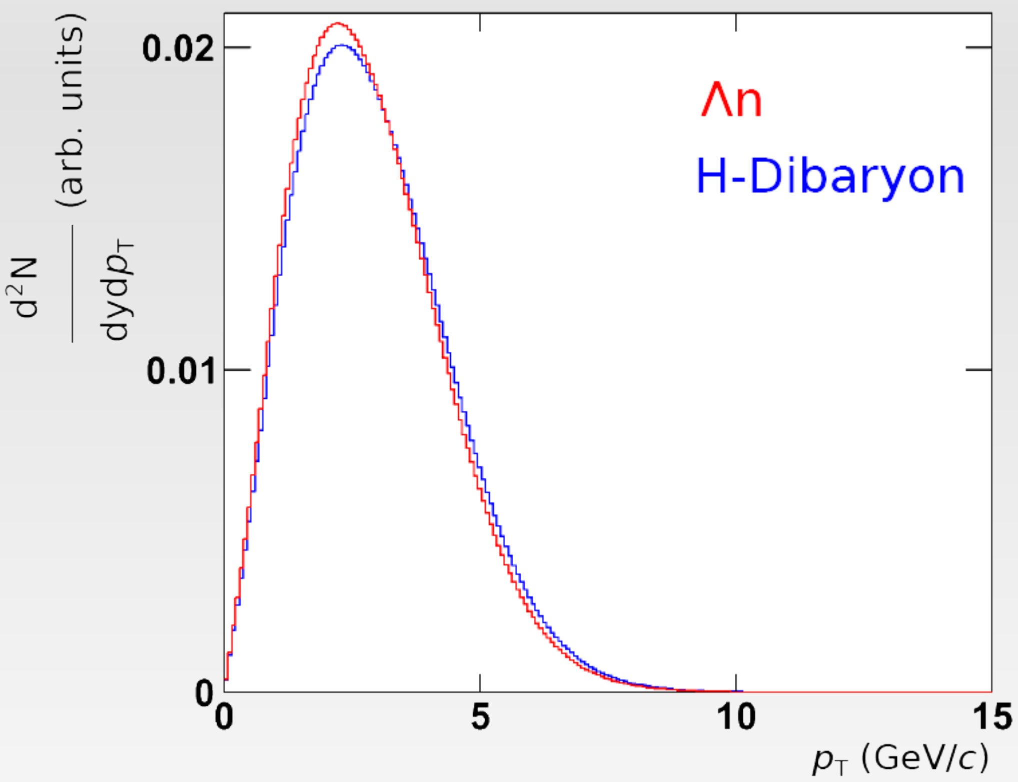
Expected yield in ALICE (efficiency)



- Detector acc. x eff. estimations from Monte Carlo simulation (particles generated flat in y and p_T)
- Assuming the lifetime to be that of the Λ

Baryon bound states

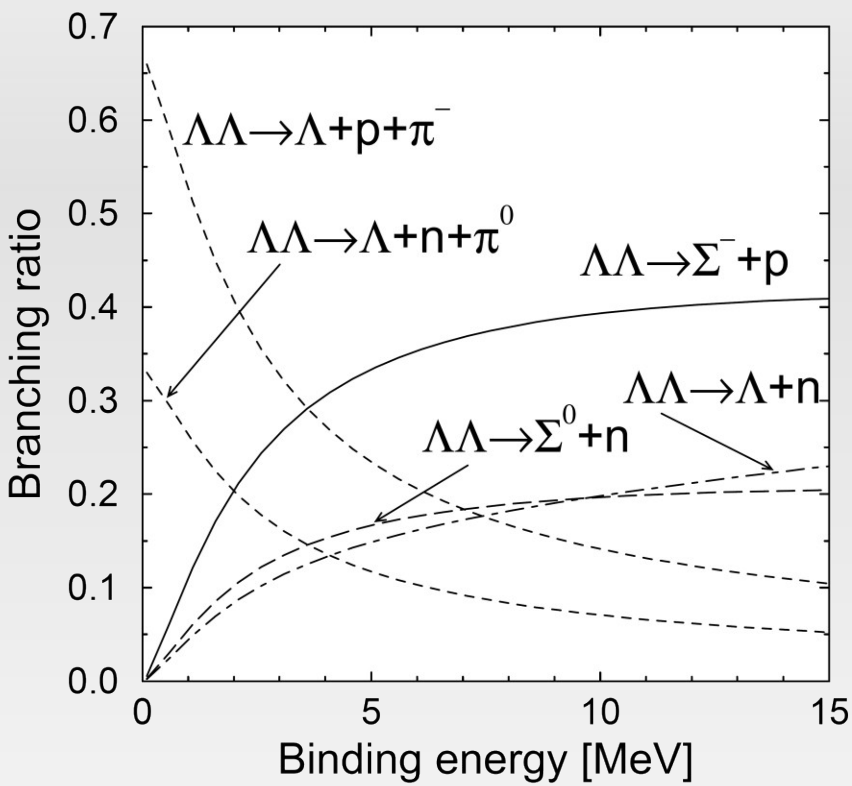
Expected yield in ALICE (p_T shape)



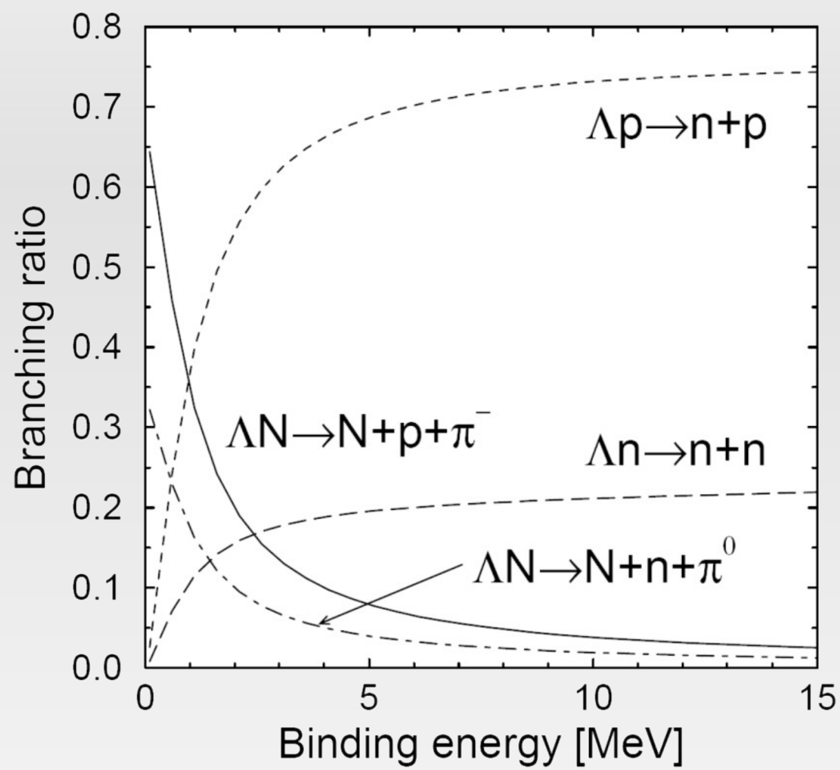
- p_T-shape of the bound states estimated from the extrapolation of blast-wave fits for π,K,p
- Normalised to 1 and convoluted with acc. x eff. to get a weighted efficiency
- Unknown p_T-shape is the main source of uncertainty:
  - different functions used for the systematics
  - limiting cases: blast-wave of deuteron and ^{3}He

Baryon bound states

Expected yield in ALICE (branching ratios)



Schaffner-Bielich et al., PRL 84, 4305 (2000)



Schaffner-Bielich, private communication

BR Limits H0 → Λpπ:
Weakly bound: 64%
Strongly bound: 10%

BR → $\bar{d}\pi^+$:
HypHI : 35%

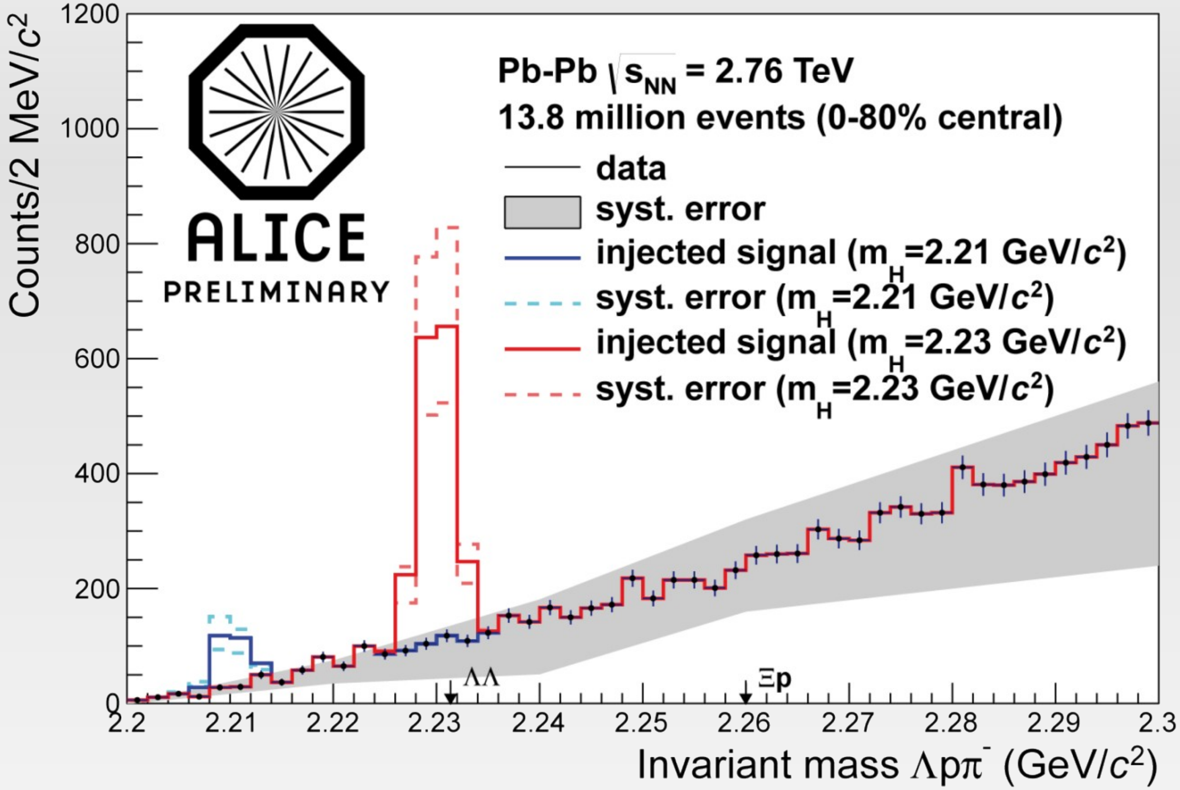
Baryon bound states

Expected yield in ALICE (final estimates)

- The considerations above yield in the following expected particle numbers in $13.8 \cdot 10^6$ events
  - H^0 weakly bound: ~1350
  - H^0 strongly bound: ~210
  - Λn: ~4000

Baryon bound states

Measurement results (H-Dibaryon)

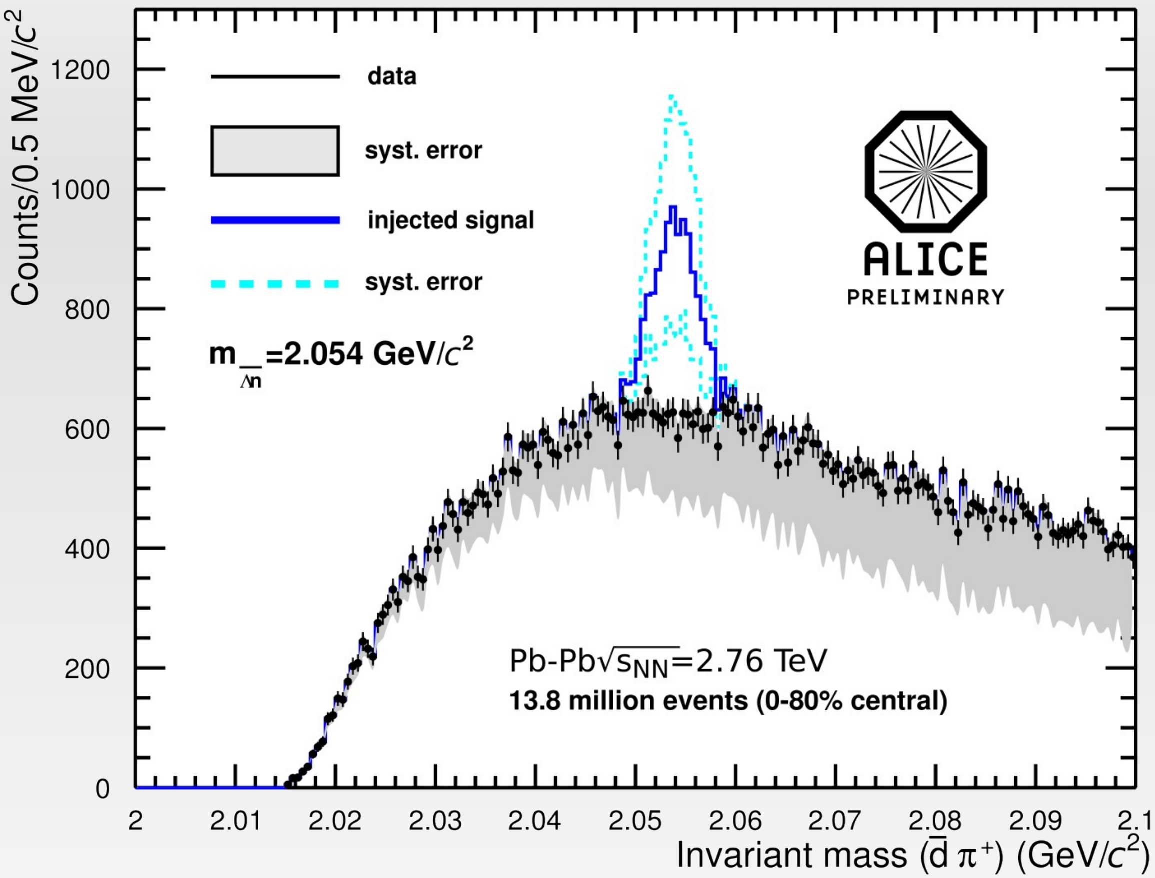


- No signal observed
- Upper limits suggested by the measurement:
  - strongly bound: $dN/dy \leq 8.4 \cdot 10^{-4}$ (99% CL)
  - weakly bound: $dN/dy \leq 2 \cdot 10^{-4}$ (99% CL)

Comparison with the thermal model input ($dN/dy = 3.1 \cdot 10^{-3}$) shows a factor ~10 difference.

Baryon bound states

Measurement results (Λn bound state)



- No signal observed
- Upper limits suggested by the measurement:
  - $dN/dy \leq 1.5 \cdot 10^{-3}$ (99% CL)

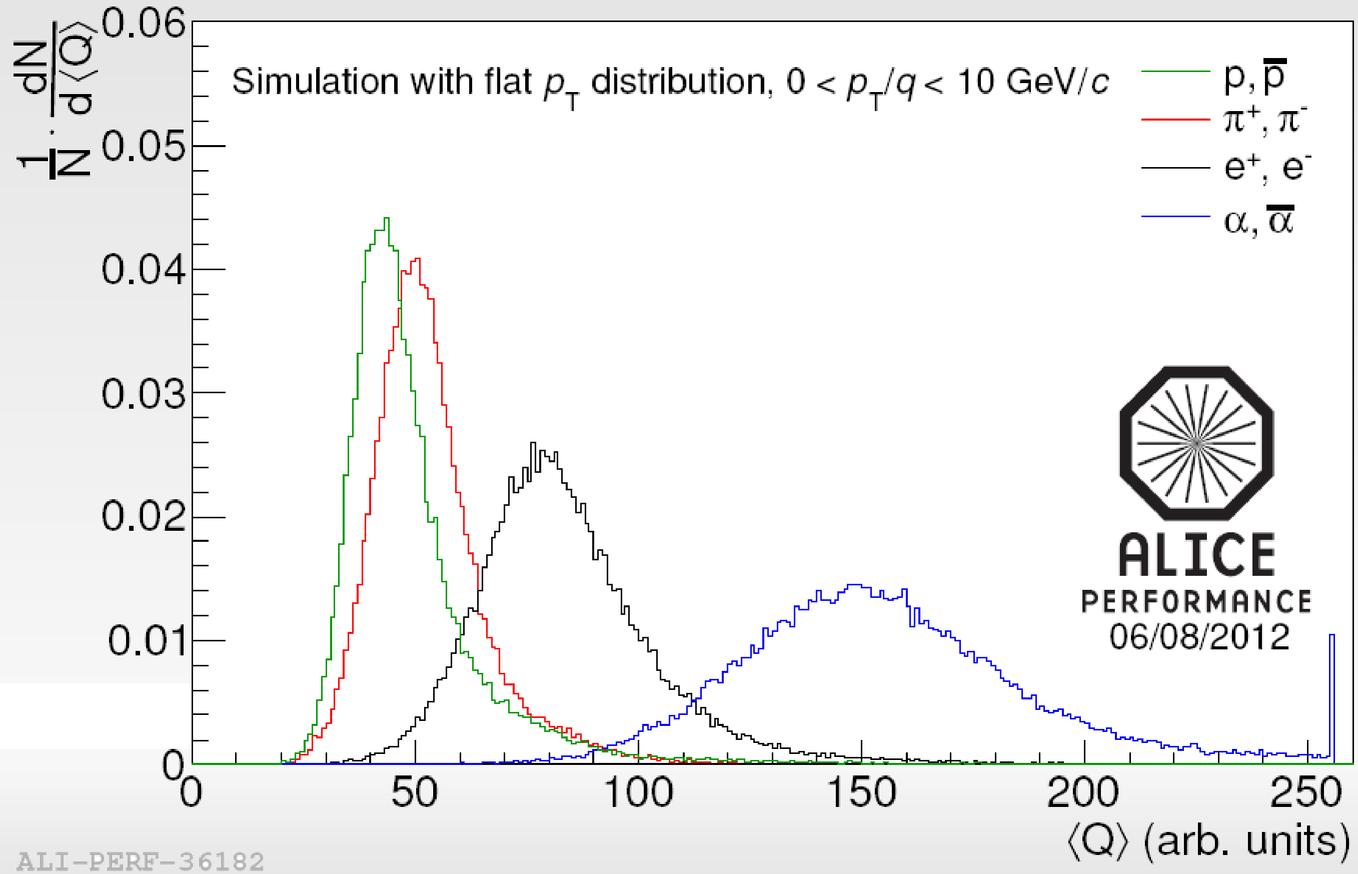
Comparison with the thermal model input ($dN/dy=1.65 \cdot 10^{-2}$) shows a factor ~10 difference.

Outlook

Online Trigger for light nuclei

Clear separation of nuclei in d*E*/d*x* of the Transition Radiation Detector allows to trigger on them

Working on the efficiency and rejection estimation from data in pp and Pb-Pb



Outlook

Particle	Yield
Anti-alpha $^4\overline{\mathrm{He}}$	3.0×10^4
Anti-hypertriton $^3_{\bar\Lambda}\overline{\mathrm{H}}$ $(\bar\Lambda\bar{p}\bar{n})$	3.0×10^5
$^4_{\bar\Lambda}\overline{\mathrm{H}}$ $(\bar\Lambda\bar{p}\bar{n}\bar{n})$	8.0×10^2
$^5_{\bar\Lambda}\overline{\mathrm{H}}$ $(\bar\Lambda\bar{p}\bar{n}\bar{n}\bar{n})$	3.0
$^4_{\bar\Lambda\bar\Lambda}\overline{\mathrm{H}}$ $(\bar\Lambda\bar\Lambda\bar{p}\bar{n})$	3.4×10^1
$^5_{\bar\Lambda\bar\Lambda}\overline{\mathrm{H}}$ $(\bar\Lambda\bar\Lambda\bar{p}\bar{n}\bar{n})$	0.2
H-Dibaryon $(\Lambda\Lambda)$	5.0×10^6
$\Xi\Xi$	1.5×10^5
Λn	8.0×10^7

Expected yields of exotica from thermal model per 10^{10} central collisions into the acceptance of the ALICE central barrel. The numbers include an 8% efficiency per detected baryon.

ALICE upgrade *

(10^{10} central Pb-Pb collisions feasible)

- systematic study of anti-nucleus production
- Bring into reach measurements on the lightest multi-Λ hypernuclei
- search for possible dibaryons and anti-dibaryons with strangeness

* inspecting Pb-Pb collisions at 50 kHz

Summary

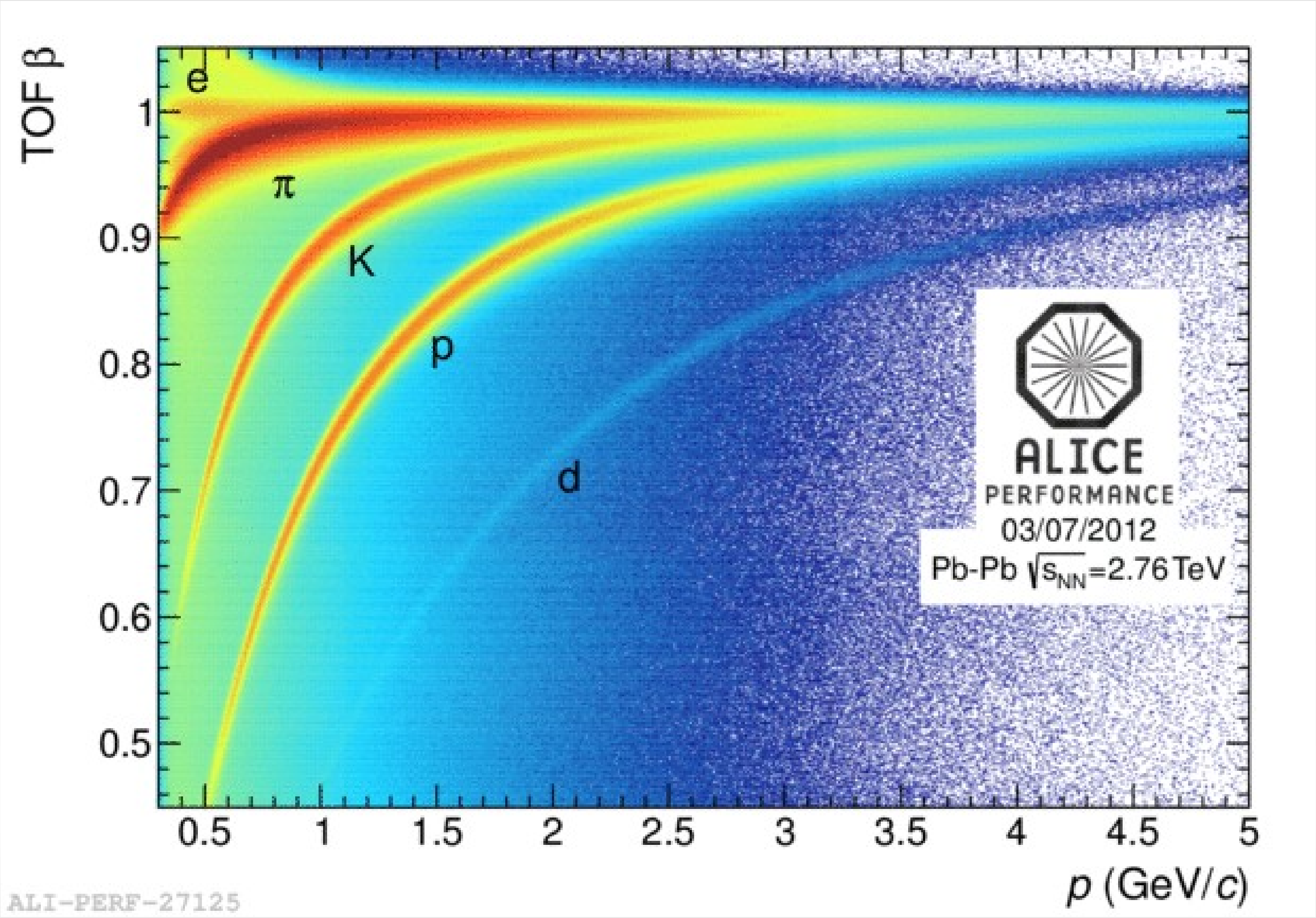
- The ALICE central barrel provides precision tracking $0.1 < p_T < 50$ GeV/*c*
- TPC has very powerful PID capabilities (even more combining several detectors)
  - Identified particle spectra up to 20 (50) GeV/*c*
  - Large dynamical range
  - Identification of Anti-Alpha candidates
  - Clear signal of (Anti-) Hypertriton (p_T spectra in reach)
- Upper limits for H-Dibaryon (2 bound cases) and the (Λn) bound state

Backup

PID in ALICE

Time of flight

Time-of-Flight (TOF)
tracks extrapolated from ITS-TPC
resolution ~85 ps (Pb-Pb)



High performace PID at high p_T

using the TPC

Requirements:

- Pad-by-pad (557k channels) gain calibration using the ^{83}Kr decay.
- Keep gain stable within 0.2 % - frequently updated (15 minutes). Calibration following the change of the pressure, temperature and gas composition.

Optimization of d*E*/d*x* algorithm for TPC:

- Signal integration - correction for the signal below threshold
- Consideration of one pad and missing clusters

Ion tail effect correction (for Pb-Pb):

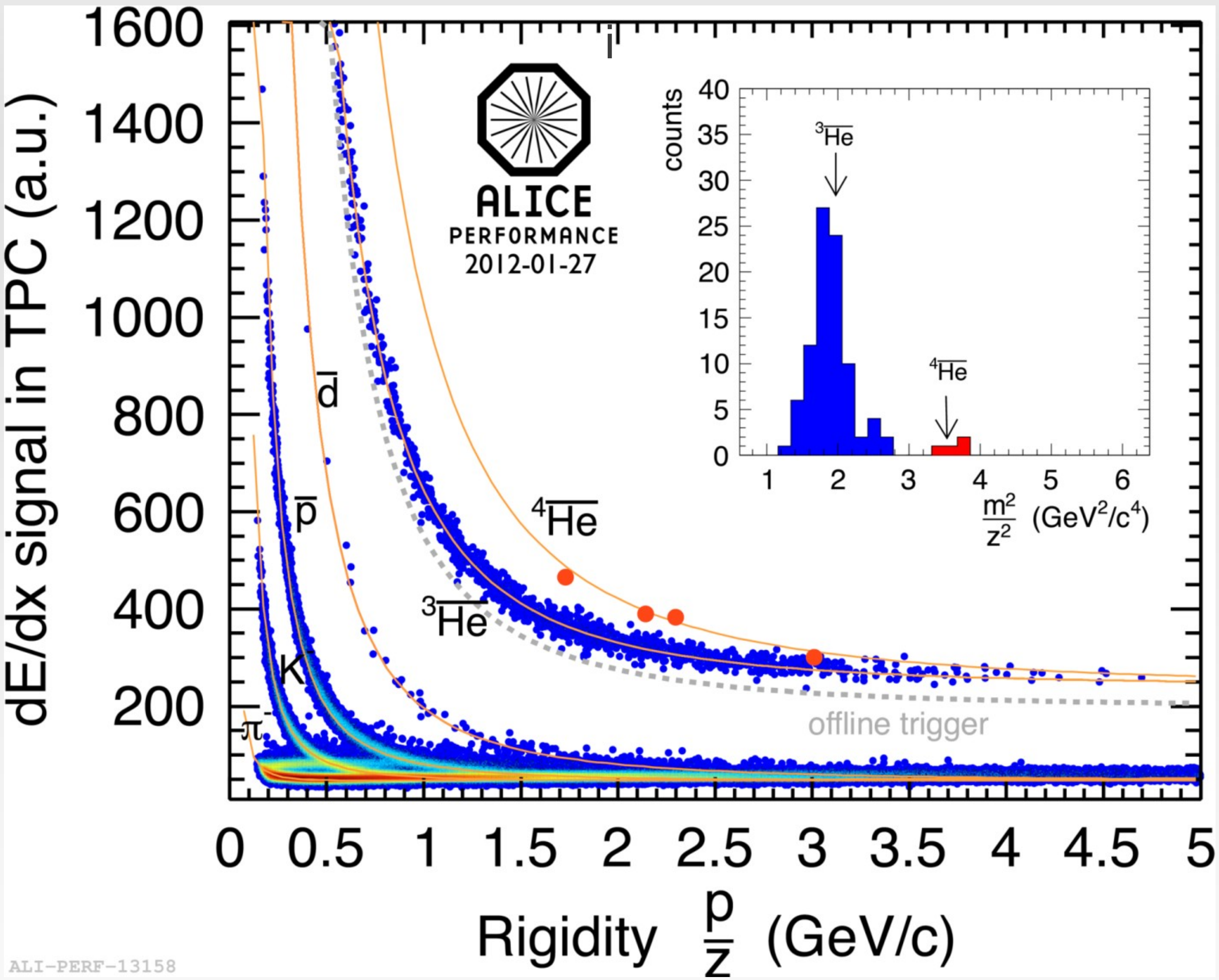
- Correction for the track - multiplicity dependent baseline shift

d*E*/d*x* resolution close to the design value ~ 5.5% at MIP position for low multiplicity and ~ 6.8% for central Pb-Pb collisions

Future improvement: precision ion tail cancellation

Anti-Alpha

Candidate Selection in 2010 data



- Combine TPC dE/dx with mass estimate of TOF
- Good Separation of Anti-Alpha from Anti-^{3}He
- Four Anti-Alpha candidates in full Pb-Pb statistics of 2010

Measuring dE/dx in the TPC