
# Strange baryon enhancement with effective energy in pp collisions at the LHC

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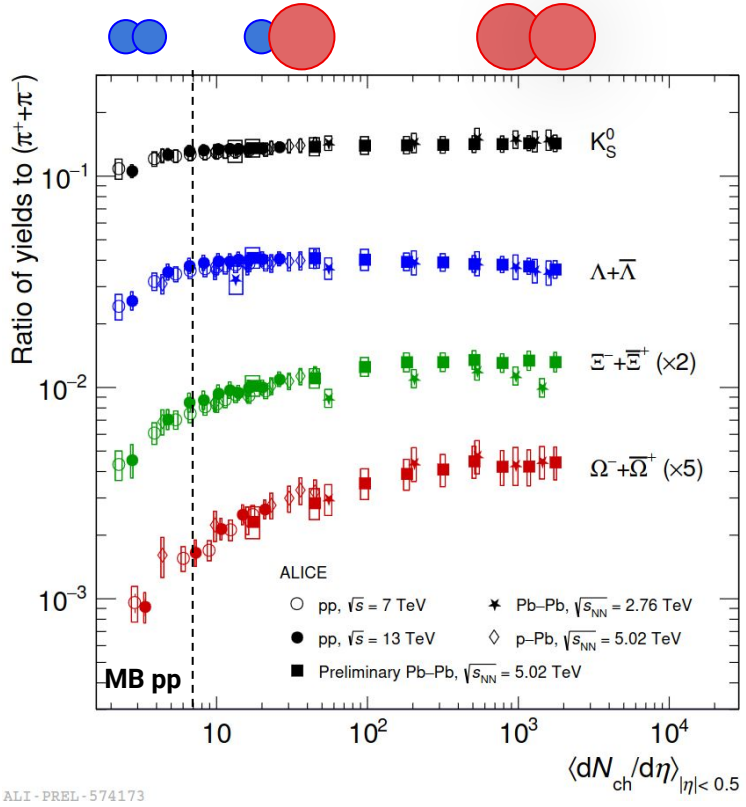
*University and INFN Bologna*

ALICE

INFN
Istituto Nazionale di Fisica Nucleare

# Strangeness production across collision systems




**Continuous evolution** of strange hadron yield ratios to pions **with the charged-particle multiplicity** observed at the LHC, smoothly connecting different systems and energies

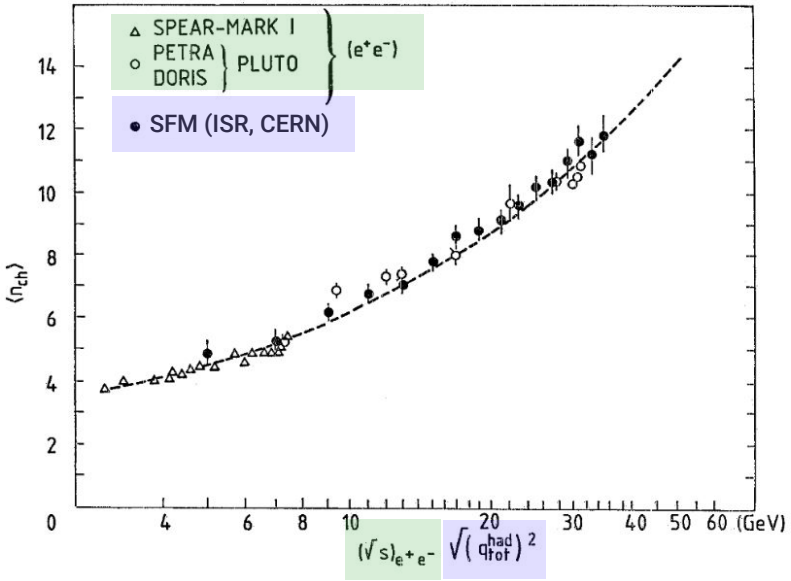
**Strangeness** production **increases with** particle **multiplicity**, saturating for central Pb–Pb

Strange content **hierarchy**:

$$|S_{\Omega^\pm}| > |S_{\Xi^\pm}| > |S_{\Lambda}| \approx |S_{K^0_S}|$$

Nature Phys 13, 535-539 (2017)
Eur. Phys. J. C 80, 167 (2020)

# Multiplicity and effective energy



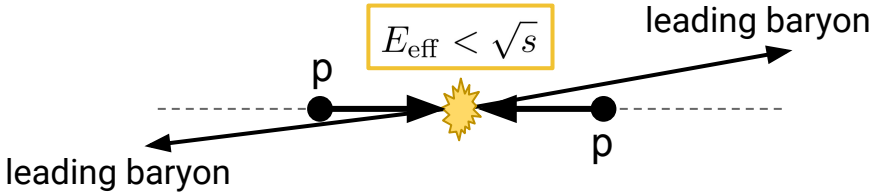

$$E_{\text{eff}} = \sqrt{s} - E_{\text{leading}}$$

Considering other observables correlated with the charged particle multiplicity

**Effective energy**: energy available for particle production in the initial stages of the collision

In **pp reduced** due to leading baryon emission at very forward rapidity (**leading effect**)

First studied at the CERN ISR in the 80's




M. Basile et al., Phys. Lett. B 95 (1980) 311
A. Akindinov et al., EPJ C 50 (2007) 341–352

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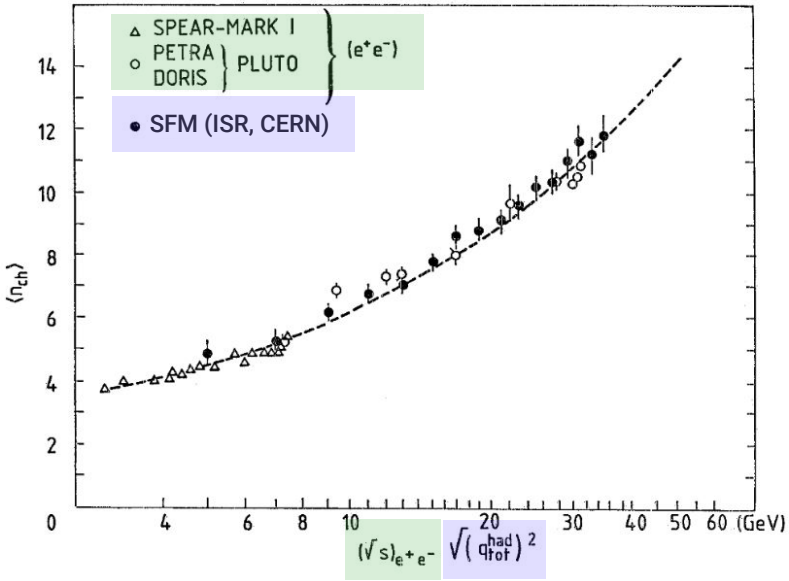


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Is strangeness enhancement in pp connected to the effective energy?

M. Basile et al., Phys. Lett. B 95 (1980) 311
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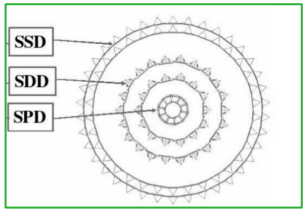
# ALICE in LHC Run 2

**Inner Tracking System (ITS)**
Six layers of silicon detectors (SPD, SDD, SSD). Tracking, triggering, vertexing




ZDC

**Zero Degree Calorimeters (ZDC)**
Hadronic calorimeters, *112.5* m from the IP
$|\eta| > 8.8$ (ZN), $6.5 < |\eta| < 7.4$ (ZP*))

**Time Projection Chamber (TPC)**
Gas-detector. Tracking, vertexing, PID (dE/dx)

**Time Of Flight (TOF)**
Based on the Multigap RPC technology.
PID via Time-Of-Flight technique

**V0 detectors (V0A and V0C)**
Arrays of scintillators. Triggering, multiplicity estimators
$2.8 < \eta < 5.1$ (V0A), $-3.7 < \eta < -1.7$ (V0C)

*considering LHC beam optics ZP acceptance for protons is $7.0 < |\eta| < 8.7$

# Strange hadron reconstruction with ALICE

**Kinematical** and **geometrical** criteria are used to reconstruct candidates for strange hadrons

Identification based on two topologies:

- **$V^0$** → neutral particle decaying weakly into a pair of charged particles (V-shaped decay)

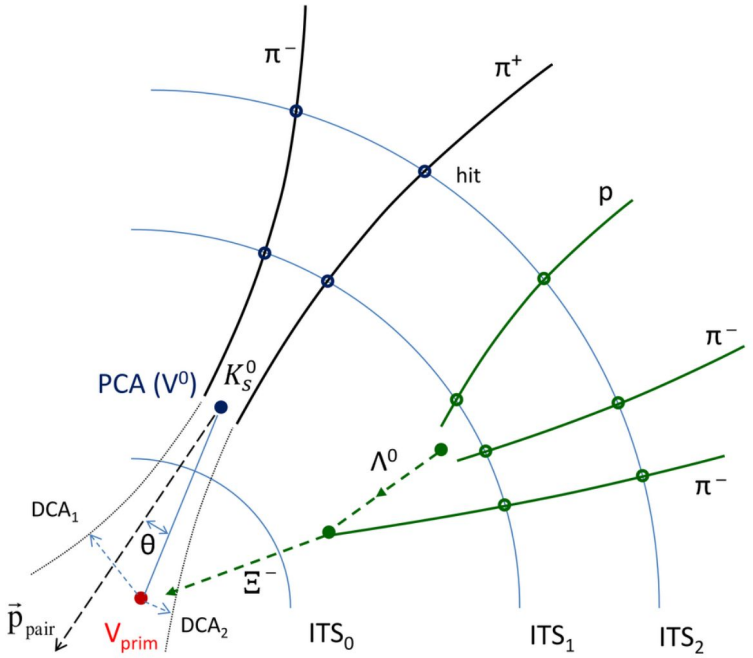
$$K^0_S \rightarrow \pi^+ + \pi^-$$

$$\Lambda \rightarrow p + \pi^-$$

- **Cascade** → charged particle decaying weakly into a $V^0$ + charged particle

$$\Xi^- \rightarrow \Lambda + \pi^-$$

$$\bar{\Xi}^+ \rightarrow \bar{\Lambda} + \pi^+$$



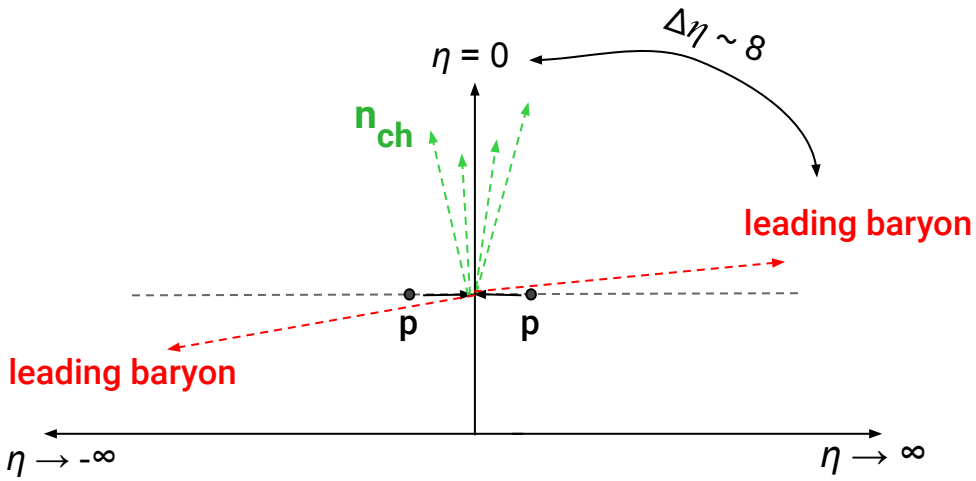
# A new experimental technique

Novel experimental technique: **two-dimensional analysis** as a function of

- **Charged-multiplicity at midrapidity**
  proxy for **local** effects, e.g. jet production, local fluctuations in the hadronization process

- **Leading energy**
  proxy for **global** effects, e.g. the initial effective energy in the collision

$$E_{\text{eff}} = \sqrt{s} - E_{\text{leading}}$$




Causally independent given the large $\eta$ separation

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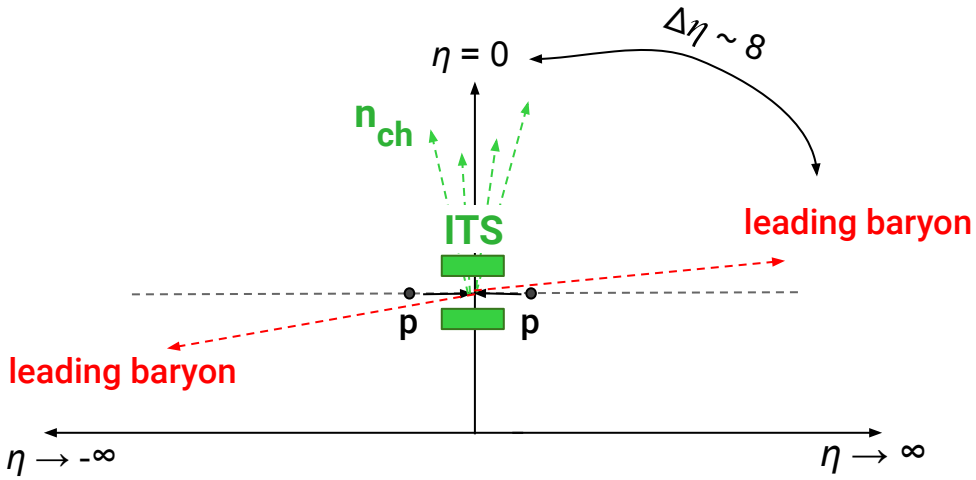


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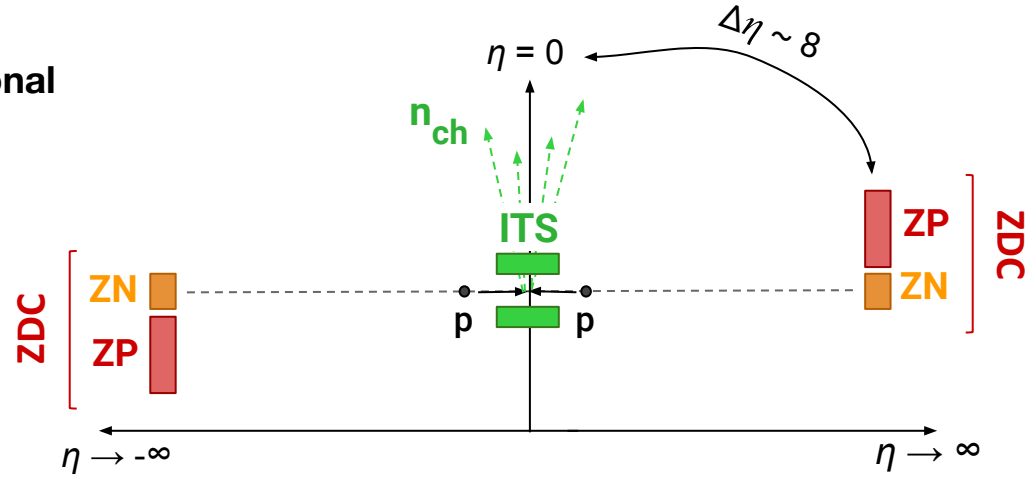


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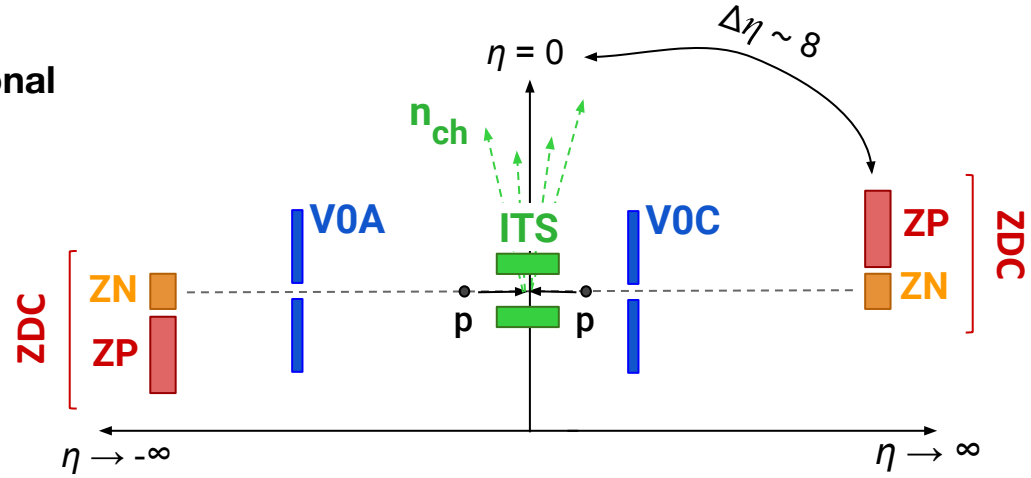


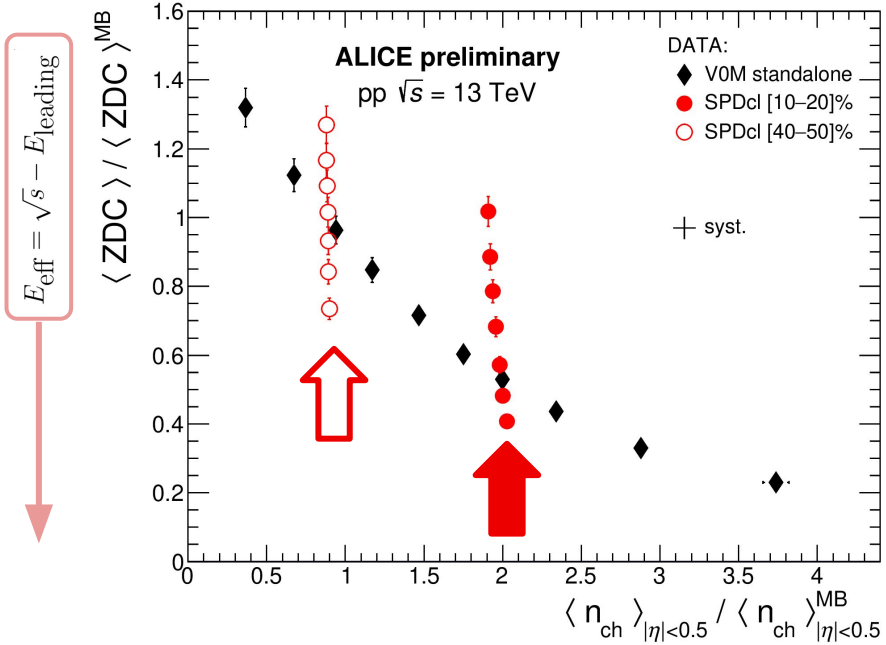

ALICE can measure:

- midrapidity multiplicity ( **SPD** )
- leading energy ( **ZDC** )
- forward multiplicity ( **V0M** = V0A+V0C )

# Event classes with a differential approach

The leading energy decreases with increasing particle multiplicity produced at midrapidity [1]

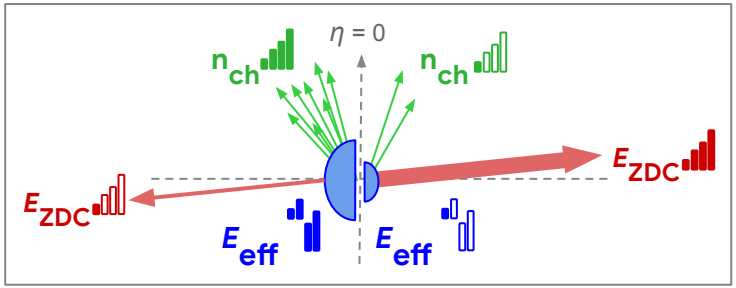
**New** multi-differential event classes: **similar midrapidity multiplicity** and **different leading energies**



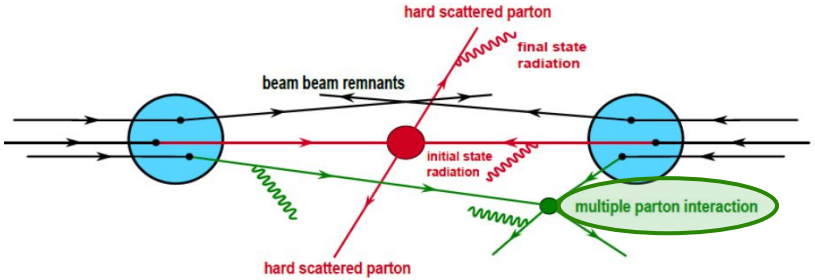

**Standalone**

**High local multiplicity** (midrapidity)

**Low local multiplicity** (midrapidity)



# Connection to the MPIs in PYTHIA

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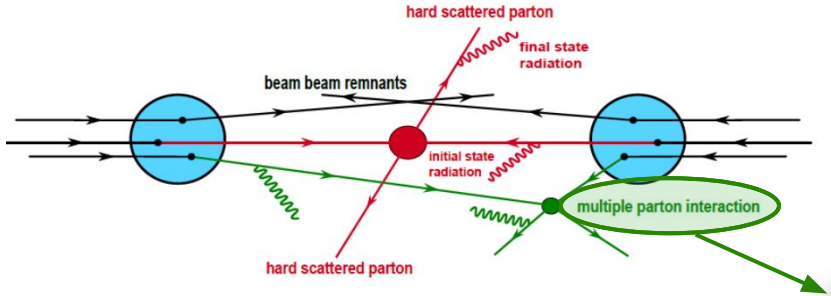


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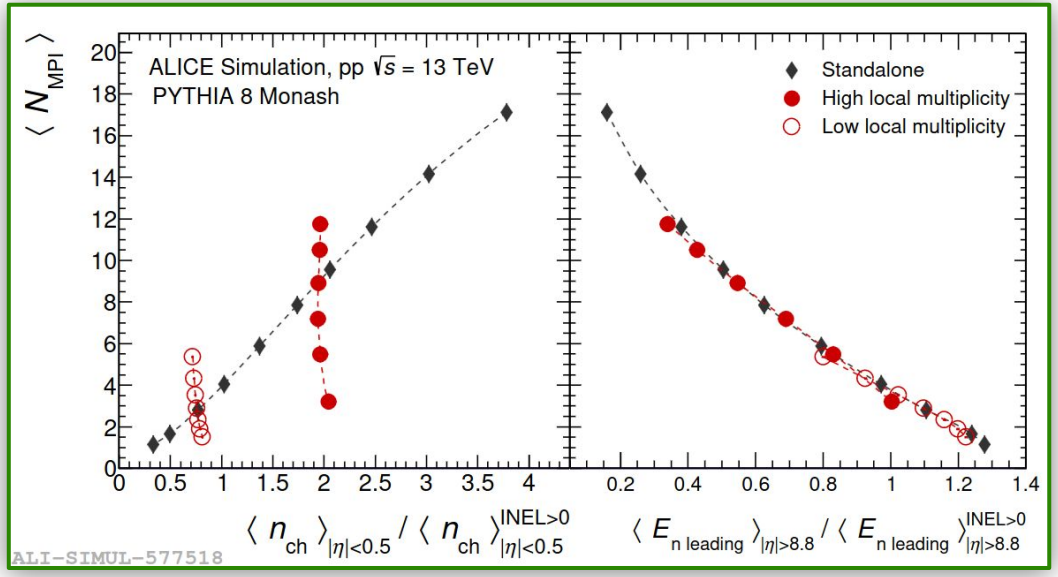
NEW!

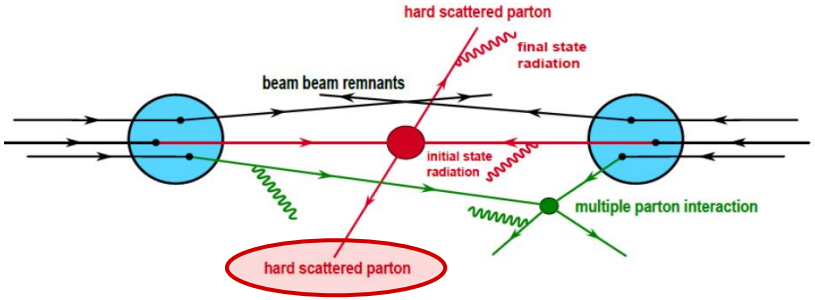



**MPIs increase** at **fixed local multiplicity** with decreasing leading energies in the model

**Universal** dependence with the leading energy, i.e. common for all selections

A powerful observable to probe the dependence of particle production on the number of MPIs in the model

# Connection to hard-scattering in PYTHIA




The presence of jets at midrapidity is studied in PYTHIA considering the $\langle p_{\mathrm{T}}^{\pi} \rangle_{|y|<0.5}$, proxy for the **$p_{\mathrm{T}}$ of the hard parton scattering process**

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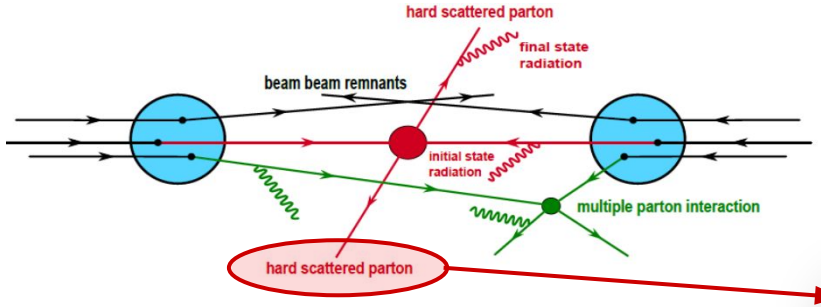


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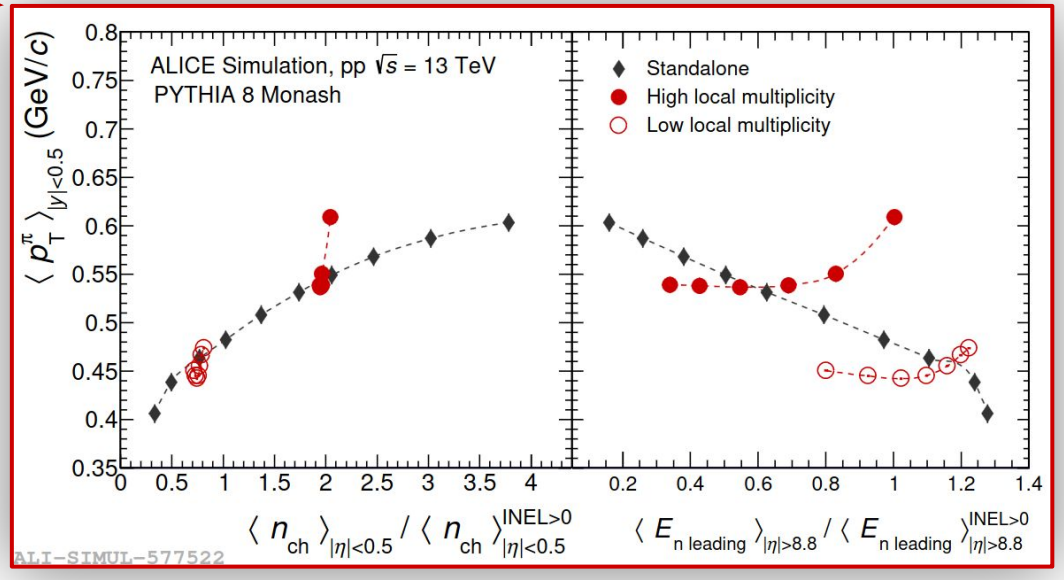


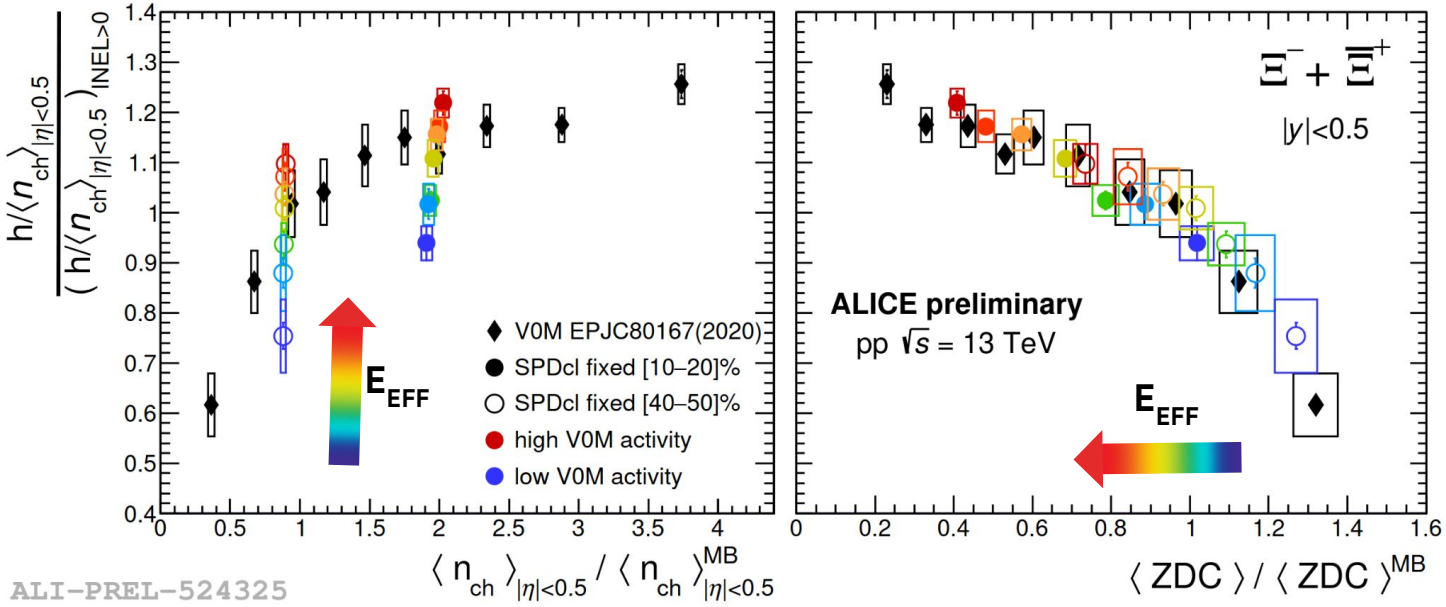

Very **mild dependence** of $\langle p_{\mathrm{T}}^{\pi} \rangle_{|y|<0.5}$ with the **leading energy**

Local phenomena (jets at midrapidity) are correlated with local observables (charged-multiplicity)

# Strangeness production at fixed multiplicity

In events with the same particle multiplicity produced:

- **increase** in $\Xi/n_{ch}$ observed for **decreasing forward energy** (ZDC)
- universal scaling trends with ZDC energy, compatible within uncertainties



# Outlook

Strangeness production in pp collisions is studied with a **novel experimental technique** to understand the origin of its enhancement by introducing a new observable: the **effective energy**

Strange baryon enhancement ( $\Xi/n_{ch}$ ) in pp collisions:

- was **observed** at **fixed midrapidity multiplicity**
- is **connected** to the **effective energy** (initial stage)

Studies performed using the generator PYTHIA show that the **effective energy** is **strongly correlated** with the number of **MPIs** in the model

⇨ Correlation of **strange baryon enhancement** with **global properties** of the collision