Strangeness in „extremes“ of pp collisions at ALICE

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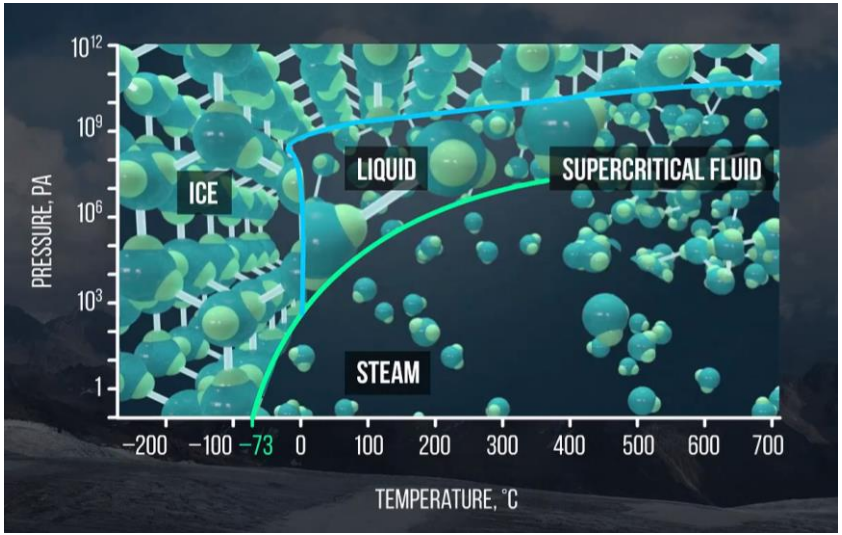
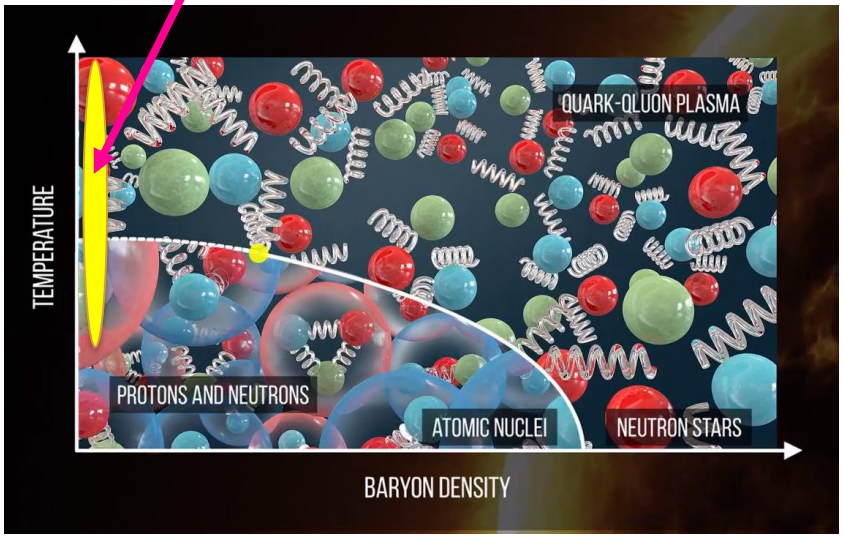
Outline

1. QGP signatures in pp collisions
2. Underlying event and R_T
3. My analysis
4. Overview of my PhD


GOOD
MORNING

Quark-gluon plasma (QGP)

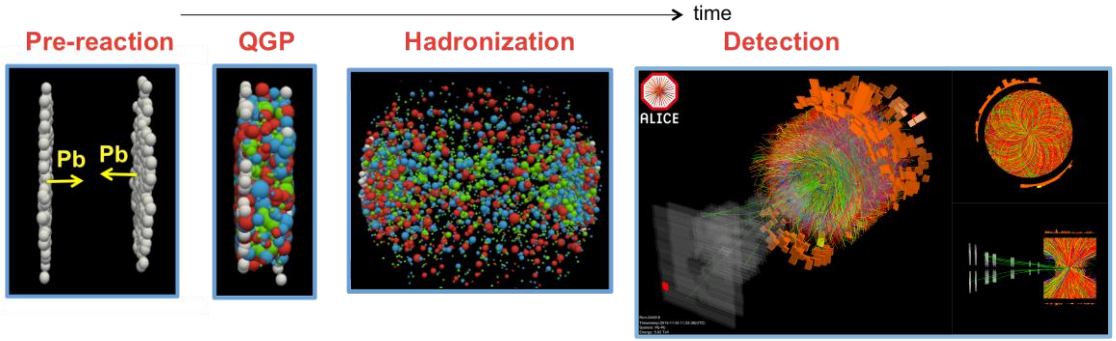




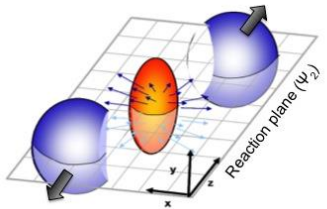
- Phase transition from hadronic matter to plasma of deconfined quarks and gluons predicted from **first principles** of QCD (lattice QCD) with melting temperature T_c~150 MeV
- Nowadays ***widely*** believed to be created in A+A collisions at the LHC

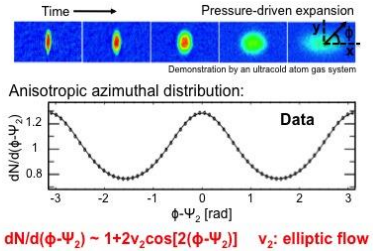
How to detect the QGP I.

- Lifetime of the QGP at the LHC ~10 fm → must be detected indirectly

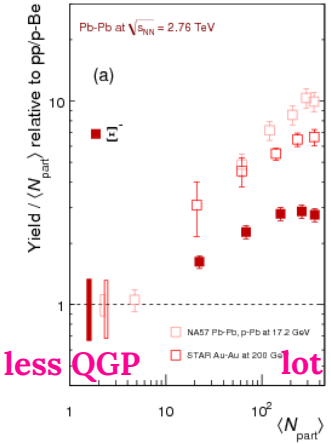


- Traditional signatures:
  - ***Collective hydrodynamical behaviour*** of plasma → initial geometry evolves into structures in $\Delta\varphi, \Delta\eta$ correlations of hadrons ***(anisotropic flow)***



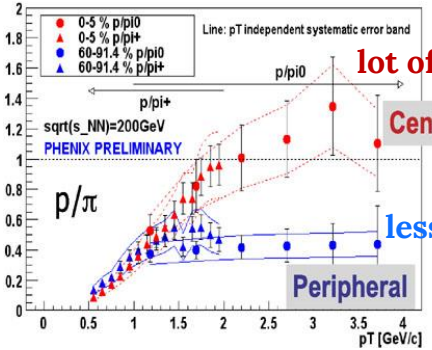


How to detect QGP – traditional signatures II.



less QGP — lot of QGP

- ***Strangeness enhancement***
  - In hadronic matter, strangeness is suppressed due to the much larger mass w.r.t. up and down
  - In QGP, thanks to large abundance of gluons, and large energy density, strange quarks are very easy to create and reach equillibrium
  - Other explanations: canonical suppression in pp; smaller reaction threshold for $gg \rightarrow \bar{s}s$ $(\sim 2m_s)$ than $hh \rightarrow \overline{h_s} h_s$ $(\sim 2m_K)$



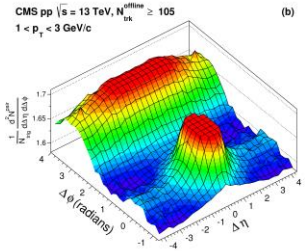
- ***Radial flow***
  - QGP as a very dense medium rapidly expands
  - Medium expanding with velocity v also accelerates objects in it to v
  - $\Delta p = m\Delta v$ → heavier objects receive larger momentum push than lighter

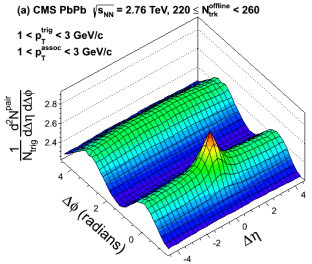
- ***Jet quenching*** – tomography of QGP with jets due to different in-medium path lengths
- ***Heavy flavour*** – not produced in-medium, modified pT-spectra due to in-medium energy loss

QGP signatures in p+p (and p+A) collisions

- QGP traditionally not thought to be possible (system size too small, not enough time to „hydrodynamize“)
- Small system (=p+p, p+A) collisions interesting for HIC community mainly as baselines

- However, when looking closely enough…
- Collective behaviour observed in pp collisions (see Adrian‘s talk)

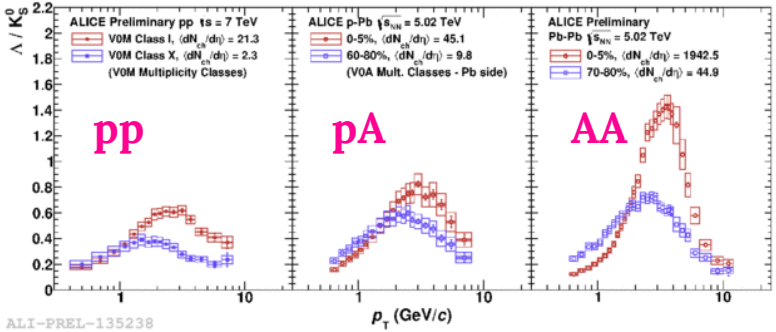




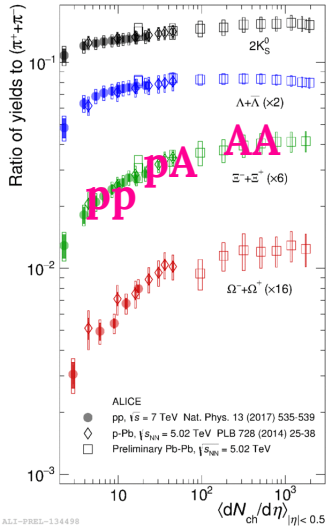
- Not just any pp collisions, but mainly those with ***very very very high multiplicities***

QGP signatures in p+p (and p+A) collisions II.

- Do other QGP phenomena show up when increasing multiplicity?
- Radial flow:



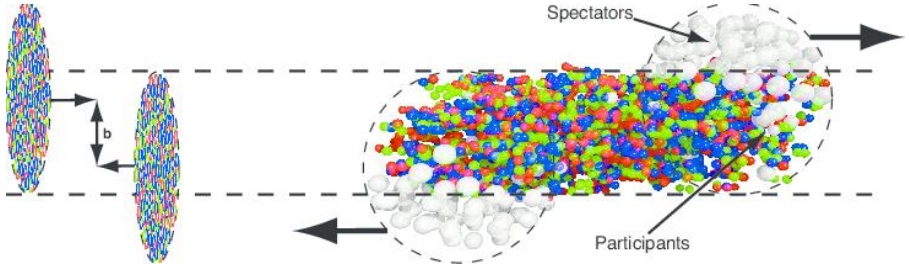
- Strangeness enhancement:



- Magnitudes are different, but the ***same dependencies on multiplicity*** are observed for multiple signatures ***<u>regardless of the system</u>***!

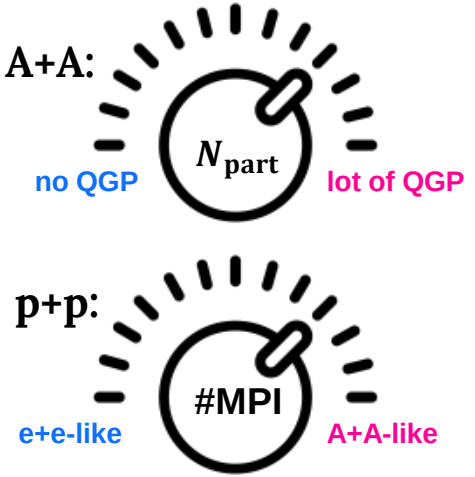
What does multiplicity tell us?

- In A+A collisions, the driving factor behind multiplicity is the energy density and medium size
- These increase the more the two nuclei overlap (generally more ***participating nucleons***)



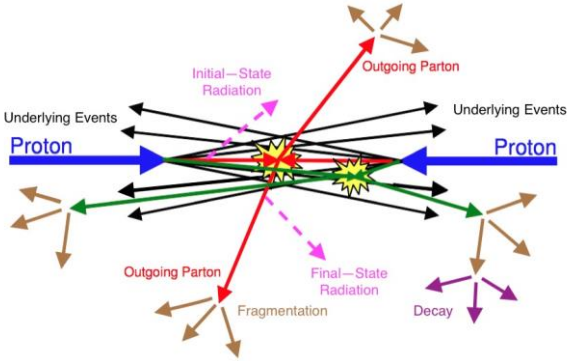
- People measure multiplicity but the interesting dial controlling the collision is actually N_{part}
- What about pp?
  - Only two participant nucleons! However, ***multiple partons*** can ***interact*** in one collisions (MPI), increasing the multiplicity
  - Not so clean, because multiplicity also increases with ***hardness of the primary scattering***

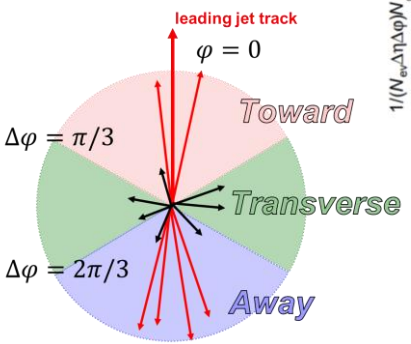
Dials for QGP signatures:

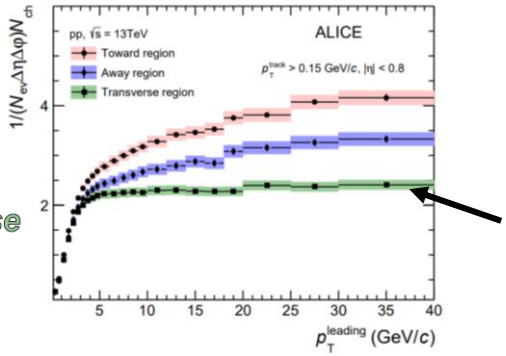


Accessing #MPI experimentally

- How do we access the number of multiple partonic interactions experimentally?
- With underlying event!
- ***Underlying event (UE):*** collection of particles not originating from the primary parton-parton scattering or the related fragmentation
- Constant particle production due to UE can be seen as a „jet pedestal effect“



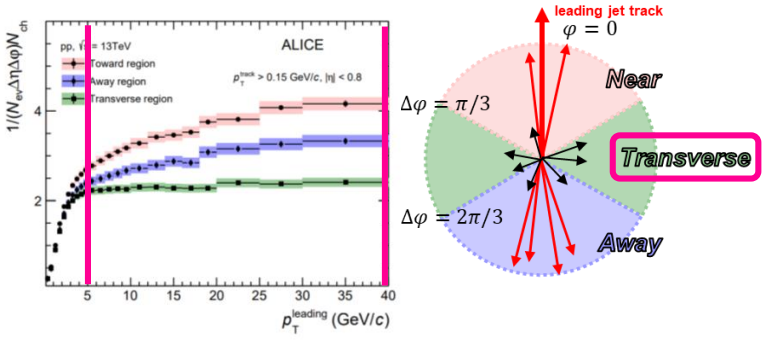




- In this region, in events with a jet, the particle multiplicity is constant independent on the jet momentum
- We found something that is sensitive to the #MPI yet completely insensitive to the hardness of the collision

→ let‘s build a control variable out of that

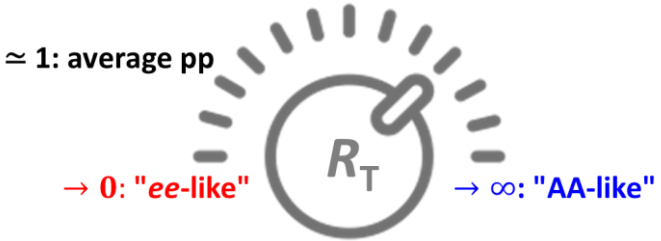
Underlying event activity R_T

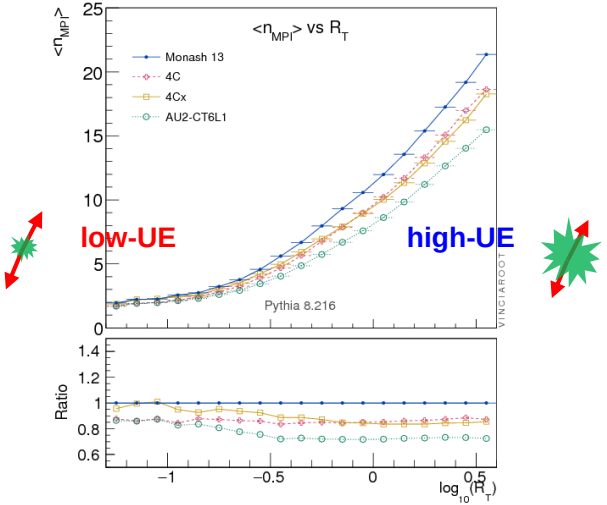


$$R_T = \frac{N_{ch}^{trans}}{<N_{ch}^{trans}>}$$

- Self-normalised so that we can directly compare across different collision energies and systems

- We can use this instead of multiplicity as a cleaner variable
- It can also be shown that R_T is directly related to the #MPI

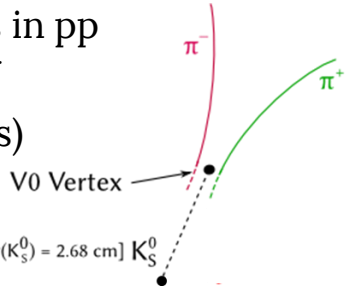


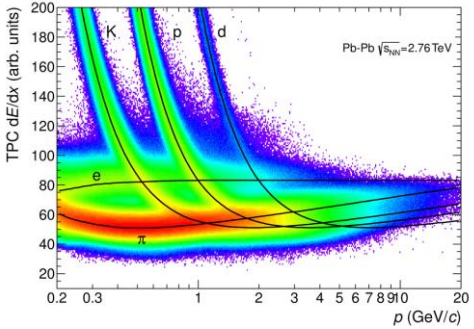


My analysis right now

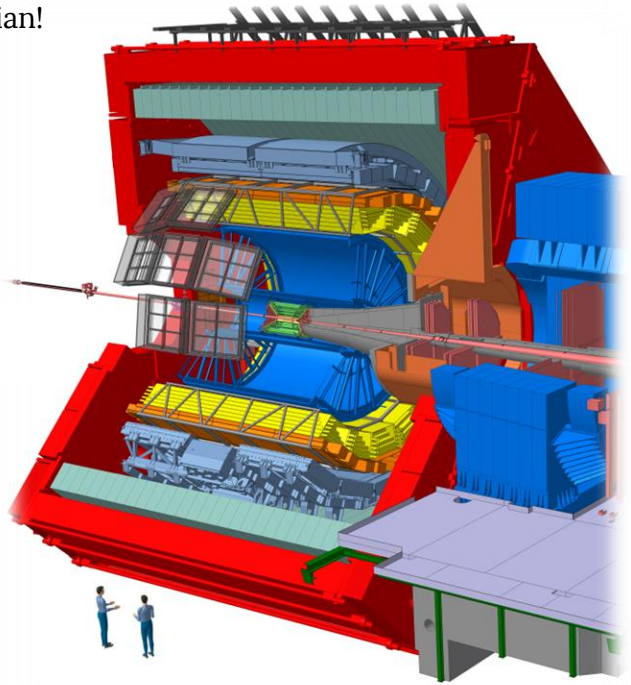
*spherocity covered by Adrian!

- Production of neutral open-strange hadrons in pp collisions as a function of R_T and ***spherocity****
- $= K^0_S \rightarrow \pi^+\pi^-$, $\Lambda \rightarrow p\pi^-$, $\bar{\Lambda} \rightarrow \bar{p}\pi^+$ (a.k.a V0s)



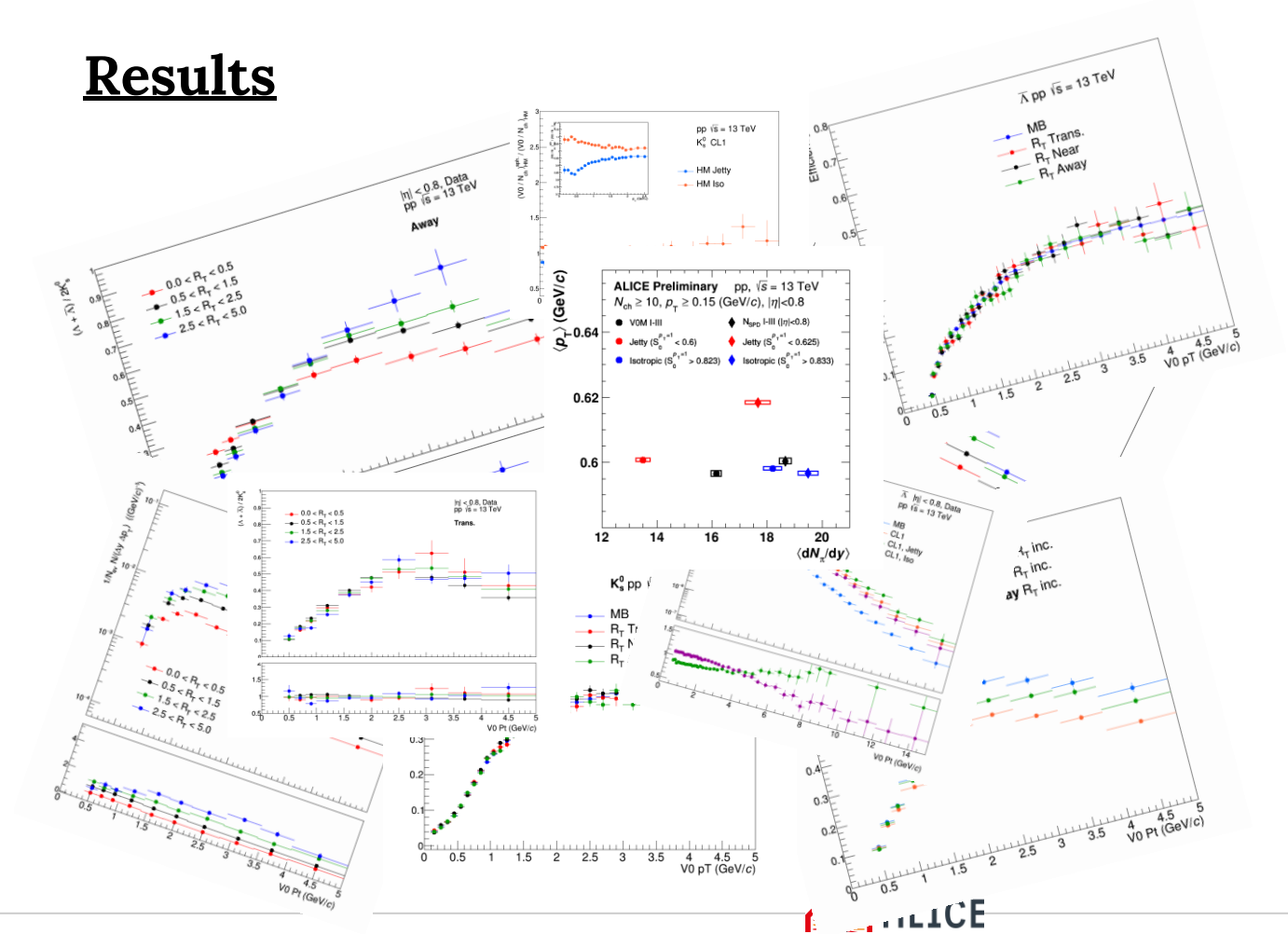


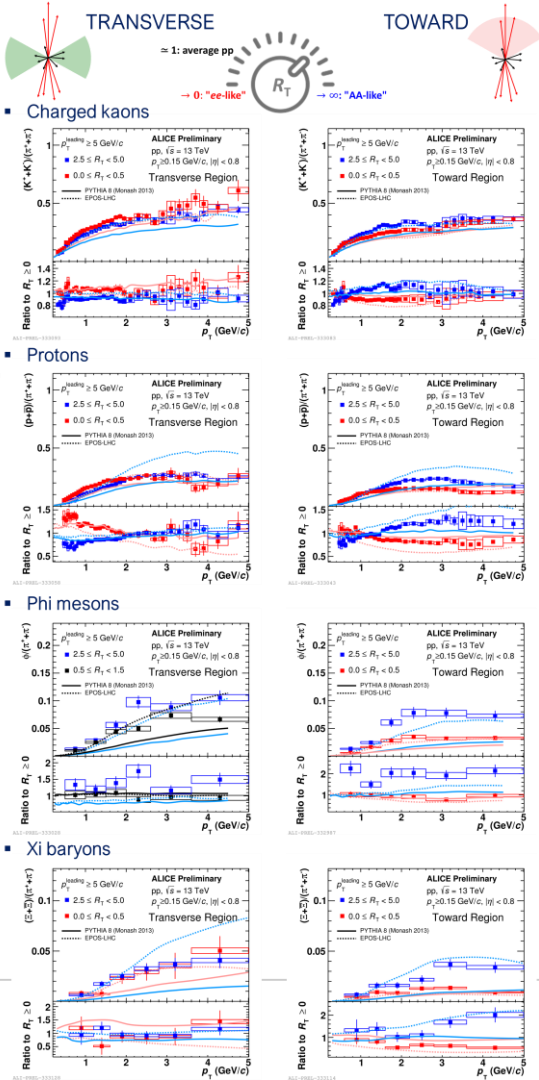
- Topological cuts
- Pions and protons are identified thanks to their specific ionisation energy loss in the Time Projection Chamber (TPC)



- Why V0s? We can get clearer interpretation by comparing
- K^0_s vs $K^{\pm}$: charge effect on the measurement (self-correlation bias)
- Λ vs p : strangeness effect
- Other analyses at LU: Ξ (Ξ vs Λ vs p : strangeness content effect), ϕ (ϕ vs Ξ : hidden vs open strangeness effect)

Results


ALICE Preliminary pp, $\sqrt{s}$ = 13 TeV
$N_{ch} \geq 10$, $p_T \geq 0.15$ (GeV/c), $|\eta|<0.8$
V0M I-III
Jetty ($S_0^{R_T=1} < 0.6$)
Isotropic ($S_0^{R_T=1} > 0.823$)
N_{SPD} I-III ($|\eta|<0.8$)
Jetty ($S_0^{R_T=1} < 0.625$)
Isotropic ($S_0^{R_T=1} > 0.833$)
$\langle p_T \rangle$ (GeV/c)
$\langle dN_{ch}/dy \rangle$
Away
Trans.
V0 pT (GeV/c)
V0 Pt (GeV/c)
MB
HM Jetty
HM Iso


TRANSVERSE
TOWARD
≃ 1: average pp
→ 0: "ee-like"
→ ∞: "AA-like"
Charged kaons
Protons
Phi mesons
Xi baryons
Transverse Region
Toward Region
ALICE Preliminary
pp, $\sqrt{s}$ = 13 TeV
PYTHIA 8 (Monash 2013)
EPOS-LHC
Ratio to $R_T \geq 0$
p_T (GeV/c)

Overview of my PhD

- ***Courses and schools taken:***
  - PhD introduction
  - CERN School of Computing (Cluj, Romania) :

  -> 2 weeks of FUN, lectures have very broad coverage (HEP computing, ML, parallelisation, data...) but don't go to a lot of depth
- ***Courses and schools I want to take:***
  - Particle Physics Phenomenology
  - GEANT4
  - Neural Networks
  - Nordic detector school
  - CERN School of HEP Asia-Europe-Pacific (S.Korea)
- ***Conferences:***
  - ALICE Physics Week 2019 Prague (talk)
  - Quark Matter 2019 Wuhan (poster)
- ***Other activities:*** teaching the muon lab (2x)