2021 KoALICE National Workshop

$\Xi_c^{0,+}$ production with ALICE and Ξ_{cc}^{++} production with ALICE 3

Jinjoo Seo
Inha University

2022. 01. 04

ALICE Overview

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2009 ~ 2013

Run 2
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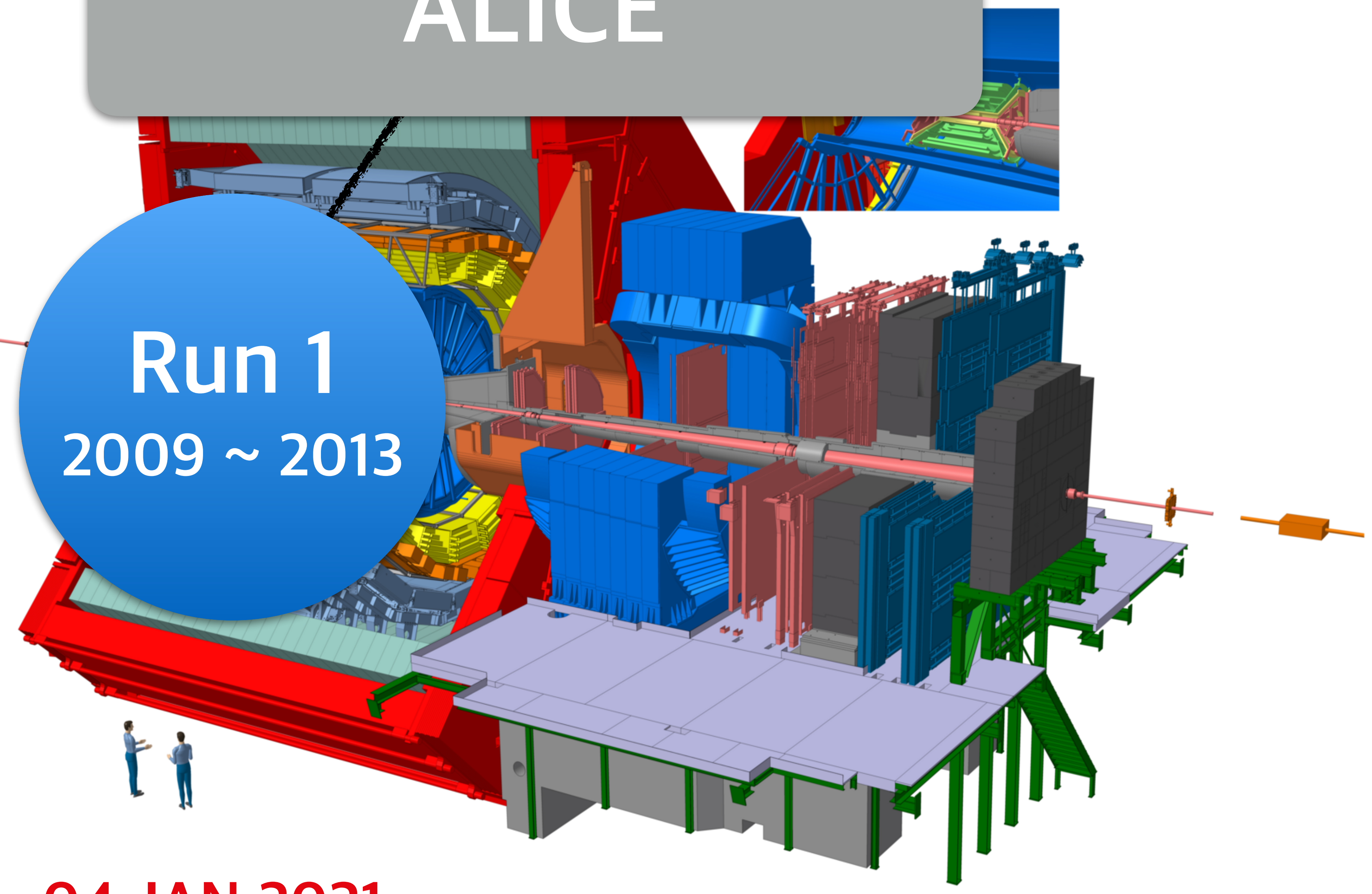
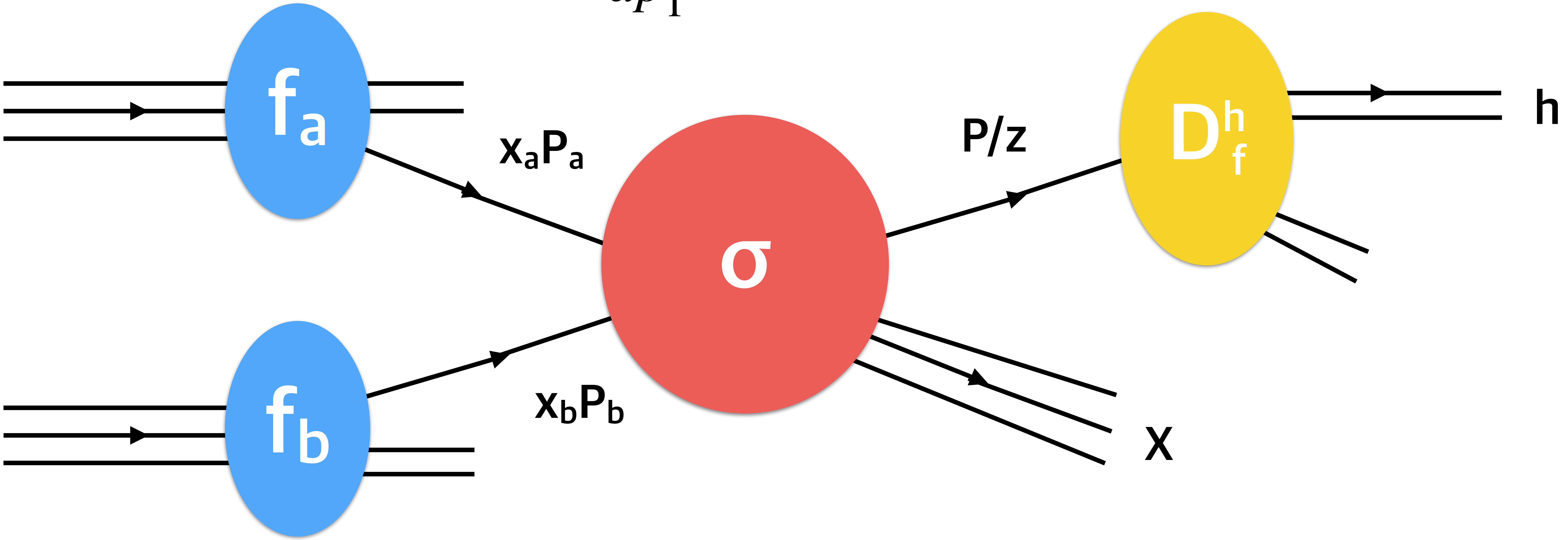
ALICE



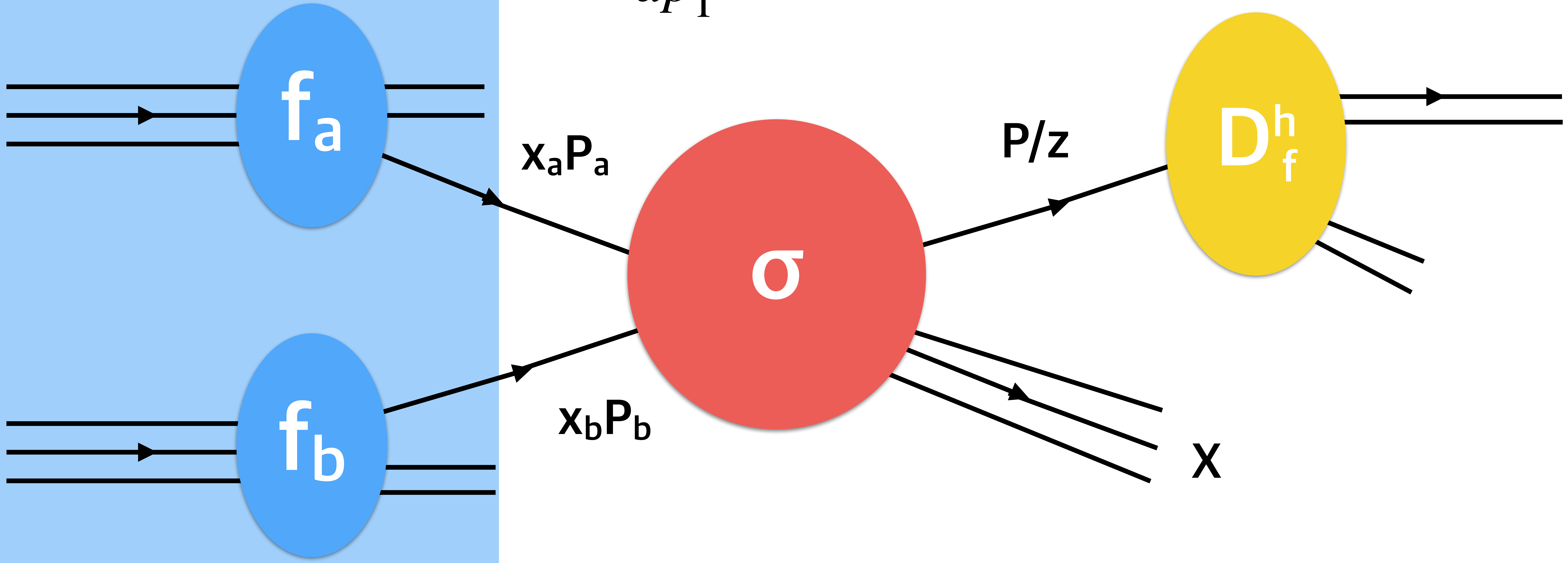
Production of charm hadrons

$$PDF(x_a, \mu_F)PDF(x_b, \mu_F) \otimes \frac{d\sigma^c}{dp_T^c}(x_a, x_b, \mu_R, \mu_F) \otimes D_{c\rightarrow H_c}(z = p_{H_c}/p_c, \mu_F)$$



Initial Parton distribution function

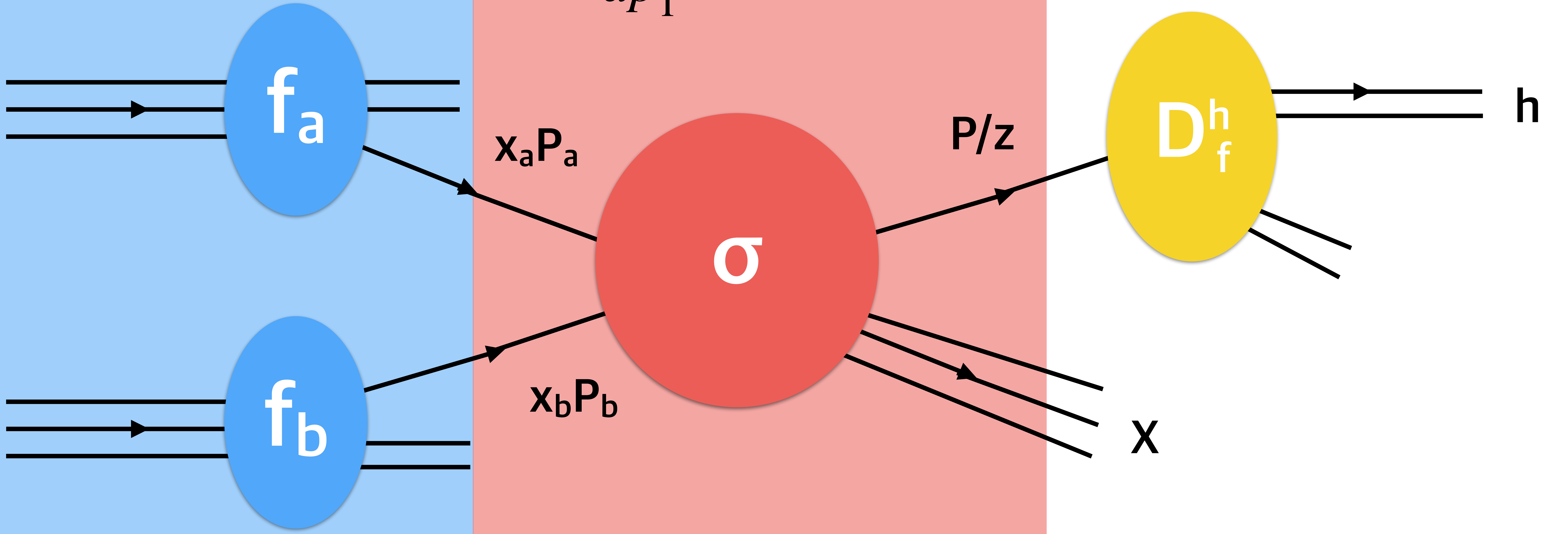
$$PDF(x_a, \mu_{\mathrm{F}})PDF(x_b, \mu_{\mathrm{F}}) \otimes \frac{d\sigma^{\mathrm{c}}}{dp_{\mathrm{T}}^{\mathrm{c}}}(x_a, x_b, \mu_{\mathrm{R}}, \mu_{\mathrm{F}}) \otimes D_{\mathrm{c}\rightarrow\mathrm{H_c}}(z = p_{\mathrm{H_c}}/p_c, \mu_{\mathrm{F}})$$



Initial Parton distribution function

pQCD partonic cross section

$$PDF(x_a, \mu_F) PDF(x_b, \mu_F) \otimes \frac{d\sigma^c}{dp_T^c}(x_a, x_b, \mu_R, \mu_F) \otimes D_{c \to H_c}(z = p_{H_c}/p_c, \mu_F)$$



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Hadronisation by fragmentation

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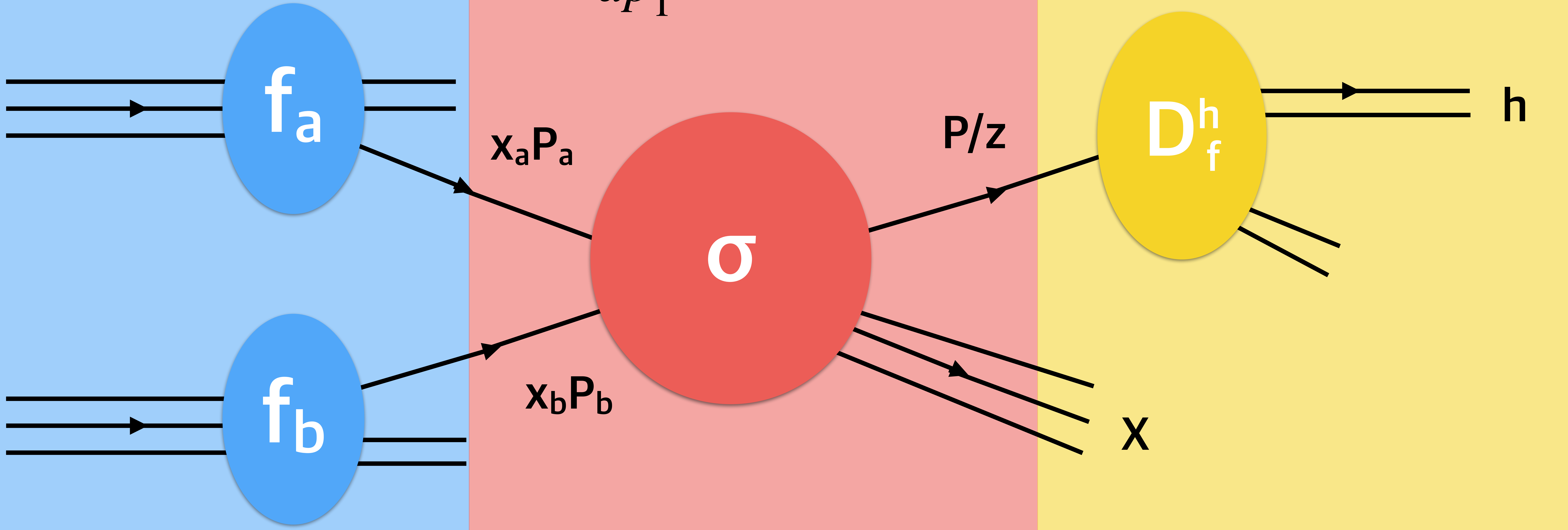

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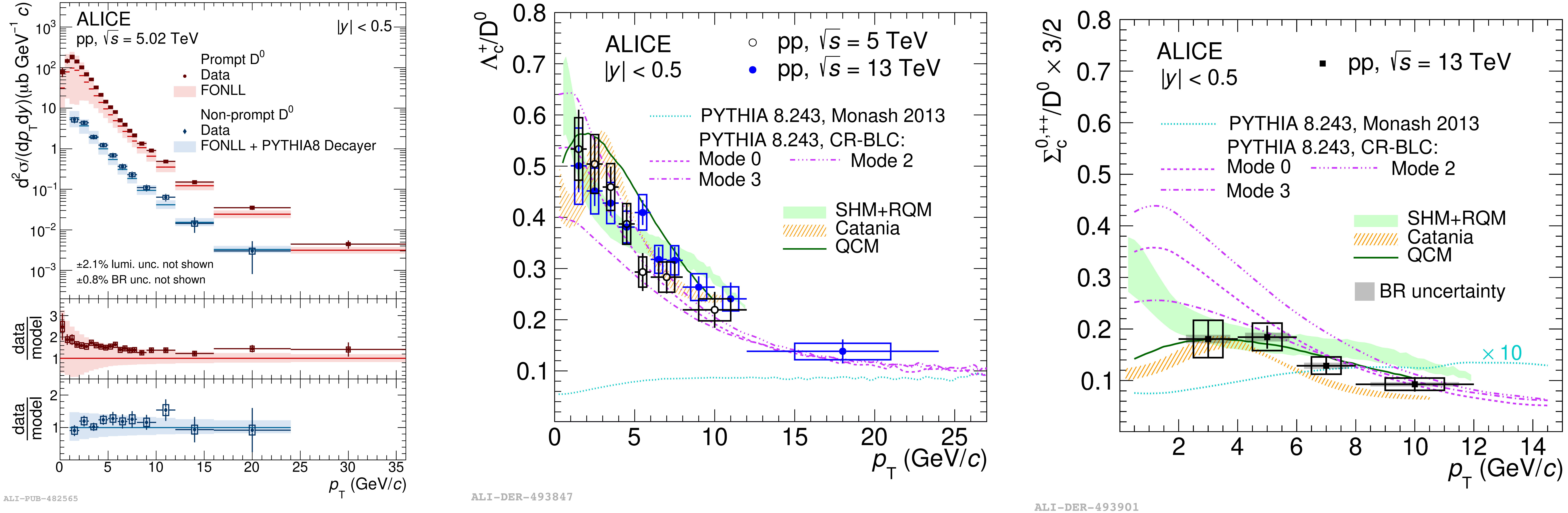
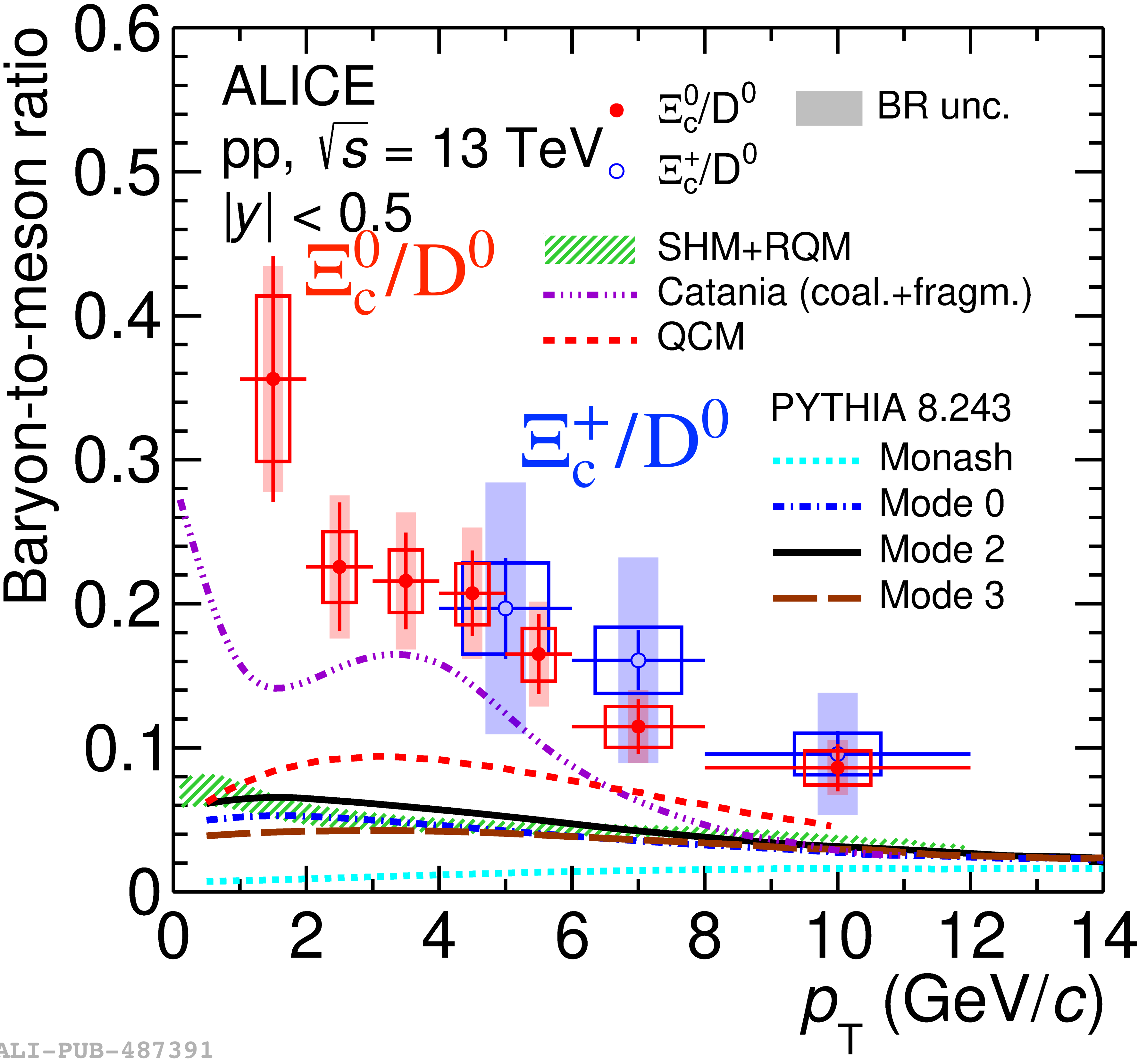
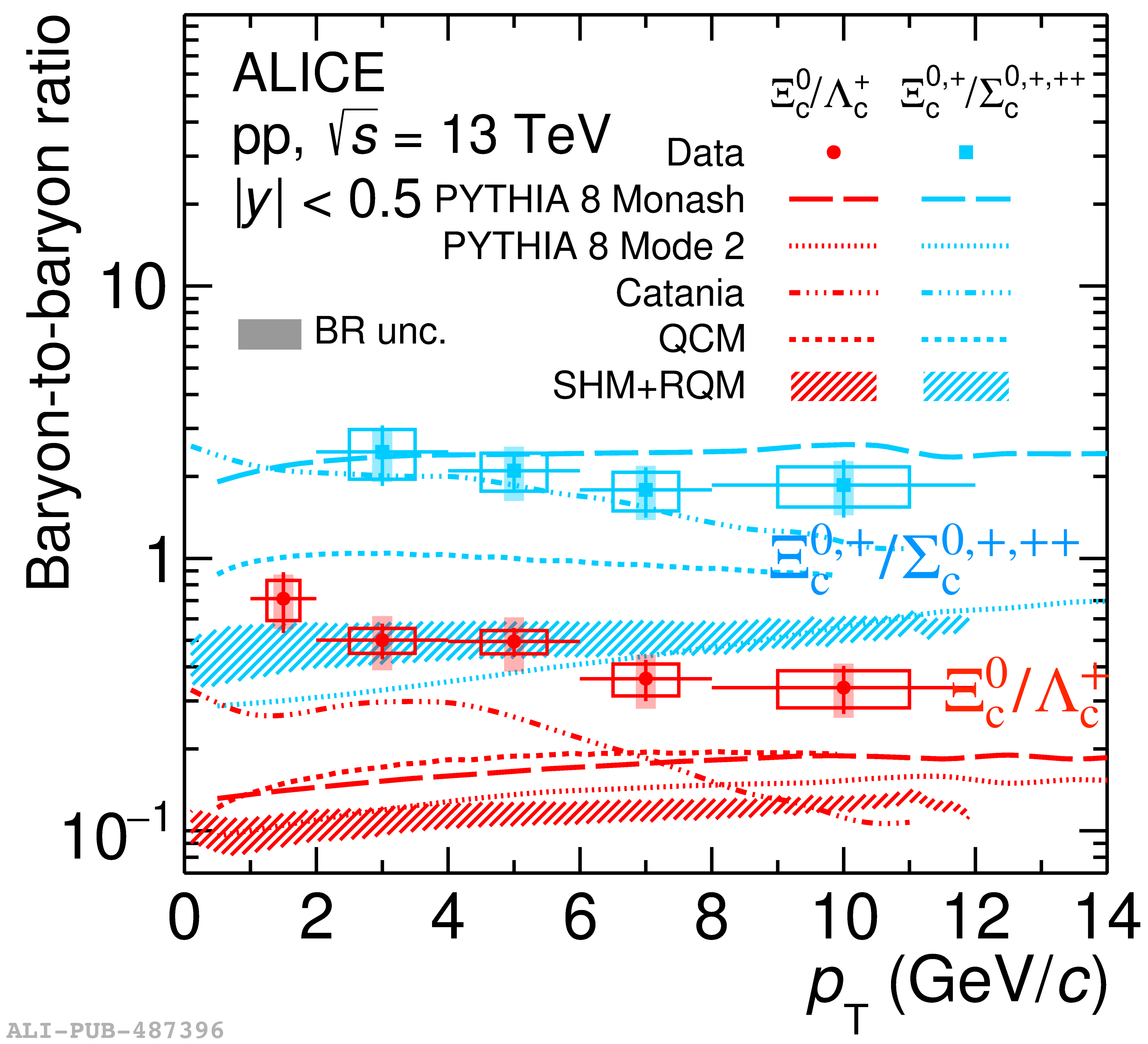
Charmed meson and Charm non-strange baryon can be described by model prediction!



$\Xi_c^{0,+}$ measurements in ALICE

- **$\Xi_c^{0,+}$ measurements in pp collisions at 13 TeV**
  - Charm-strange baryon measurements were underestimated by most models.

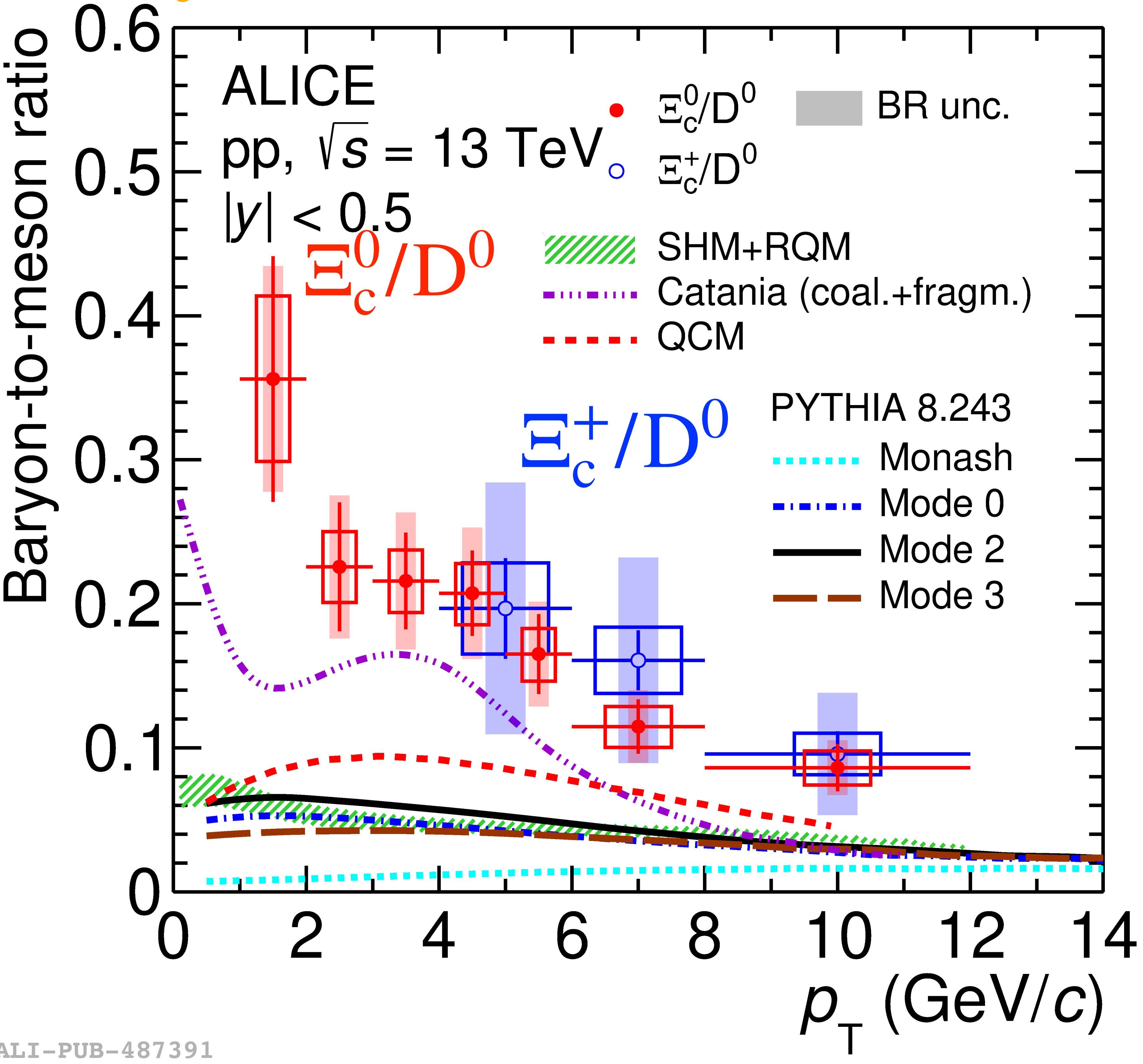


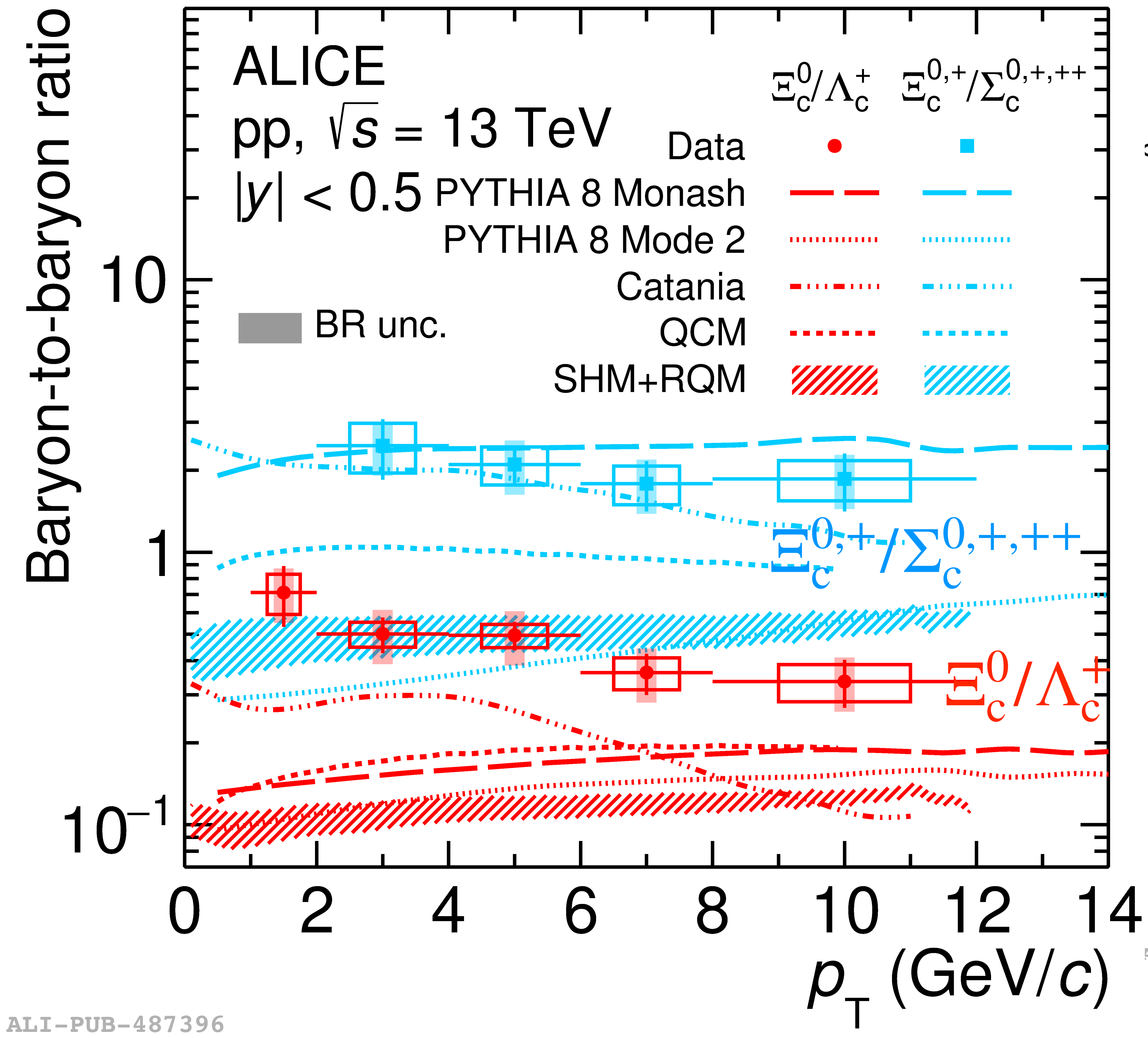


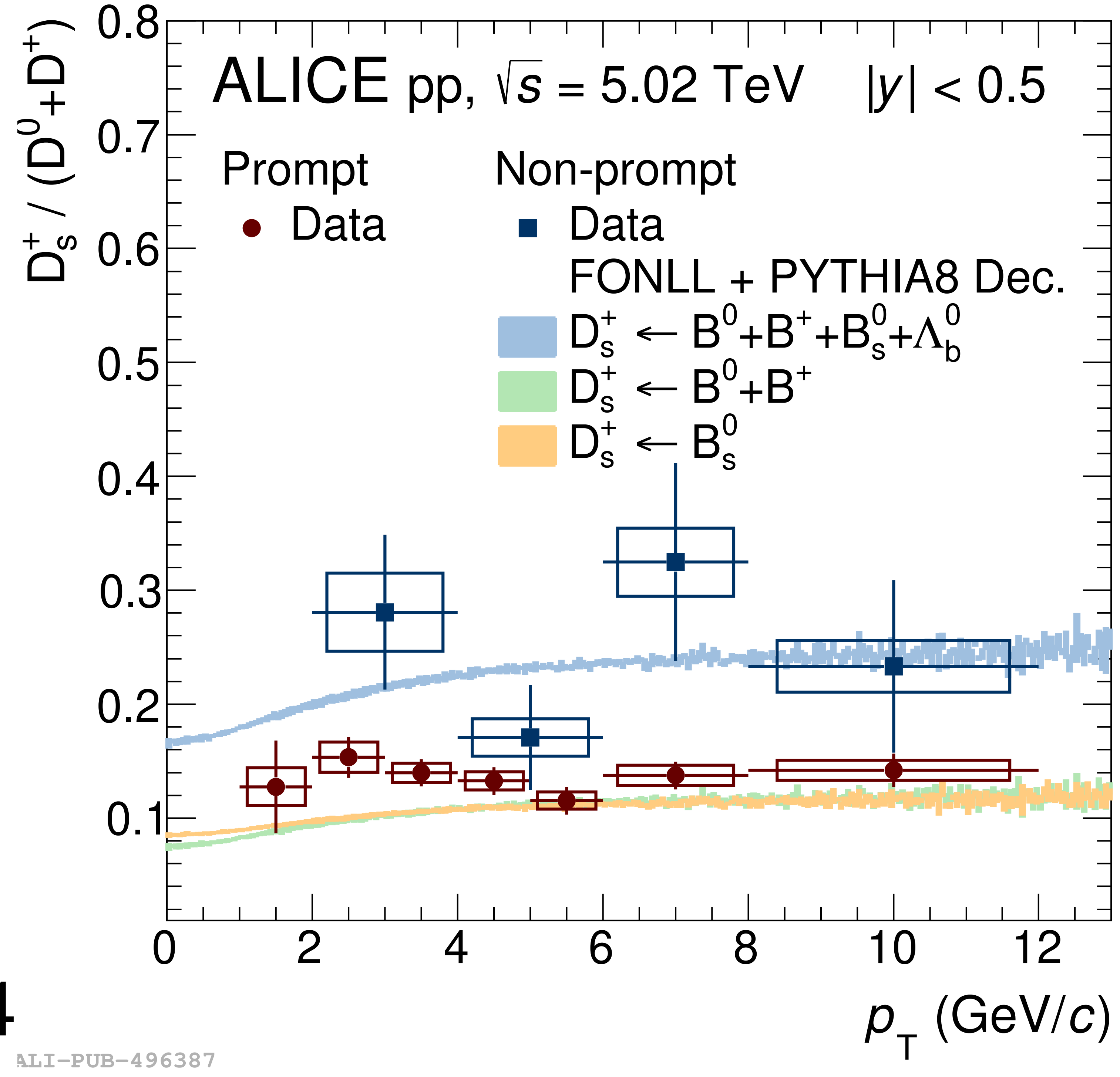
$\Xi_c^{0,+}$ measurements in ALICE

- $\Xi_c^{0,+}$ **measurements in pp collisions at 13 TeV**
  - Charm-strange baryon measurements were underestimated by most models.
    - **cf)** $D_s^+/(D^0+D^+)$ (Non-prompt) compatible with expectations from e+e-.

$\Xi_c^{0,+}$ measurements offer new constraints to the model prediction!

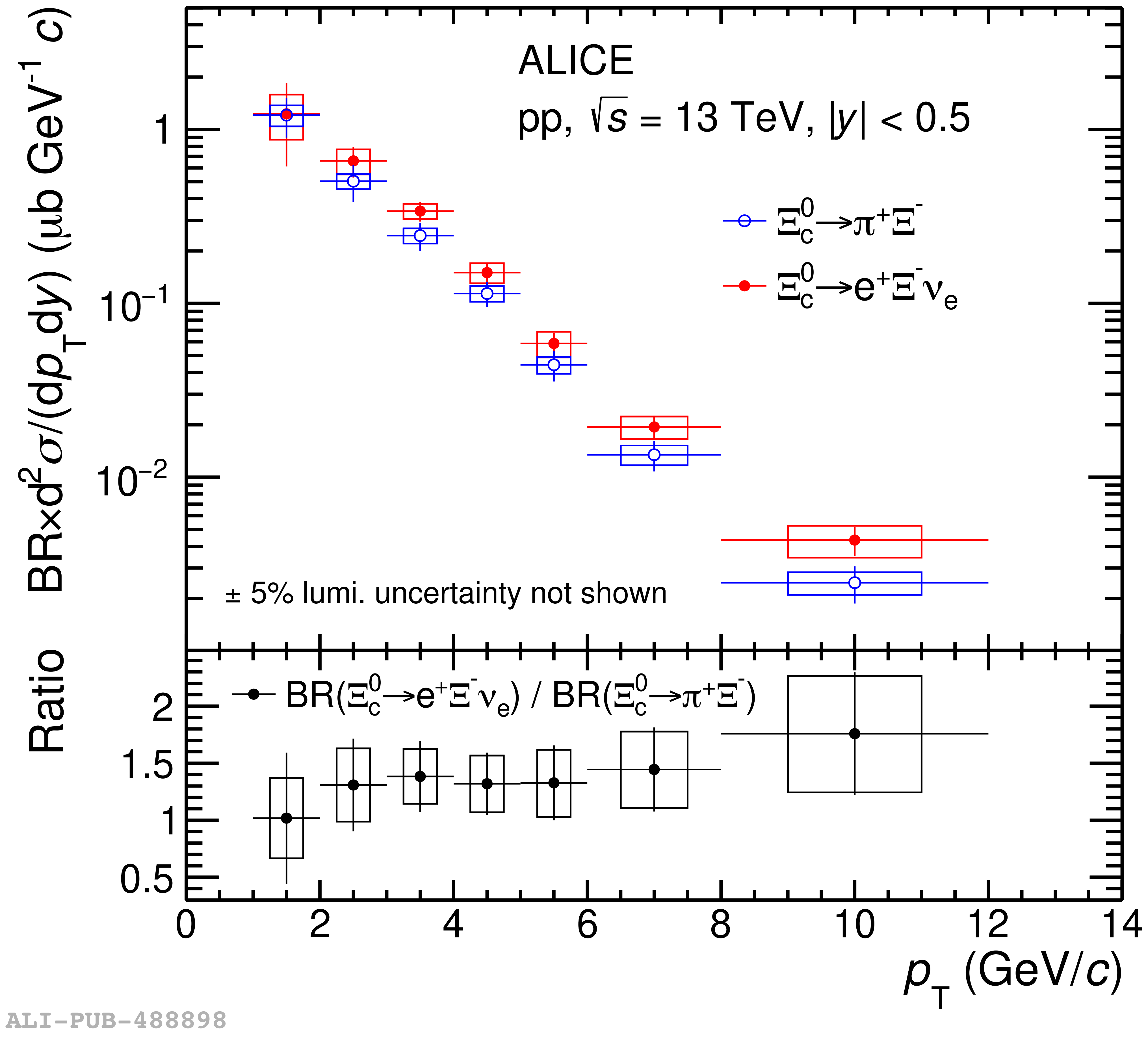


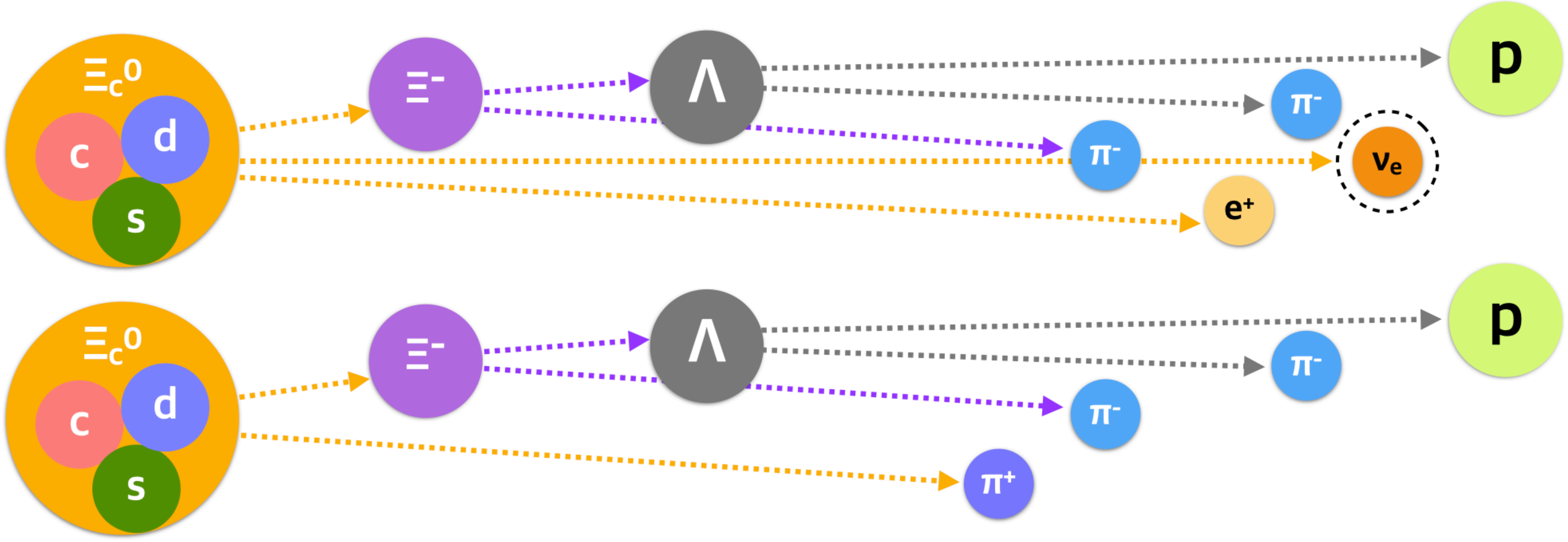




$\Xi_c^{0,+}$ measurements in ALICE

- $\Xi_c^{0,+}$ **measurements in pp collisions at 13 TeV**
  - **Branching-Fraction Ratio of** Ξ_c^{0}: Total uncertainty was reduced by a factor 3 w.r.t the PDG.





$\Xi_c^{0,+}$ measurements in ALICE

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$\Xi_c^{0,+}$ measurements in ALICE

- Status of paper
  - **Published 28 December 2021**

PHYSICAL REVIEW LETTERS **127,** 272001 (2021)

Measurement of the Cross Sections of Ξ_c^0 and Ξ_c^+ Baryons and of the Branching-Fraction Ratio $\mathrm{BR}(\Xi_c^0 \to \Xi^- e^+ \nu_e)/\mathrm{BR}(\Xi_c^0 \to \Xi^- \pi^+)$ in *pp* Collisions at $\sqrt{s} = 13$ TeV

S. Acharya *et al.*[*]
(A Large Ion Collider Experiment Collaboration)

(Received 2 August 2021; revised 18 October 2021; accepted 19 November 2021; published 28 December 2021)

The p_T-differential cross sections of prompt charm-strange baryons Ξ_c^0 and Ξ_c^+ were measured at midrapidity ($|y| < 0.5$) in proton-proton (pp) collisions at a center-of-mass energy $\sqrt{s} = 13$ TeV with the ALICE detector at the LHC. The Ξ_c^0 baryon was reconstructed via both the semileptonic decay ($\Xi^- e^+ \nu_e$) and the hadronic decay ($\Xi^- \pi^+$) channels. The Ξ_c^+ baryon was reconstructed via the hadronic decay ($\Xi^- \pi^+ \pi^+$) channel. The branching-fraction ratio $\mathrm{BR}(\Xi_c^0 \to \Xi^- e^+ \nu_e)/\mathrm{BR}(\Xi_c^0 \to \Xi^- \pi^+) = 1.38 \pm 0.14(\mathrm{stat}) \pm 0.22(\mathrm{syst})$ was measured with a total uncertainty reduced by a factor of about 3 with respect to the current world average reported by the Particle Data Group. The transverse momentum (p_T) dependence of the Ξ_c^0- and Ξ_c^+-baryon production relative to the D^0 meson and to the $\Sigma_c^{0,+,++}$- and Λ_c^+-baryon production are reported. The baryon-to-meson ratio increases toward low p_T up to a value of approximately 0.3. The measurements are compared with various models that take different hadronization mechanisms into consideration. The results provide stringent constraints to these theoretical calculations and additional evidence that different processes are involved in charm hadronization in electron-positron (e^+e^-) and hadronic collisions.

DOI: 10.1103/PhysRevLett.127.272001

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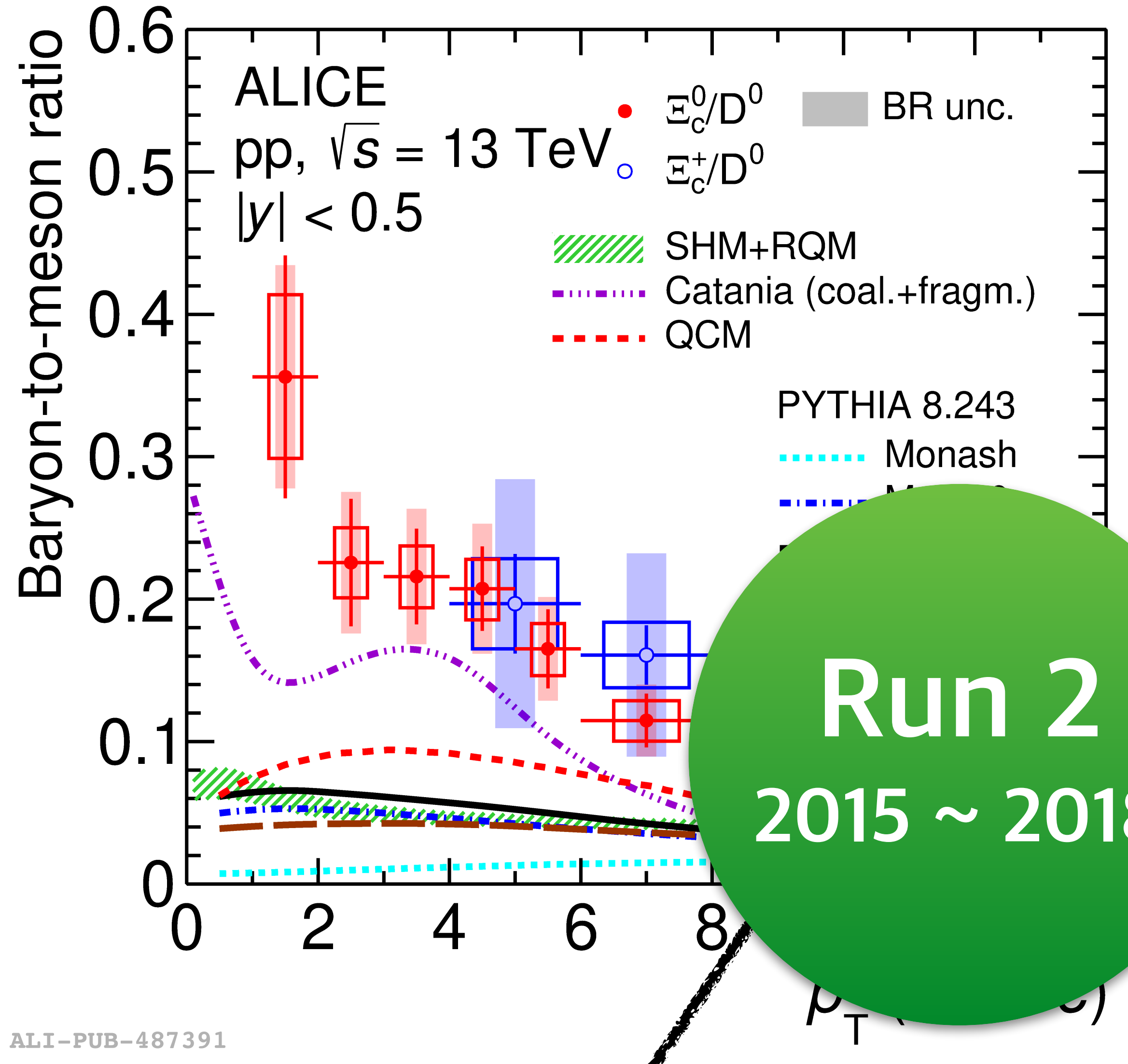
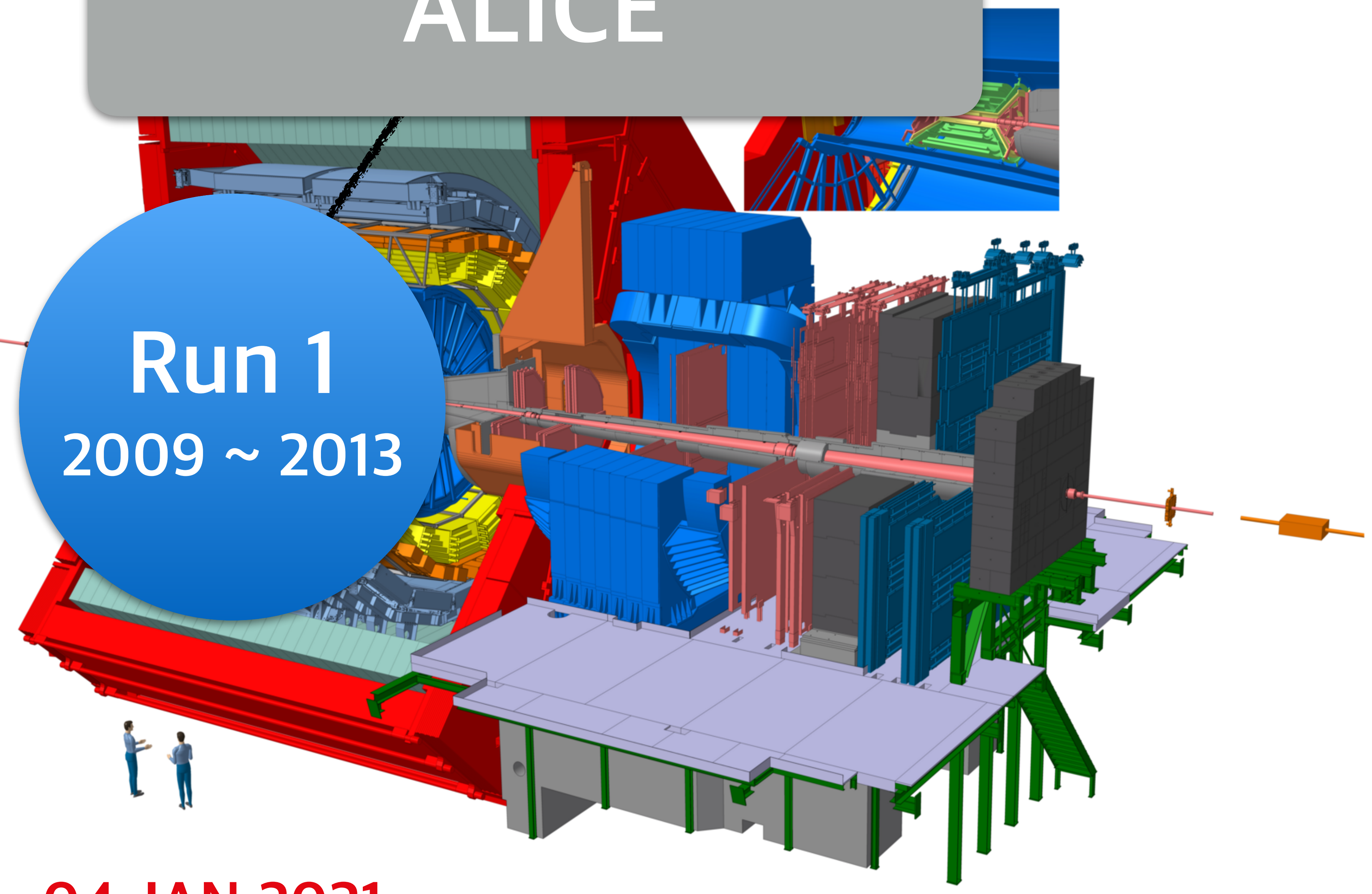


ALICE



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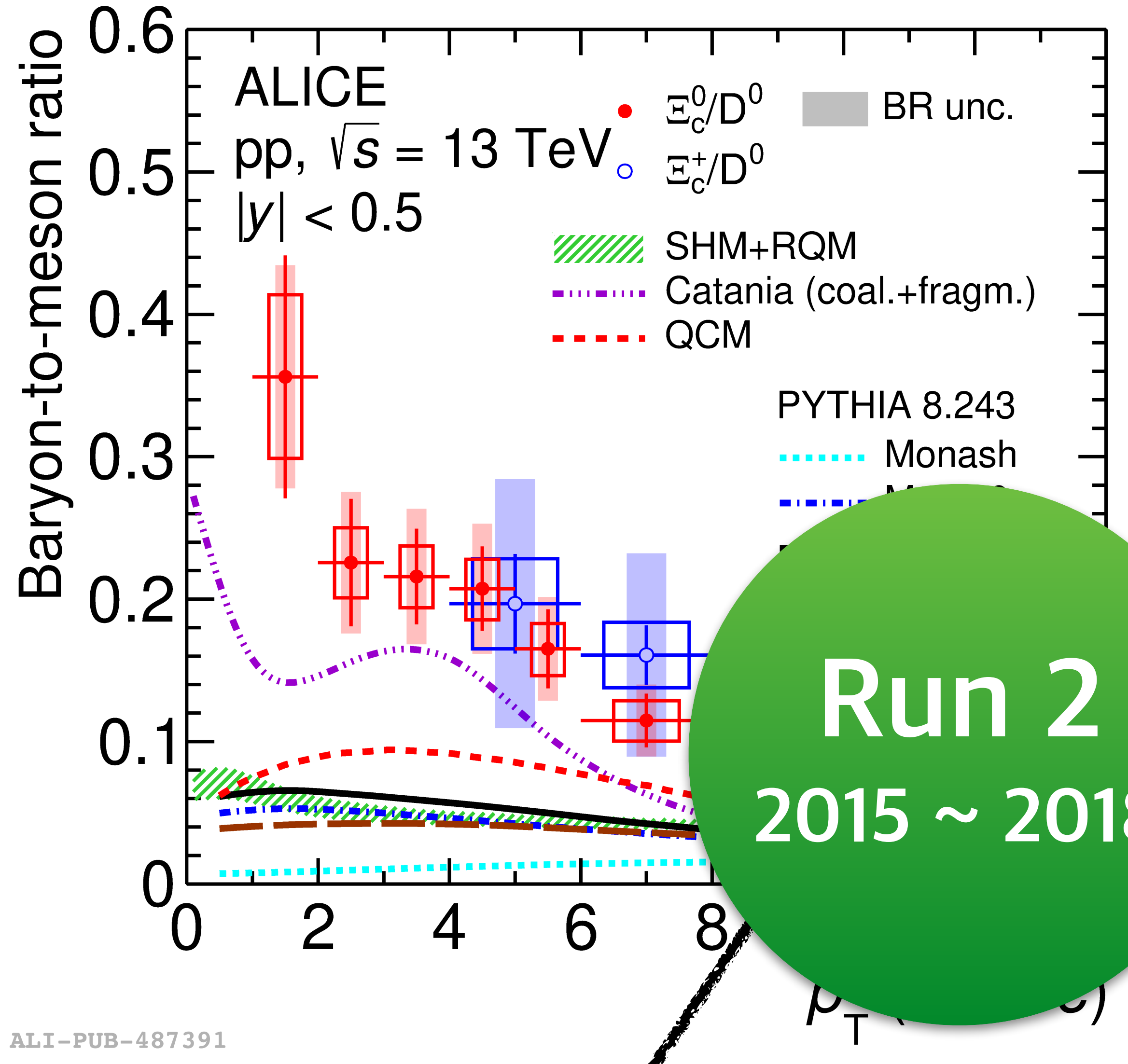

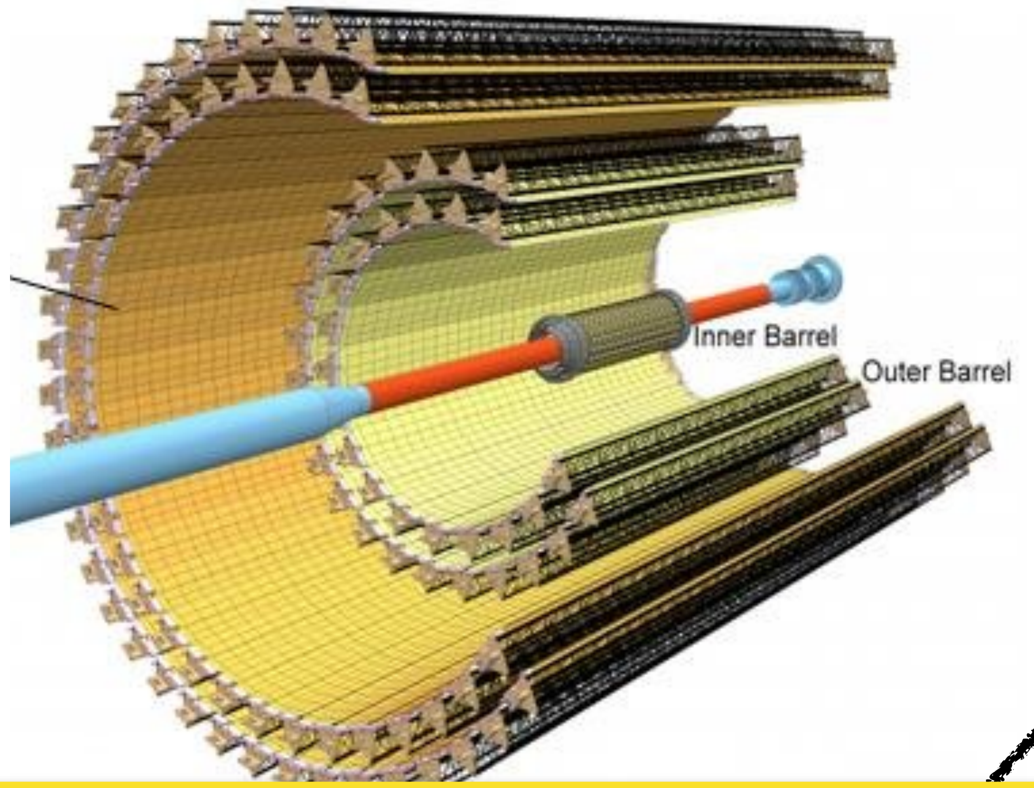

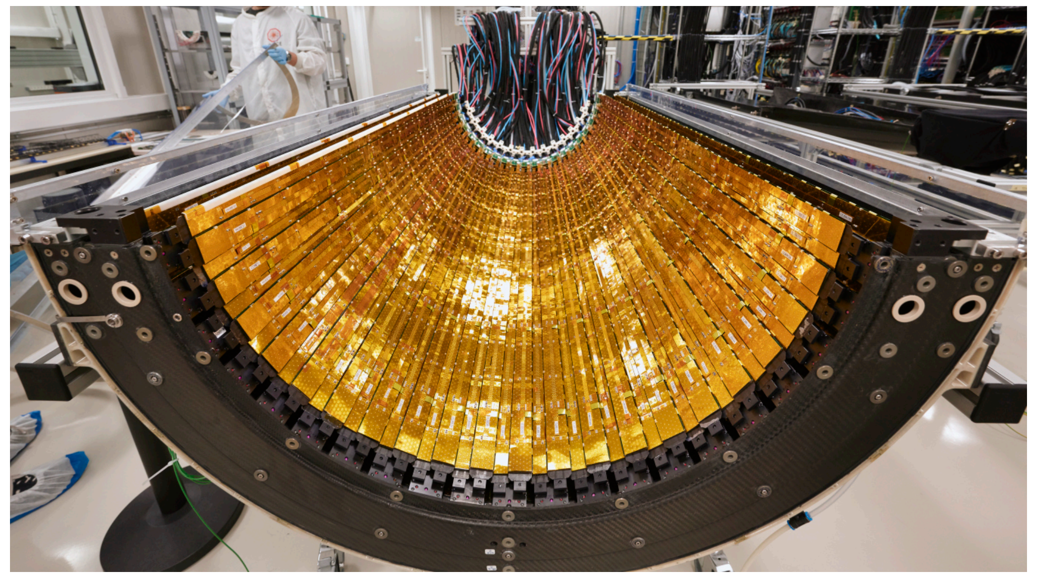

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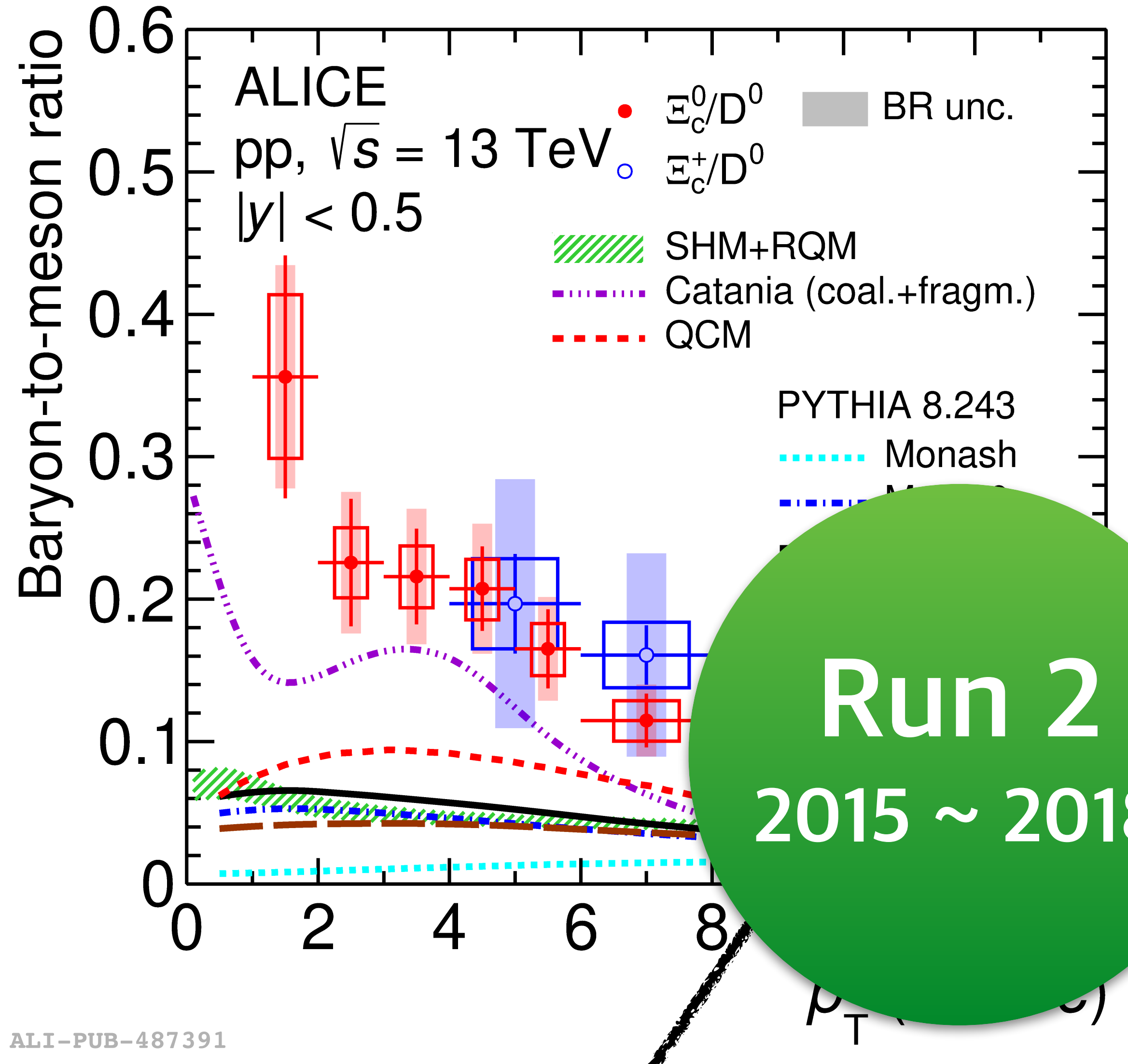
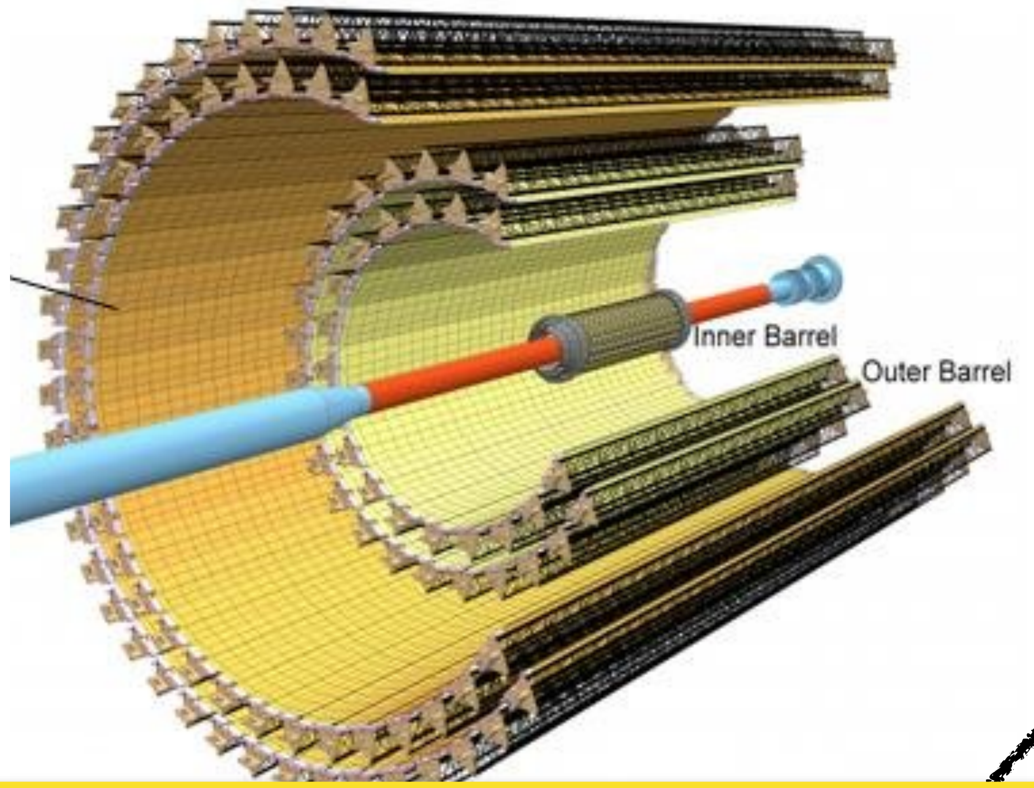
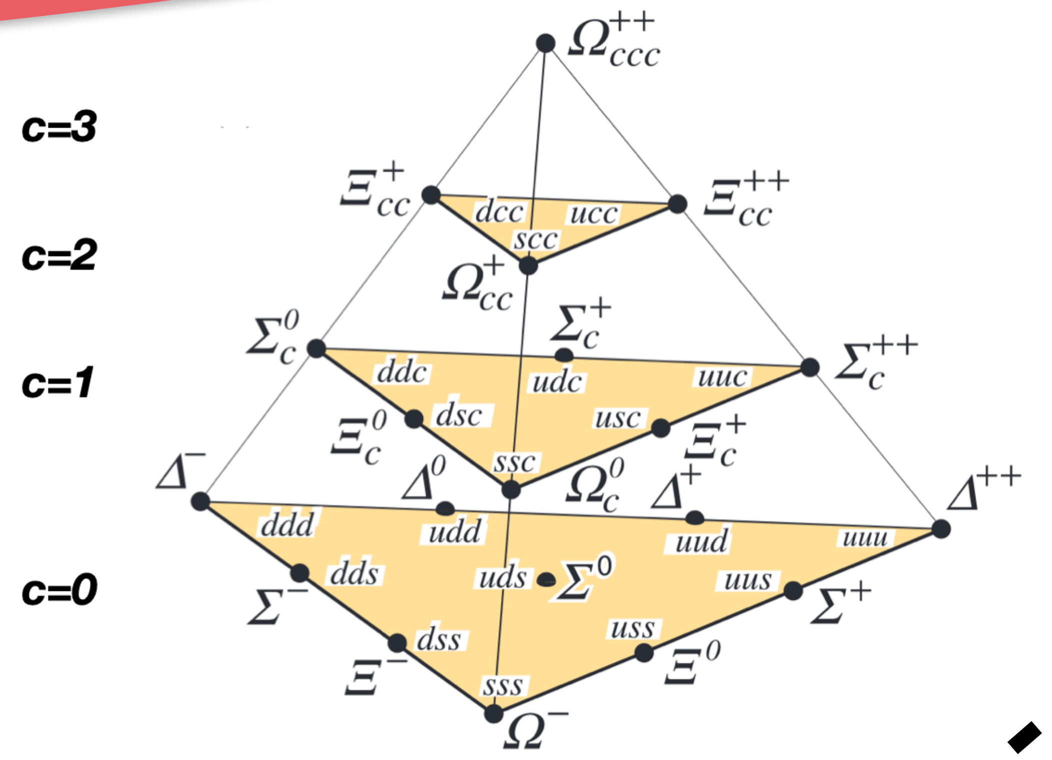


Run 2
2015 ~ 2018



Run 4
2028 ~ 2030

ALICE 2.1
(+ ITS 3 & FoCal)



Run 5
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ALICE 3

ALICE

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Run 3
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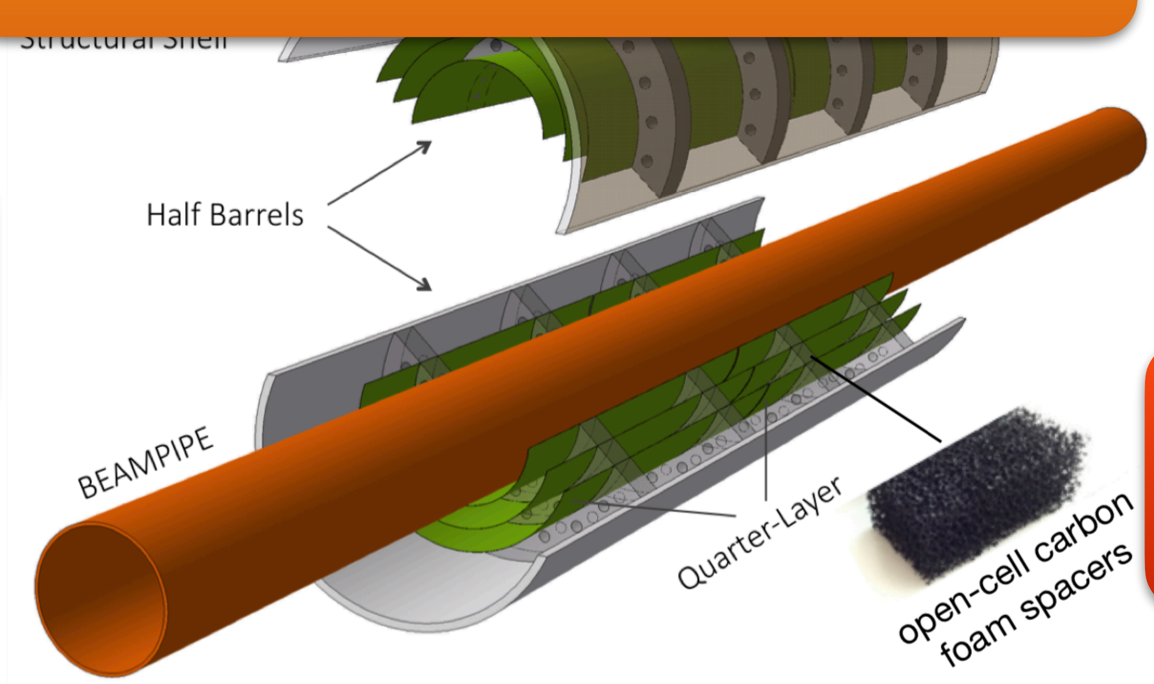
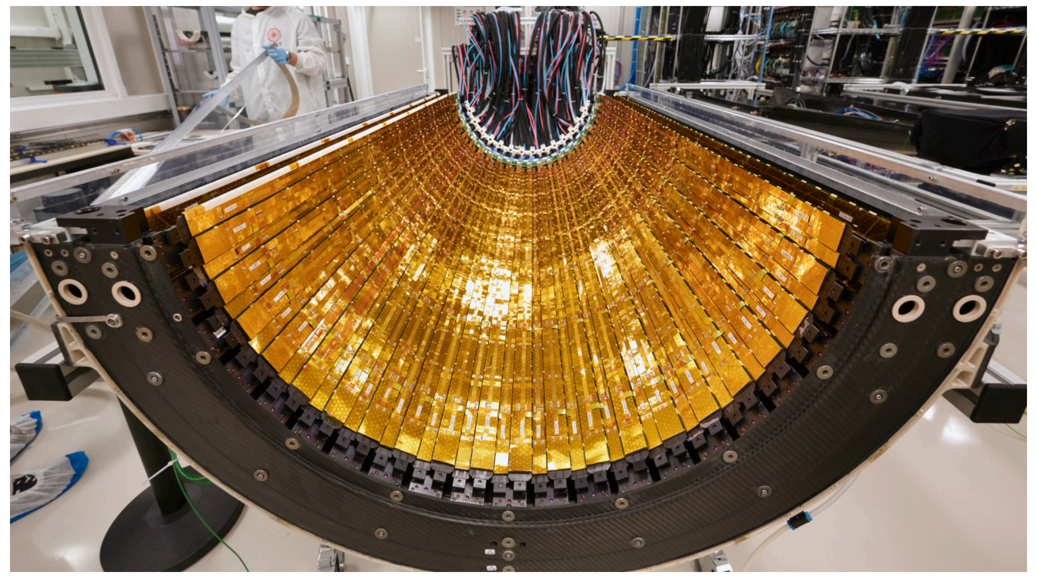
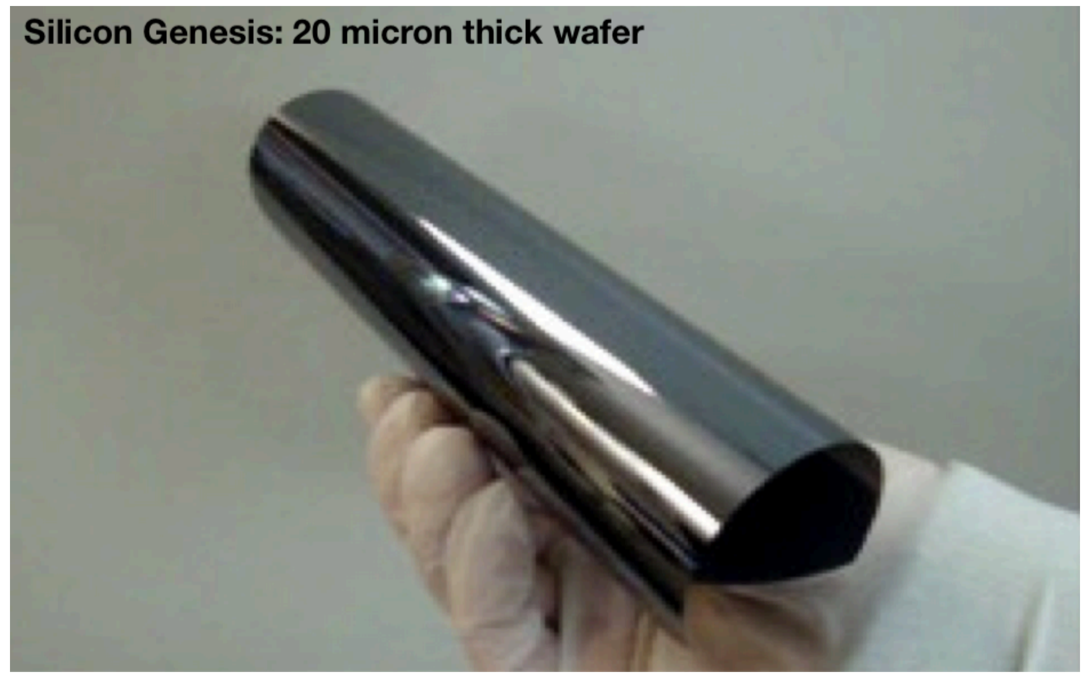
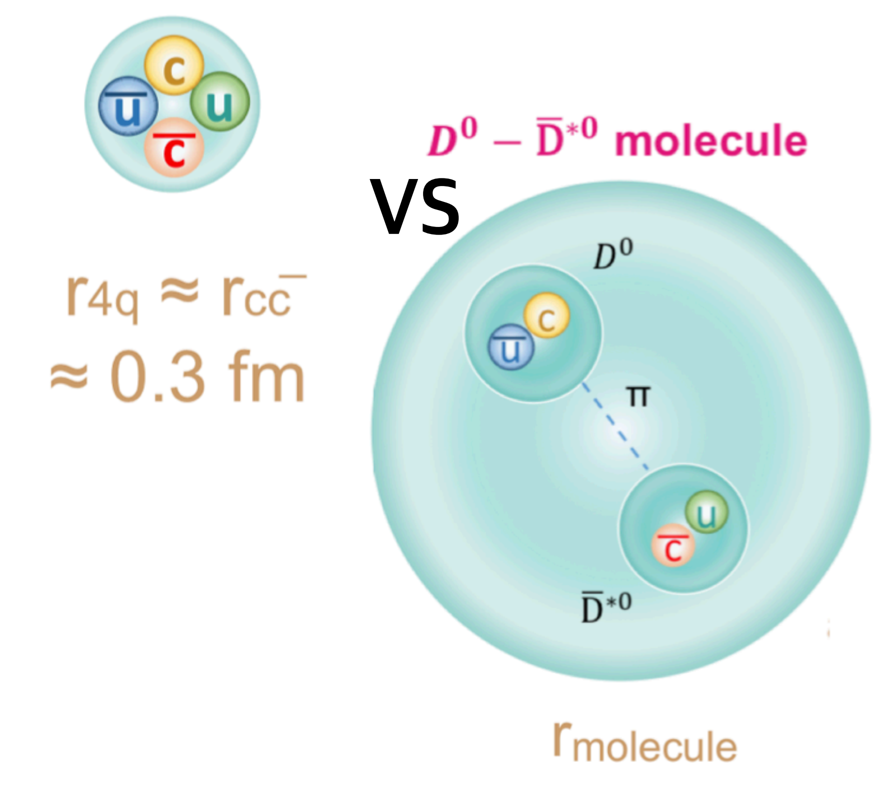




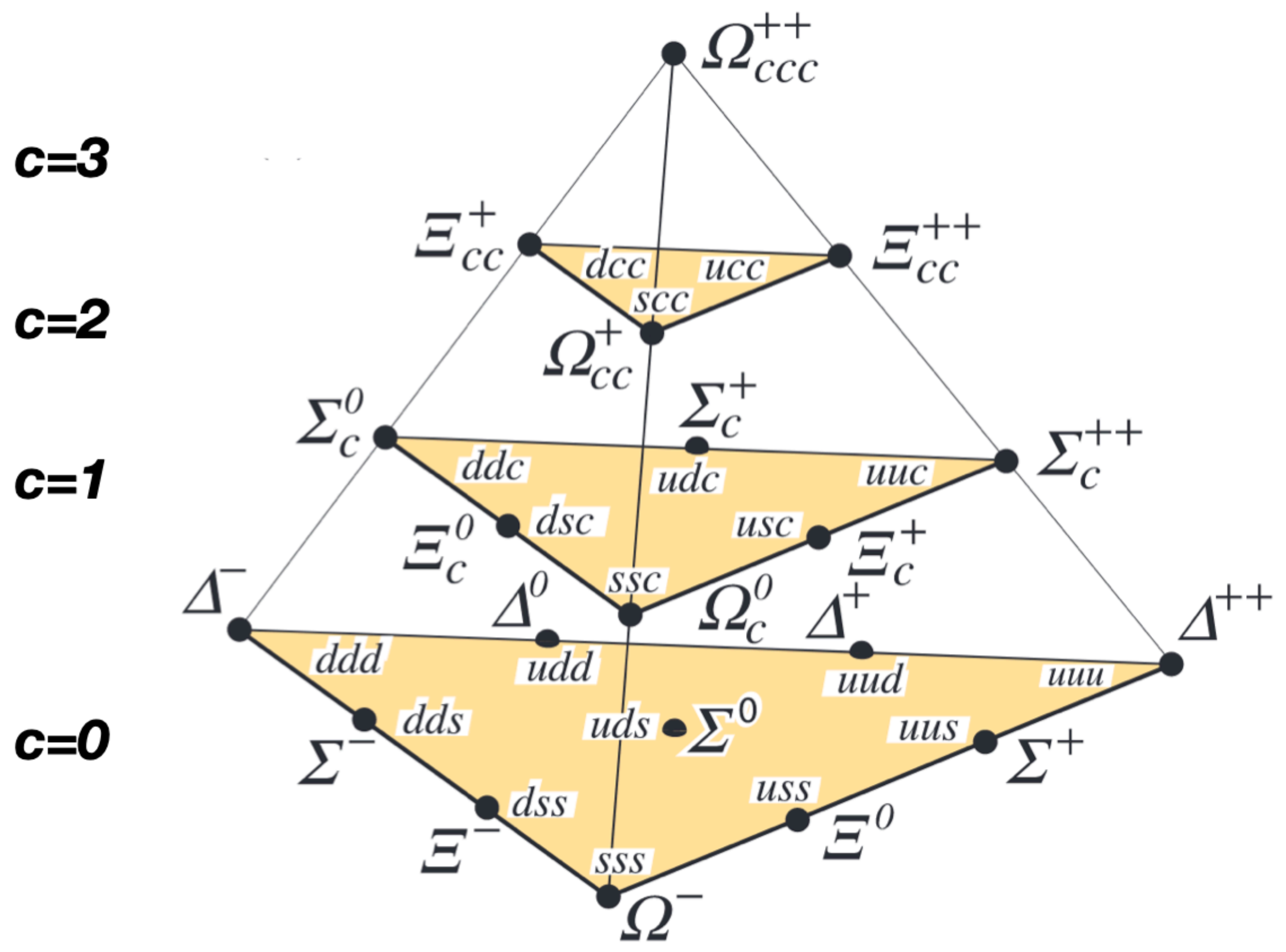


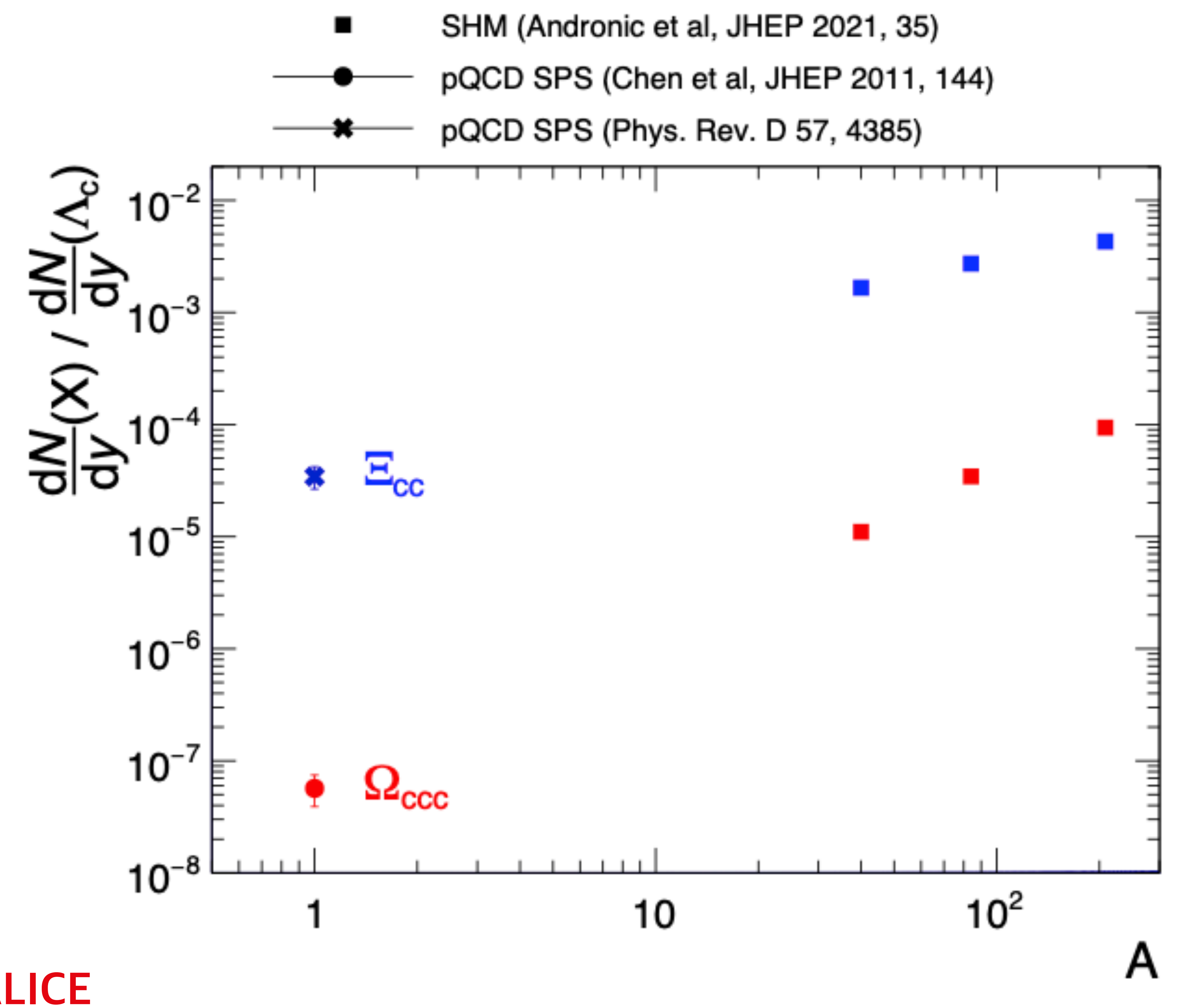
Tetraquark (4q)



ALICE 3 Physics goal

- **Multi-charm baryons**
  - Large mass of the charm quarks ($m_c \sim 1274 MeV/c^2$) → Produce initial hard scattering process
    - Strong probe to detect the QGP formation and to study the hadronisation mechanism in the medium





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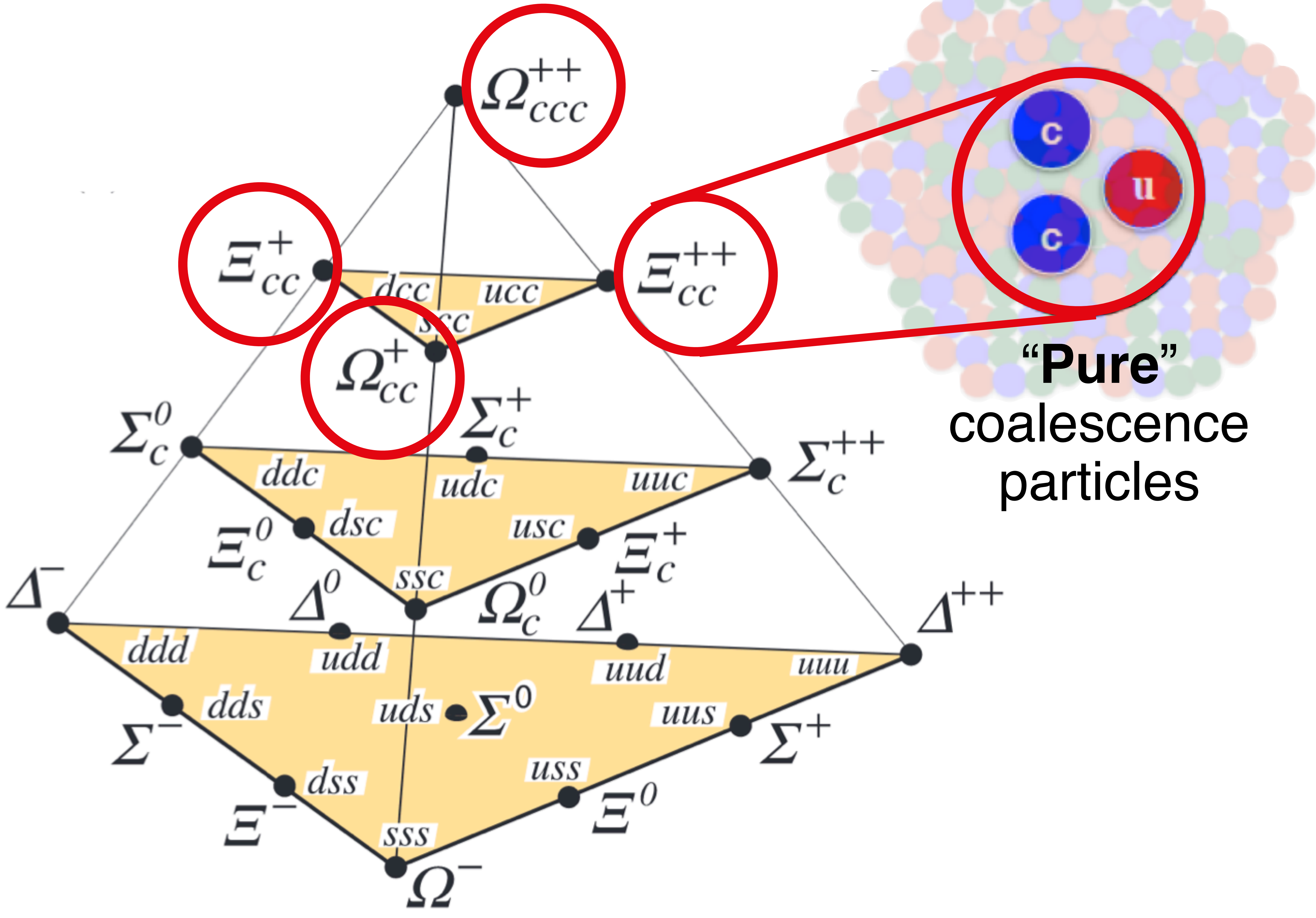

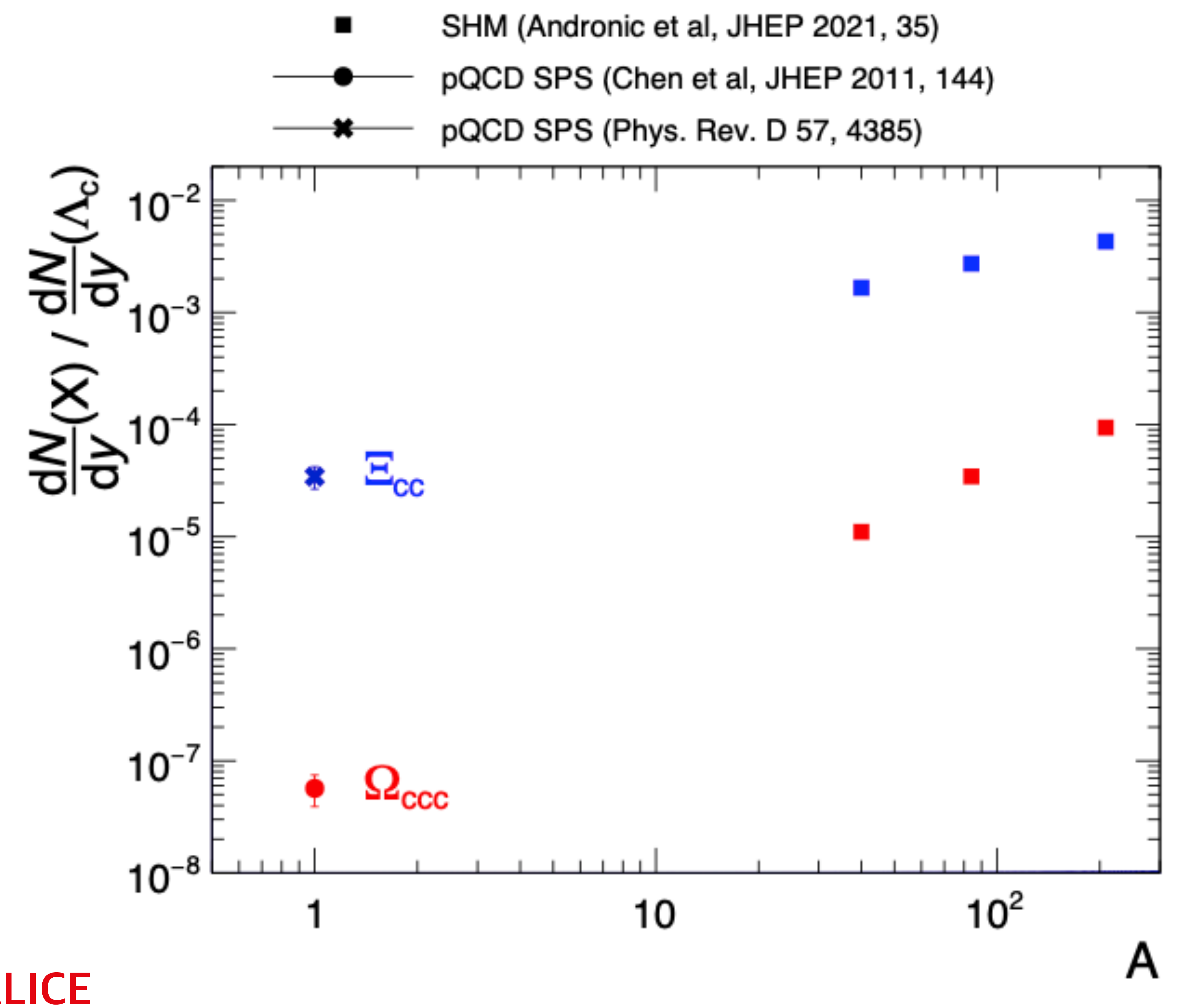

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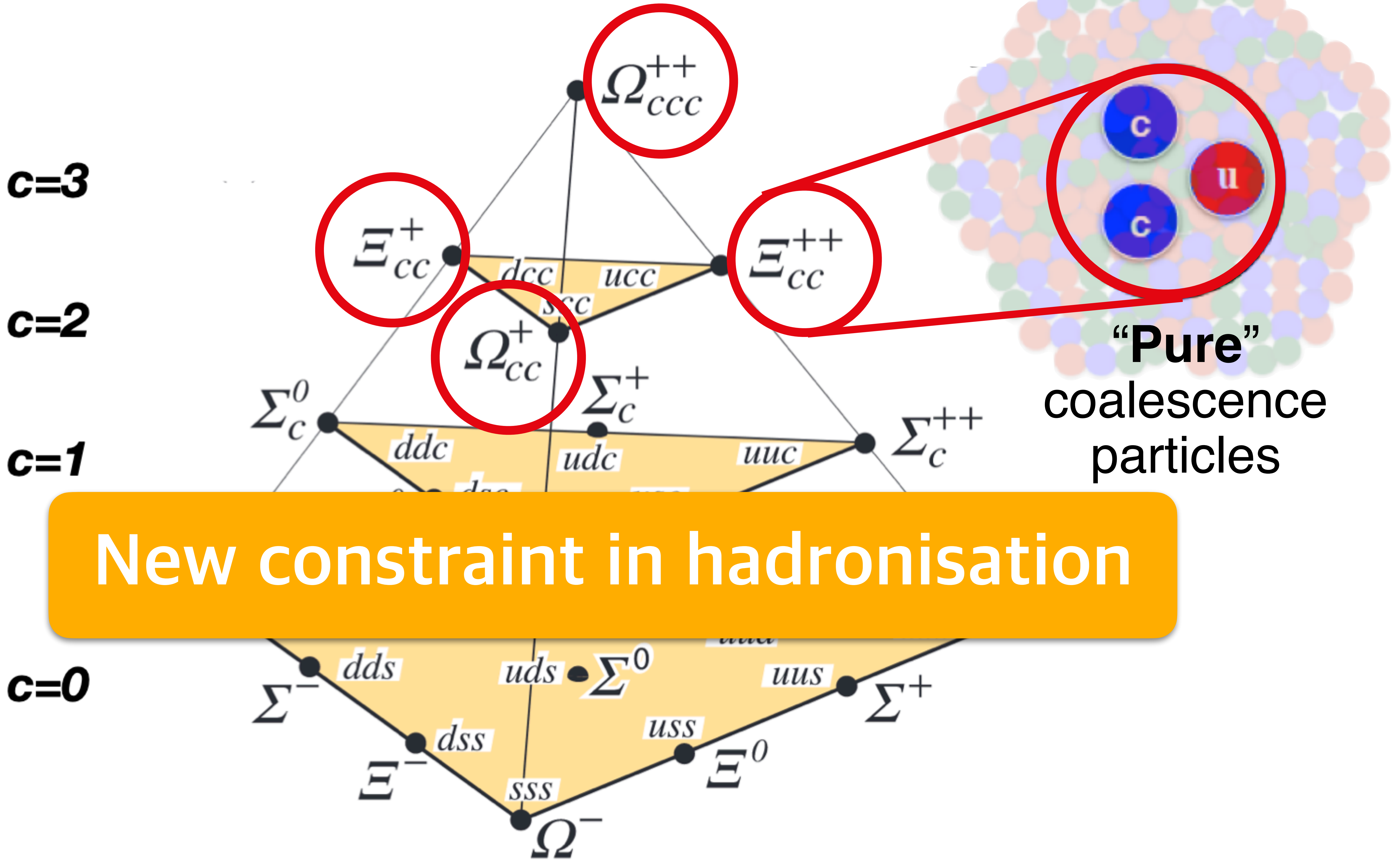

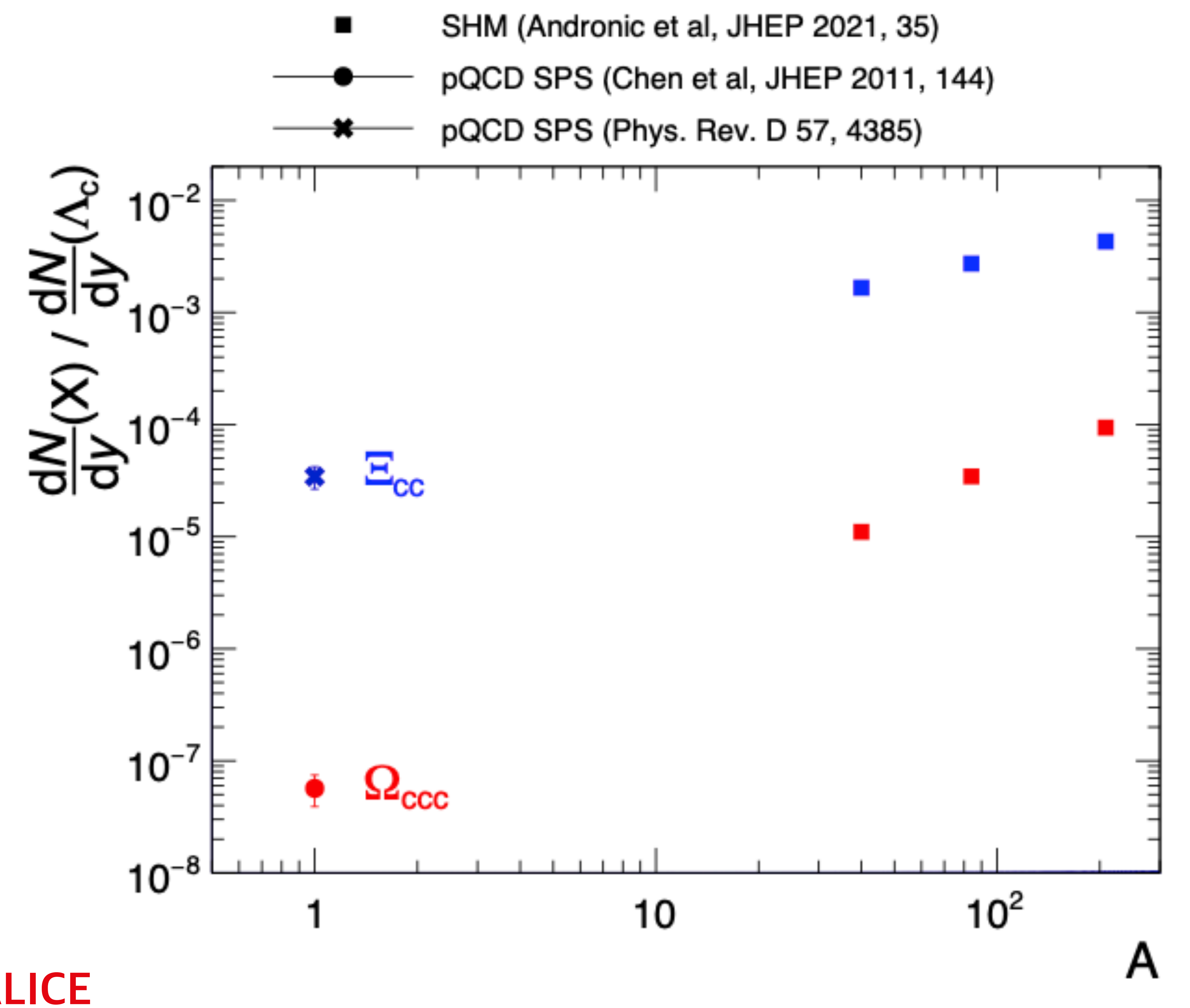

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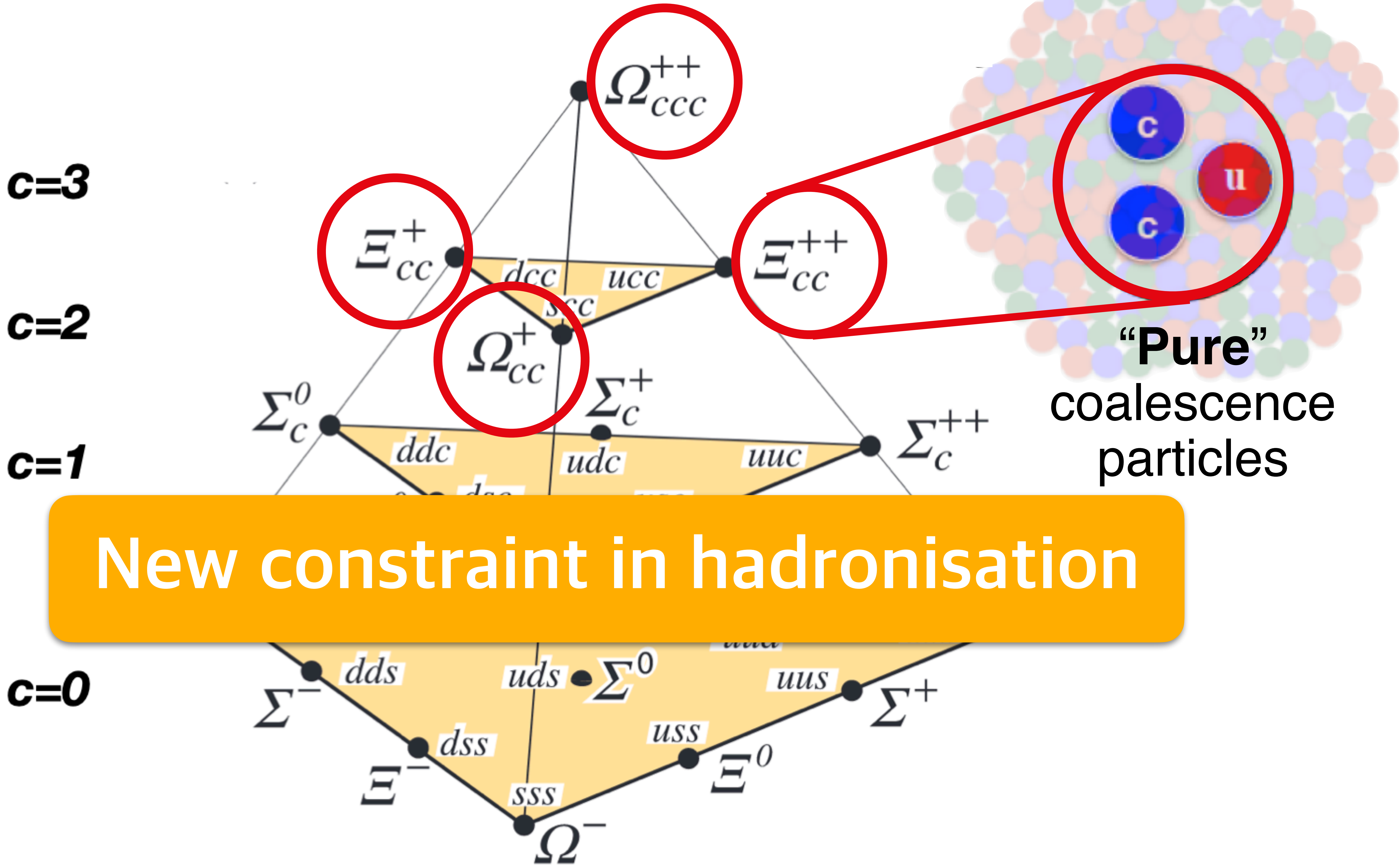

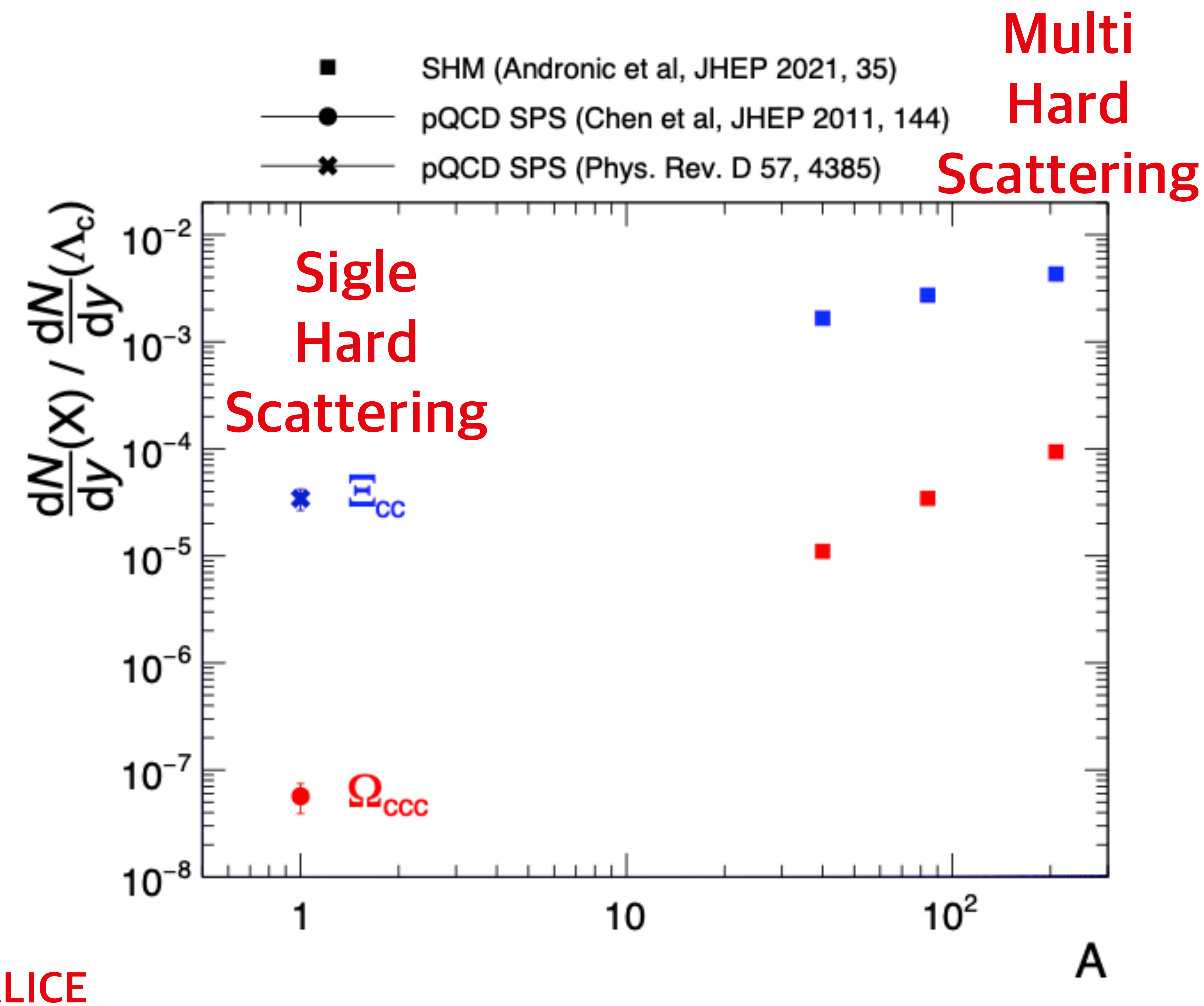

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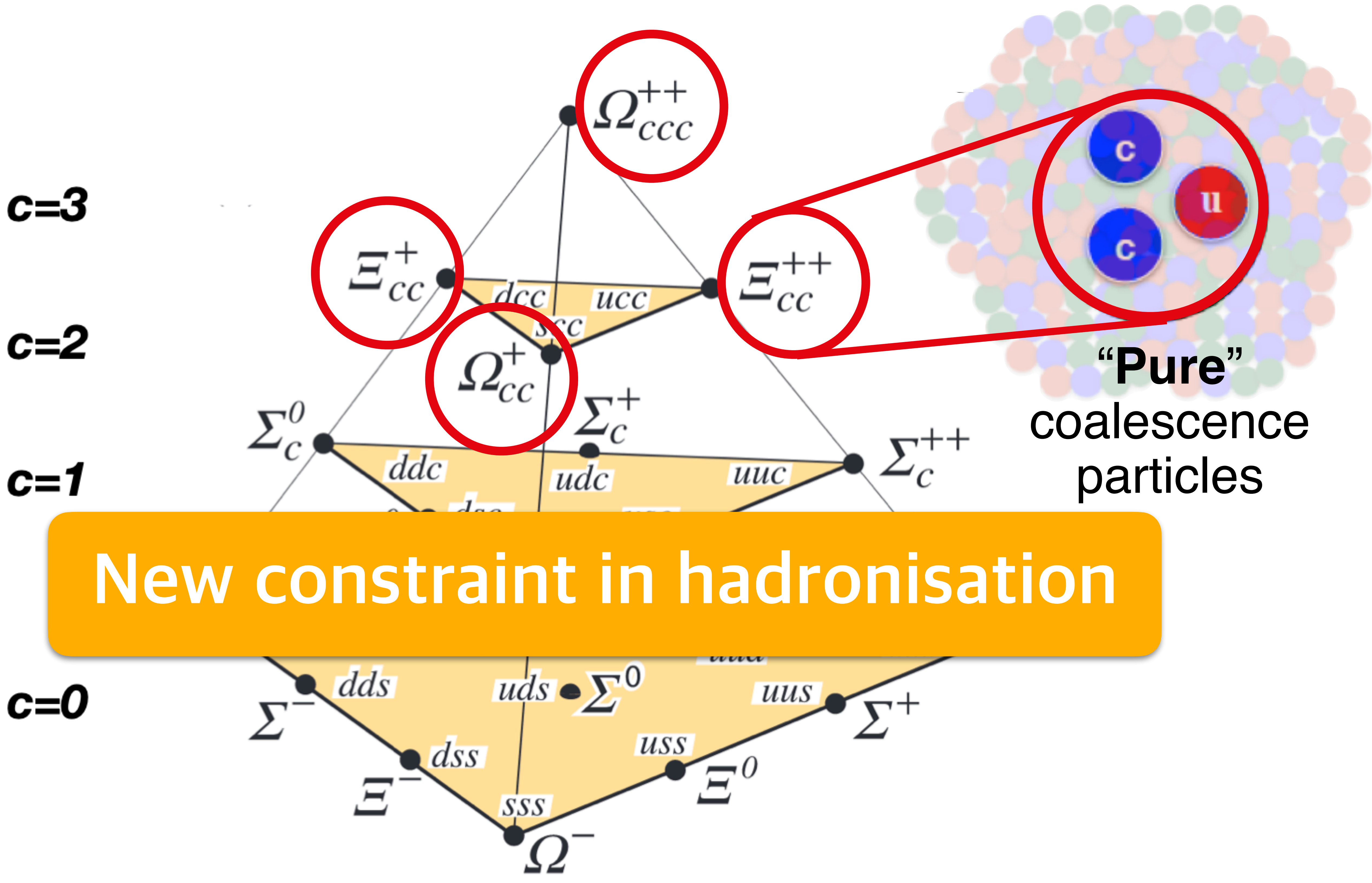
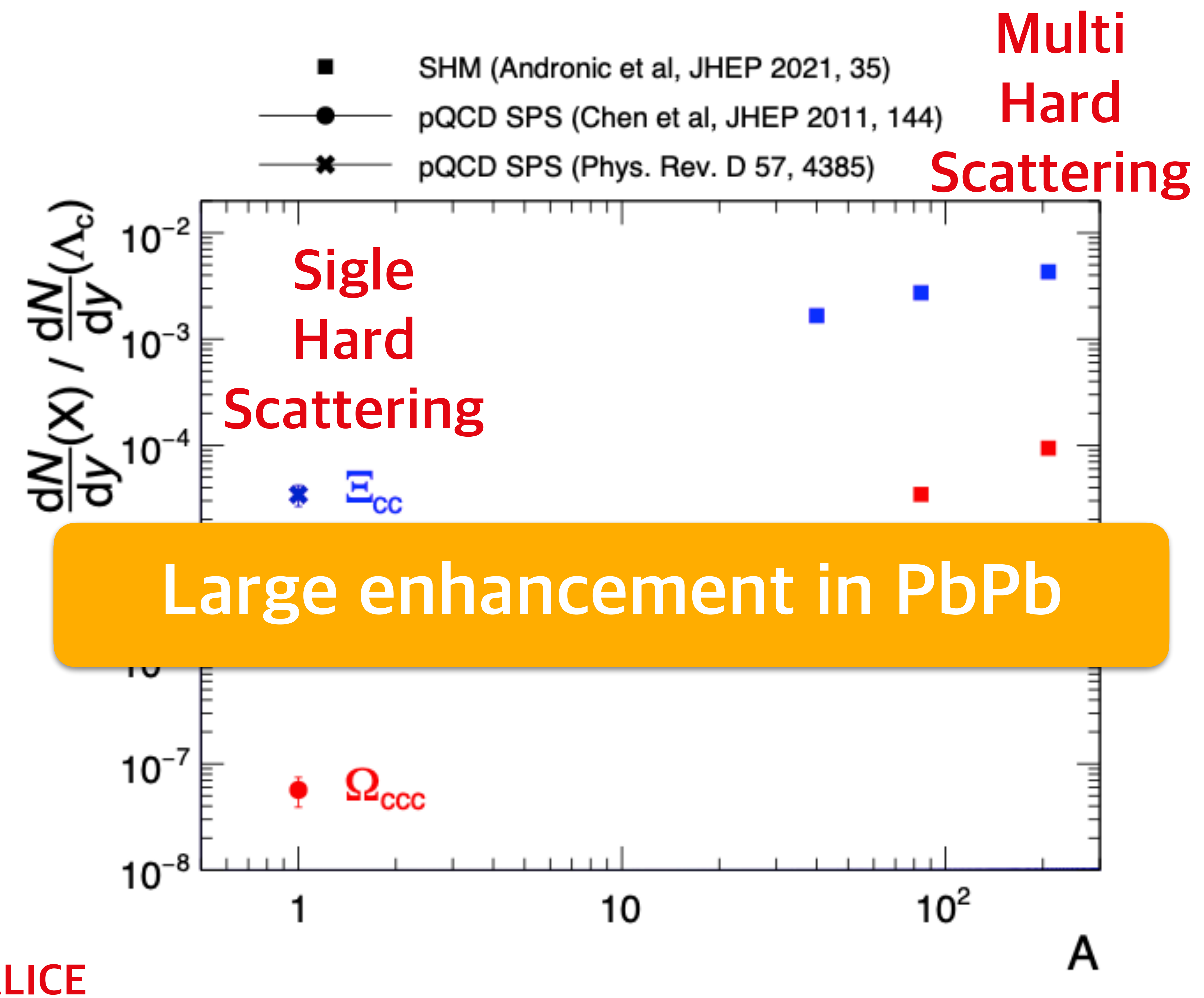
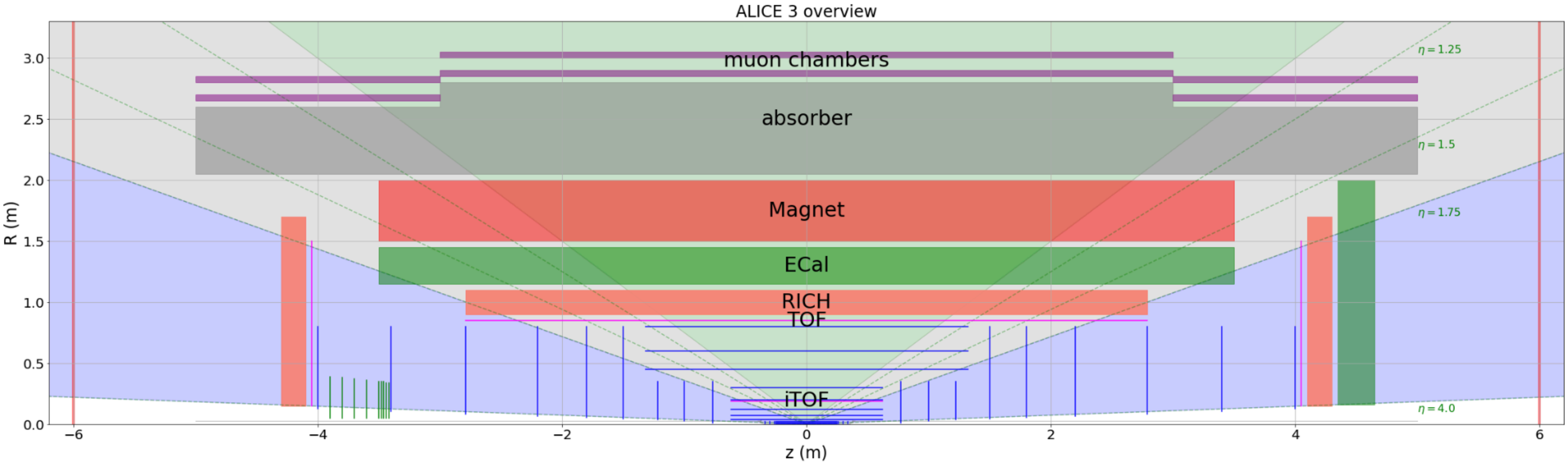




ALICE 3 Detector

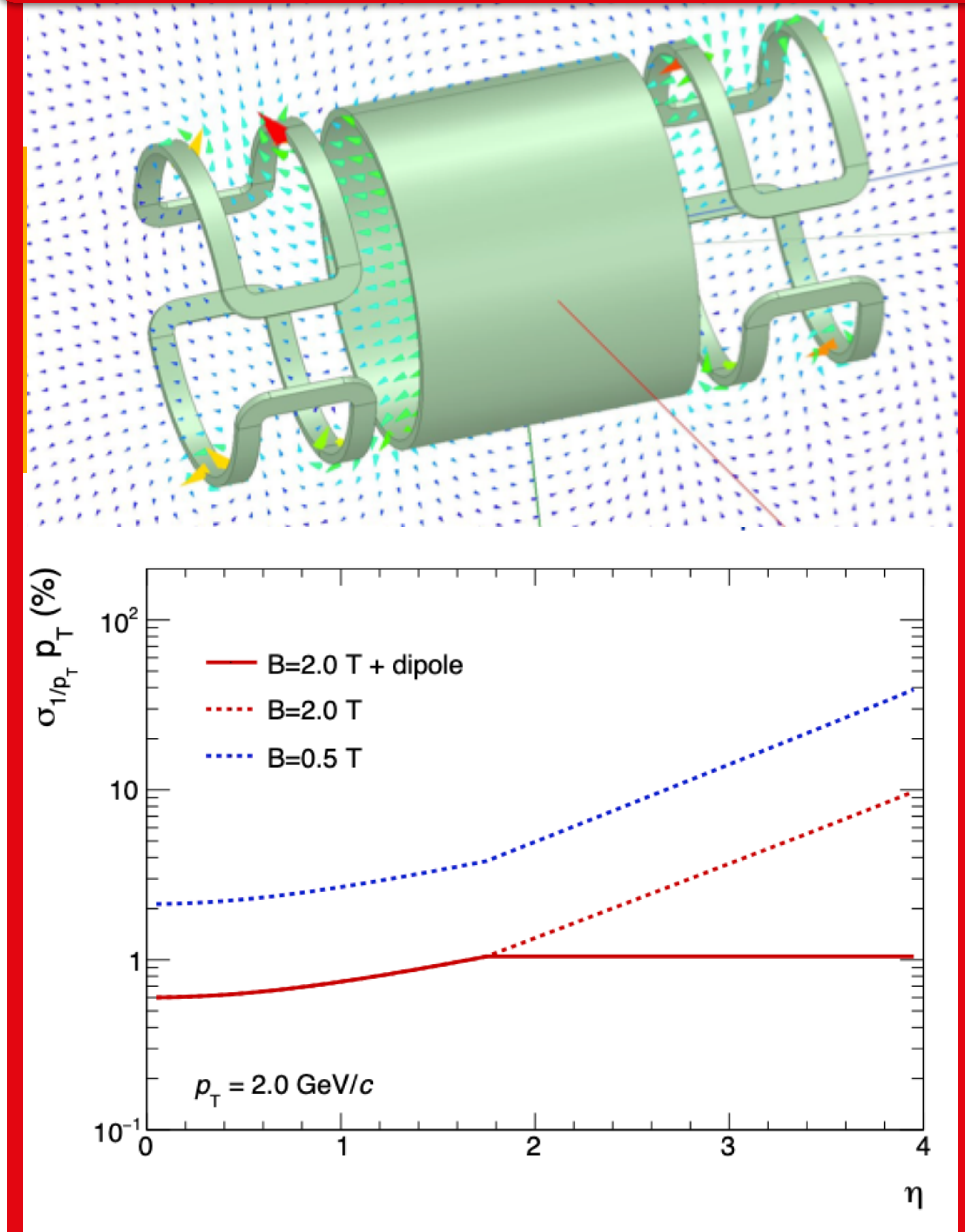


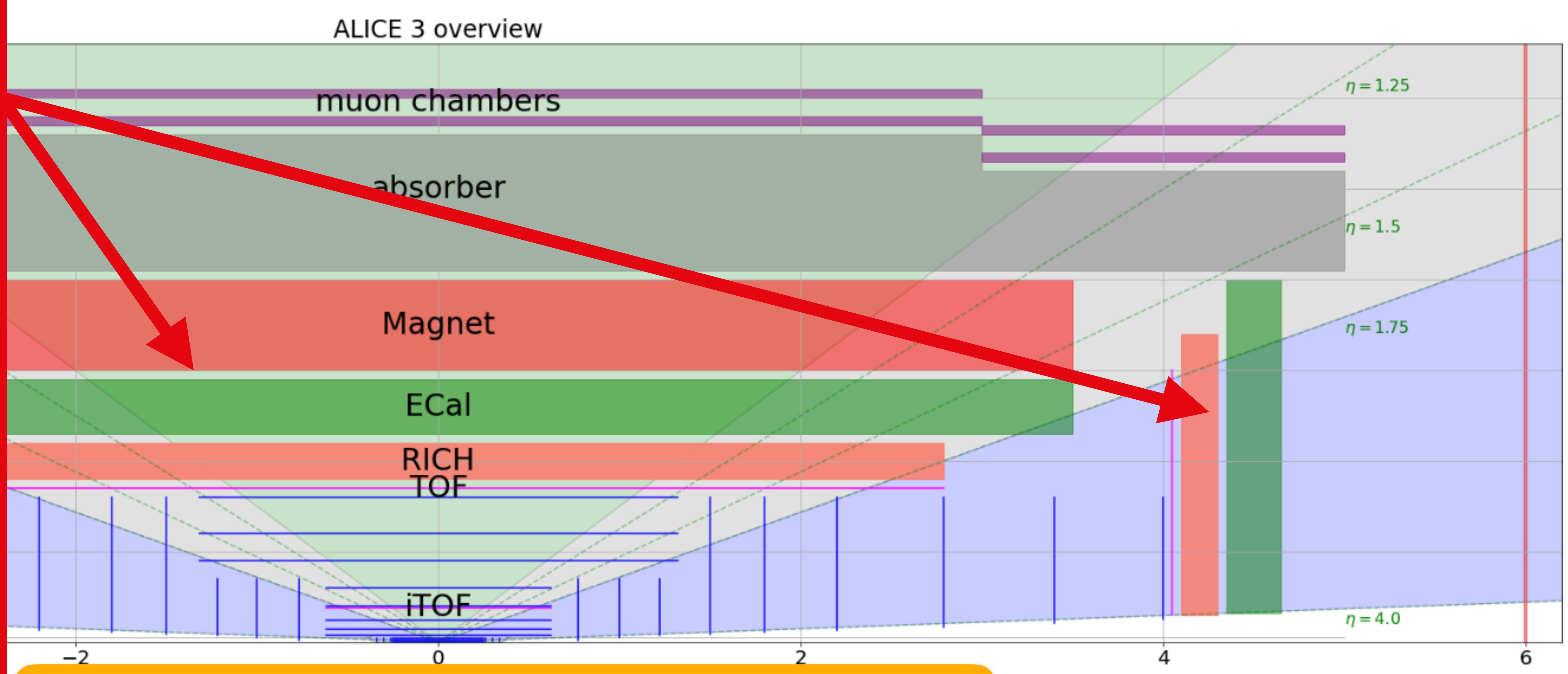
ALICE 3 Detector

Large acceptance coverage

ALICE 3 Detector

~1% over full η range





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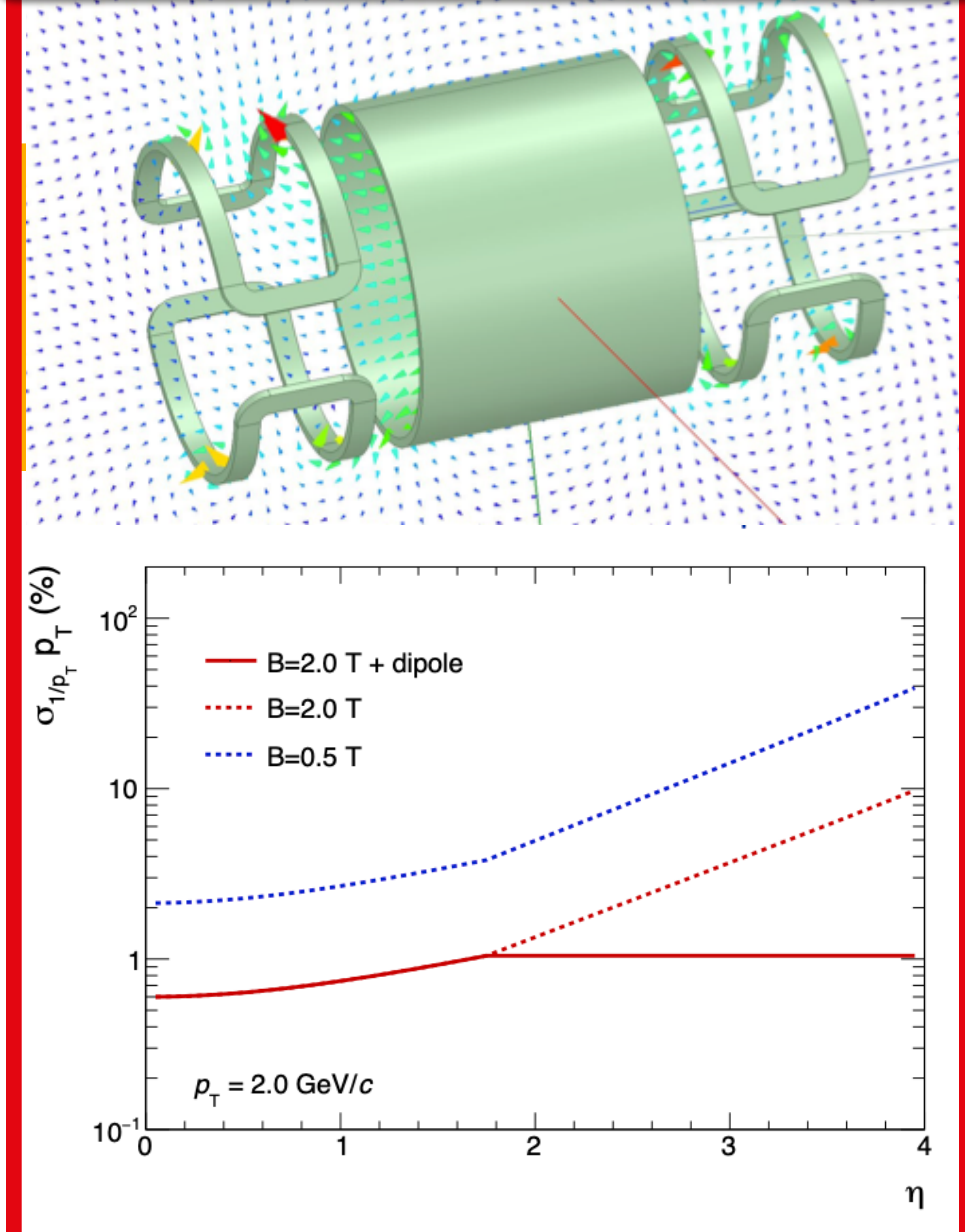
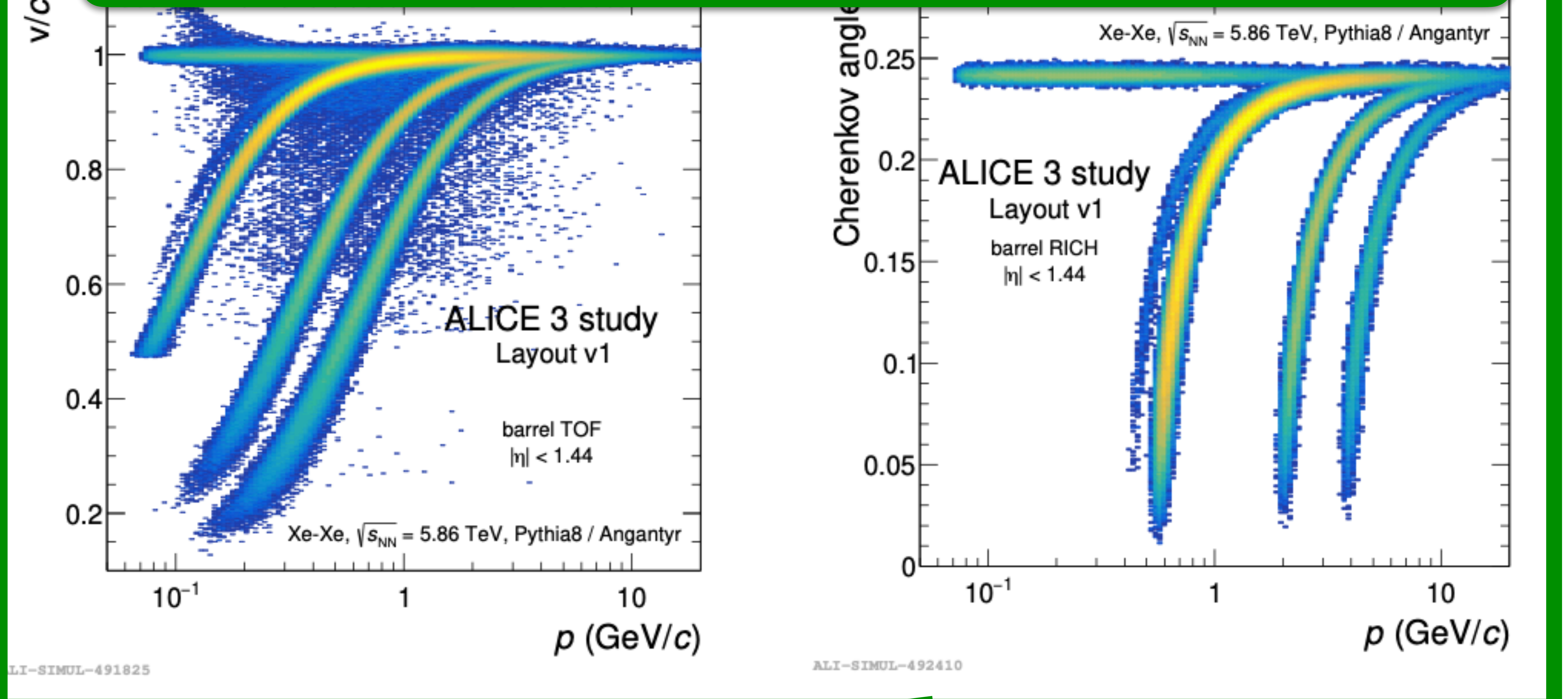
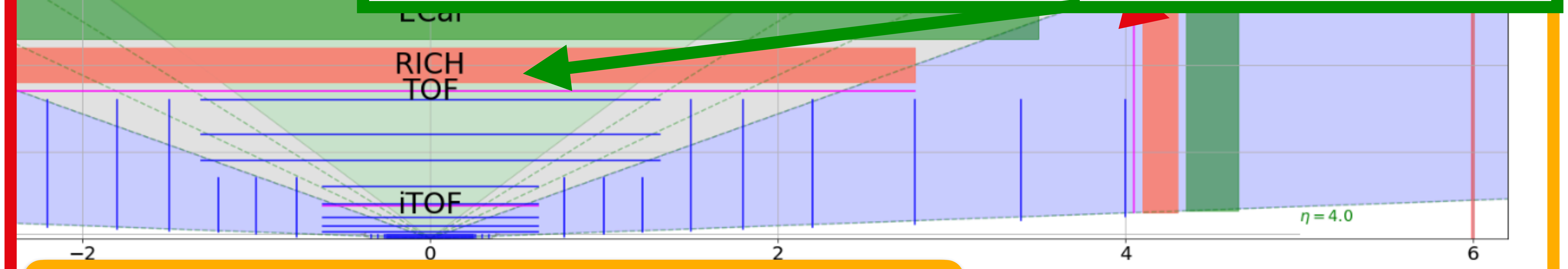


Hadron PID from p ~ 0.1 to 8 GeV/c





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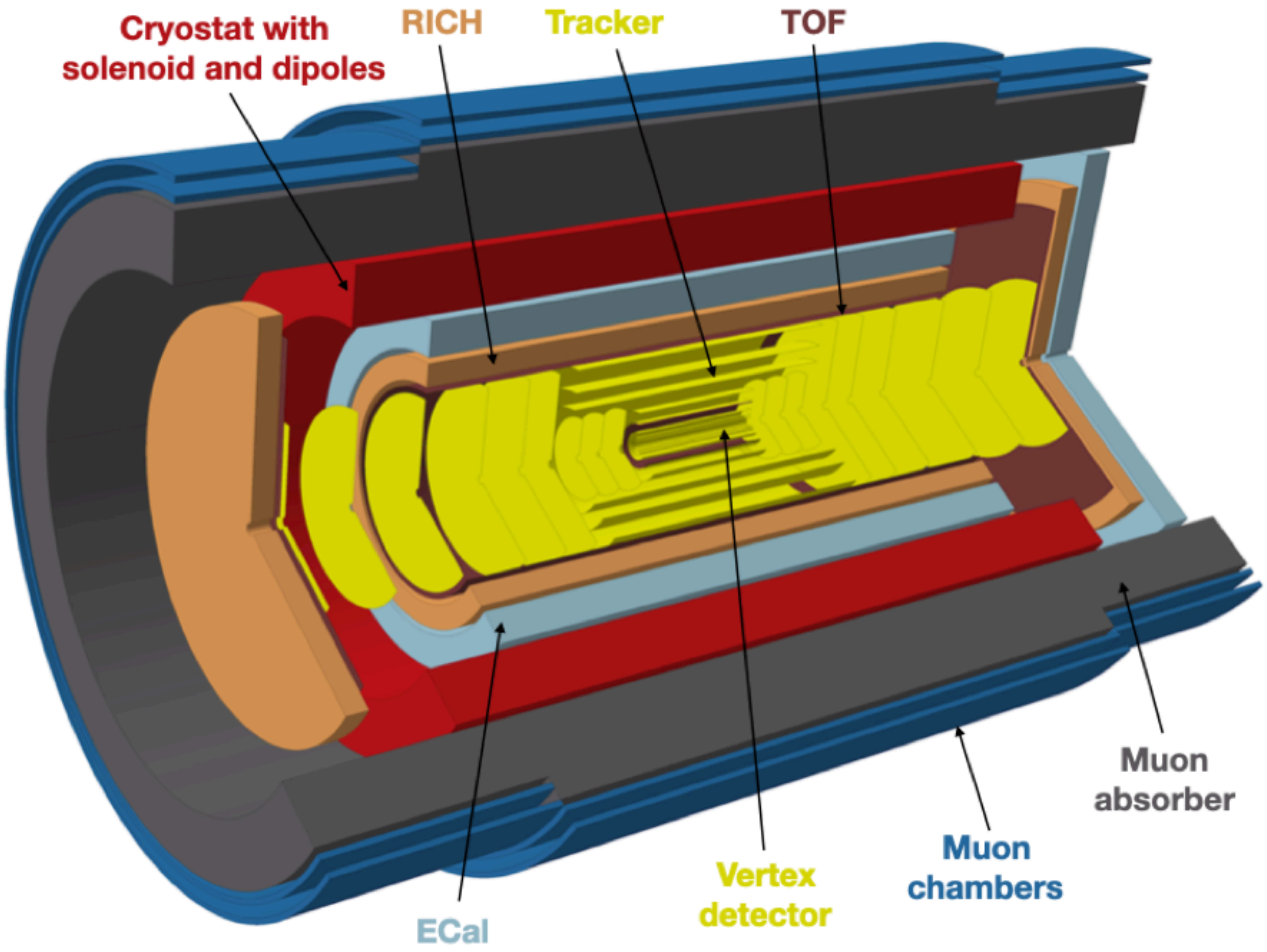

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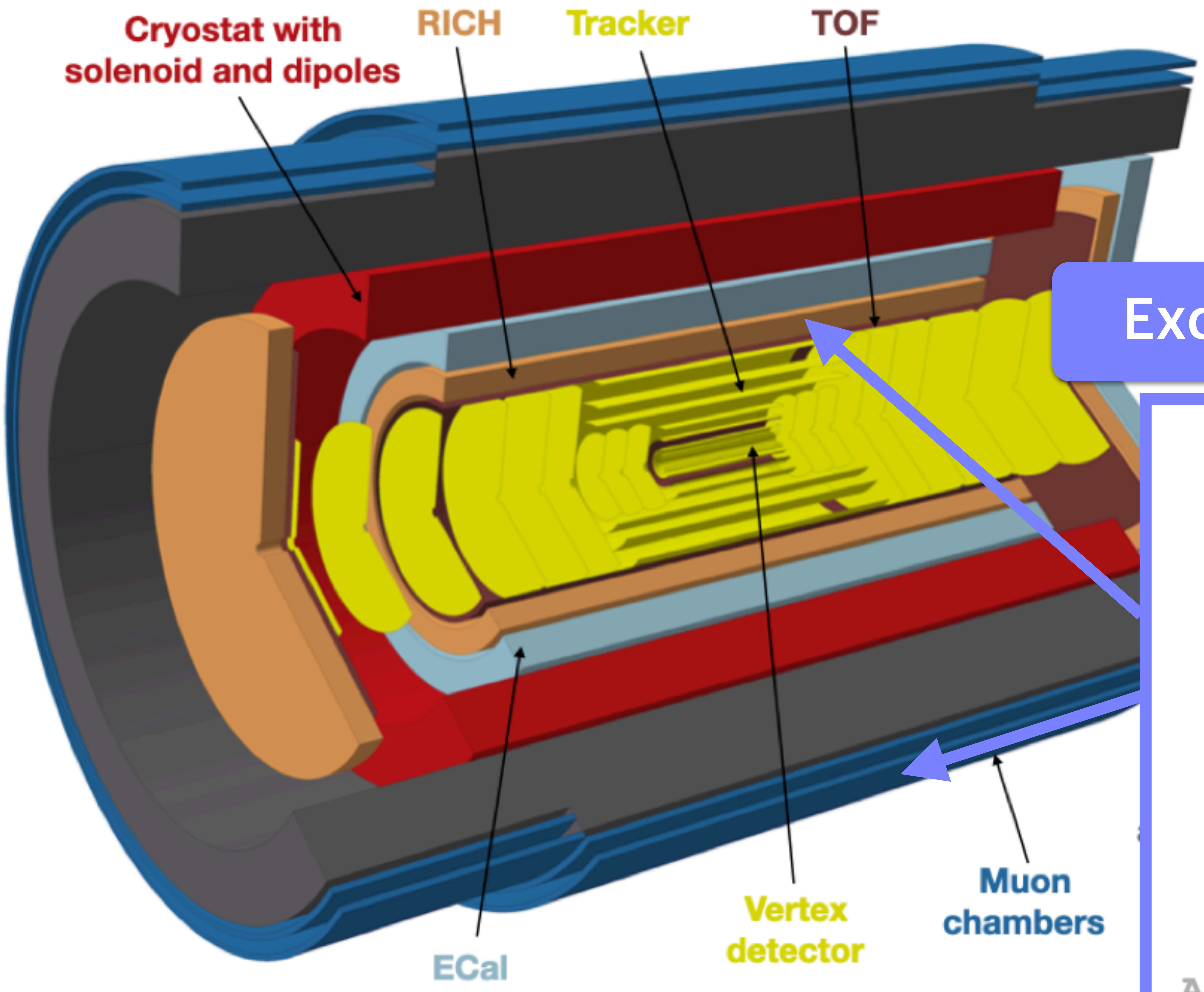
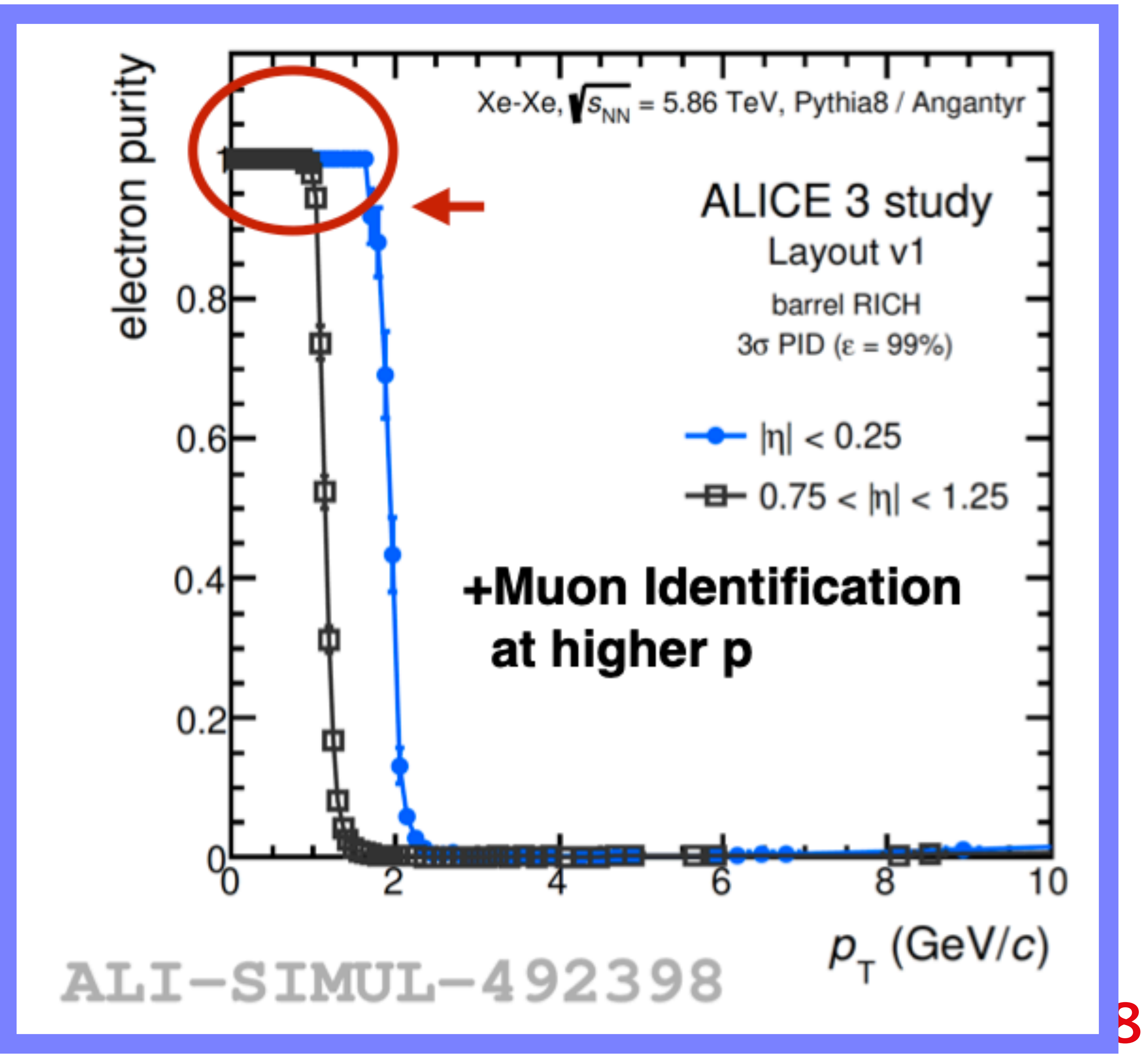


Excellent e/π separation



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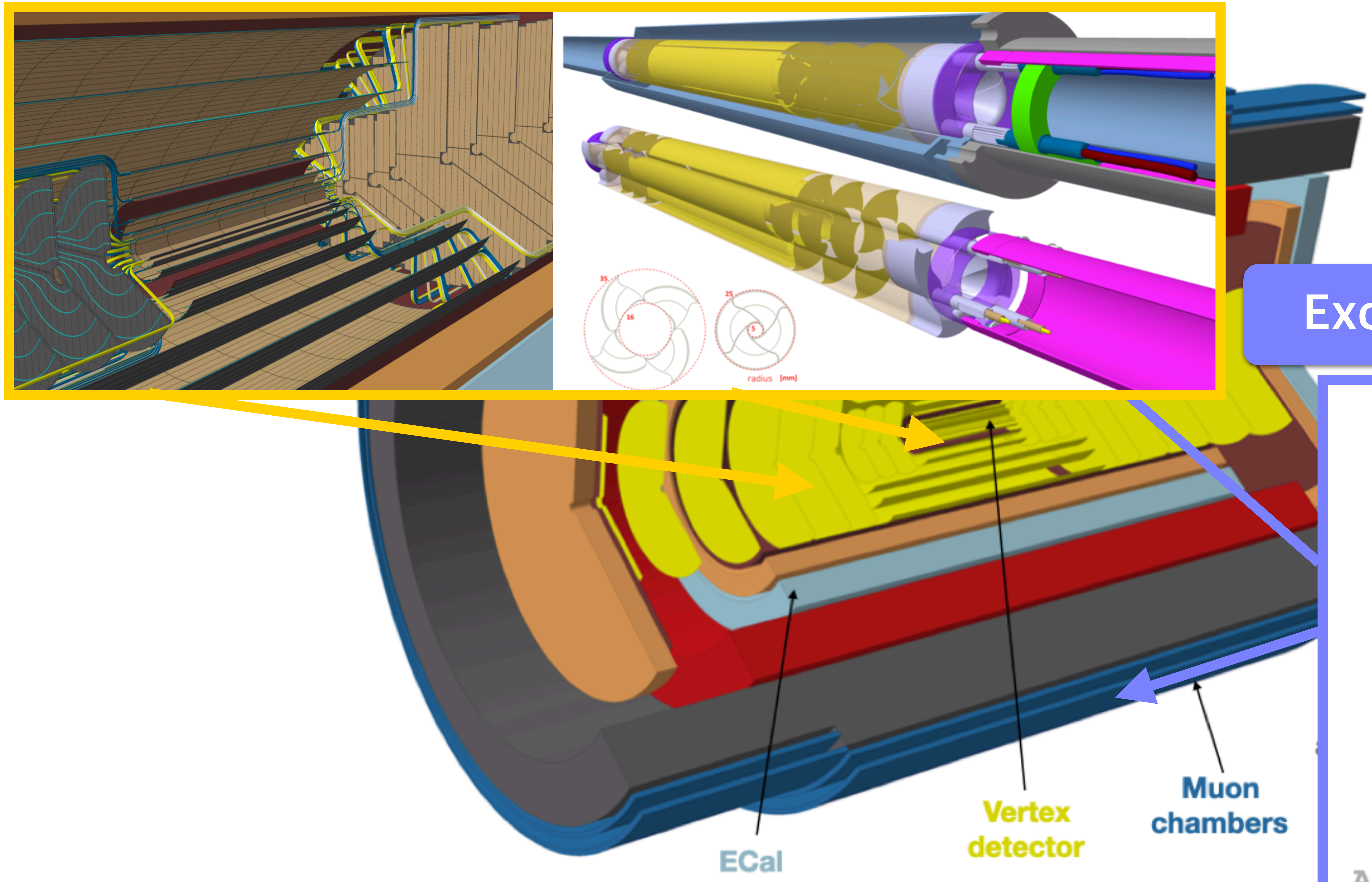

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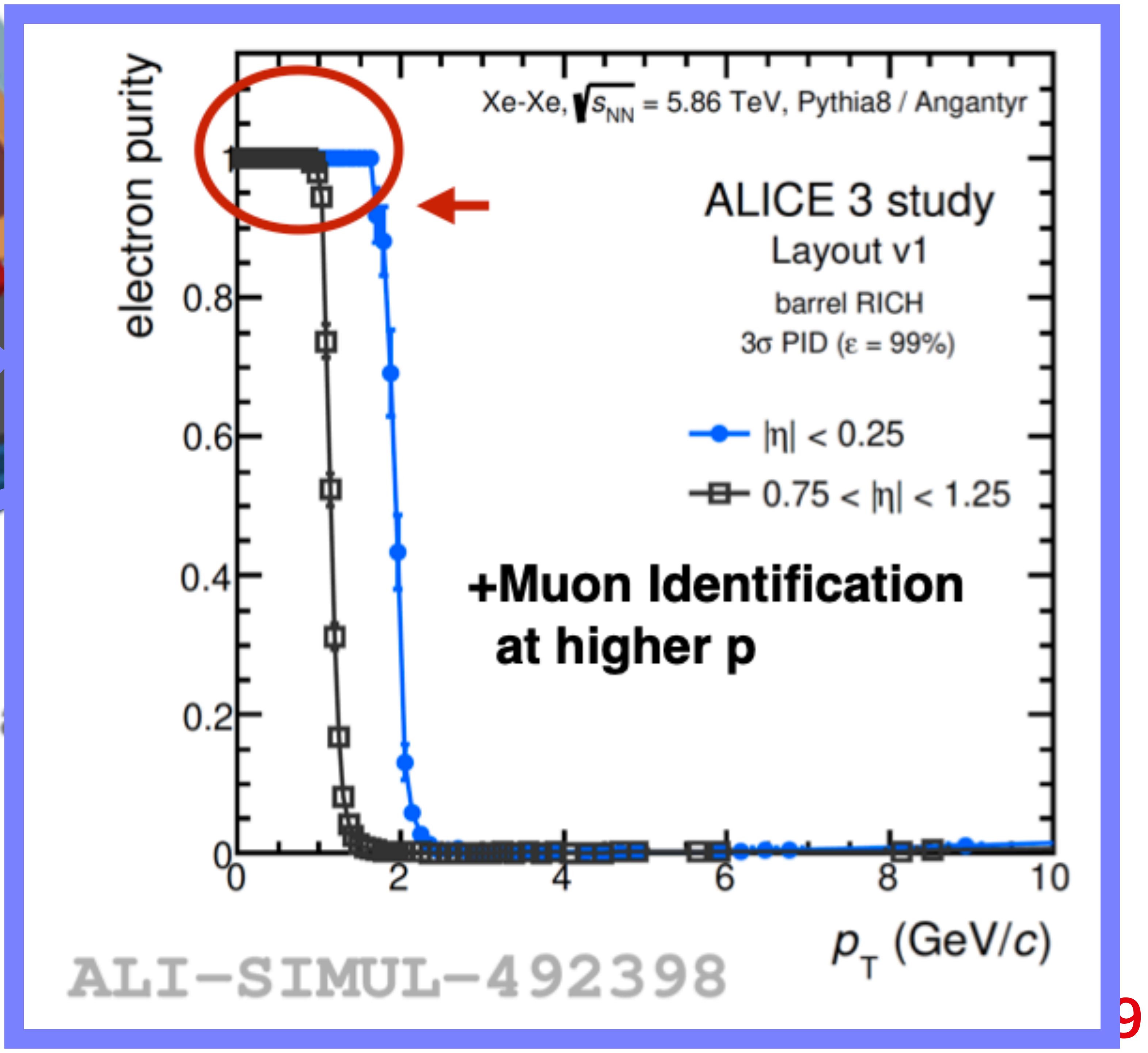

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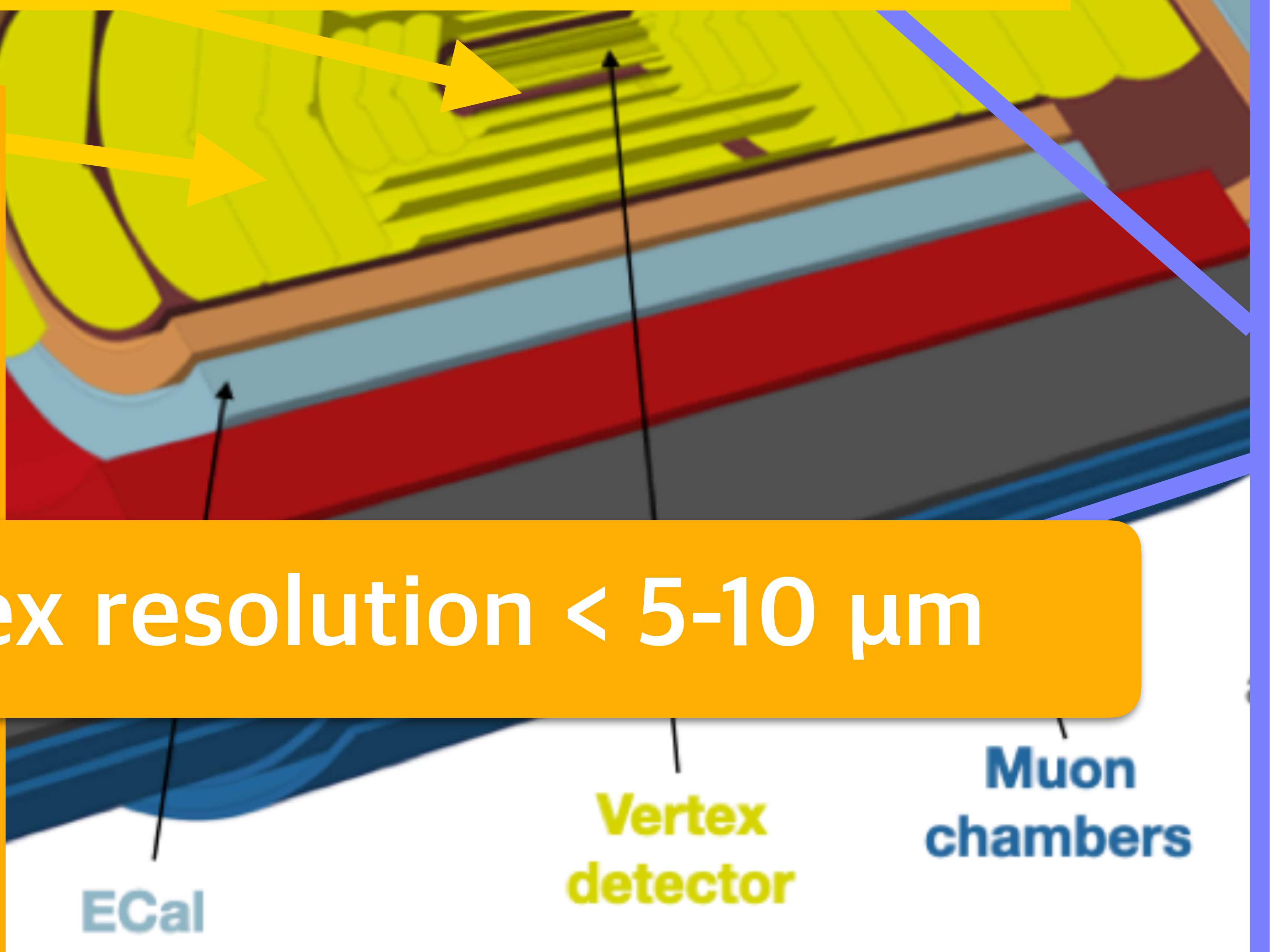
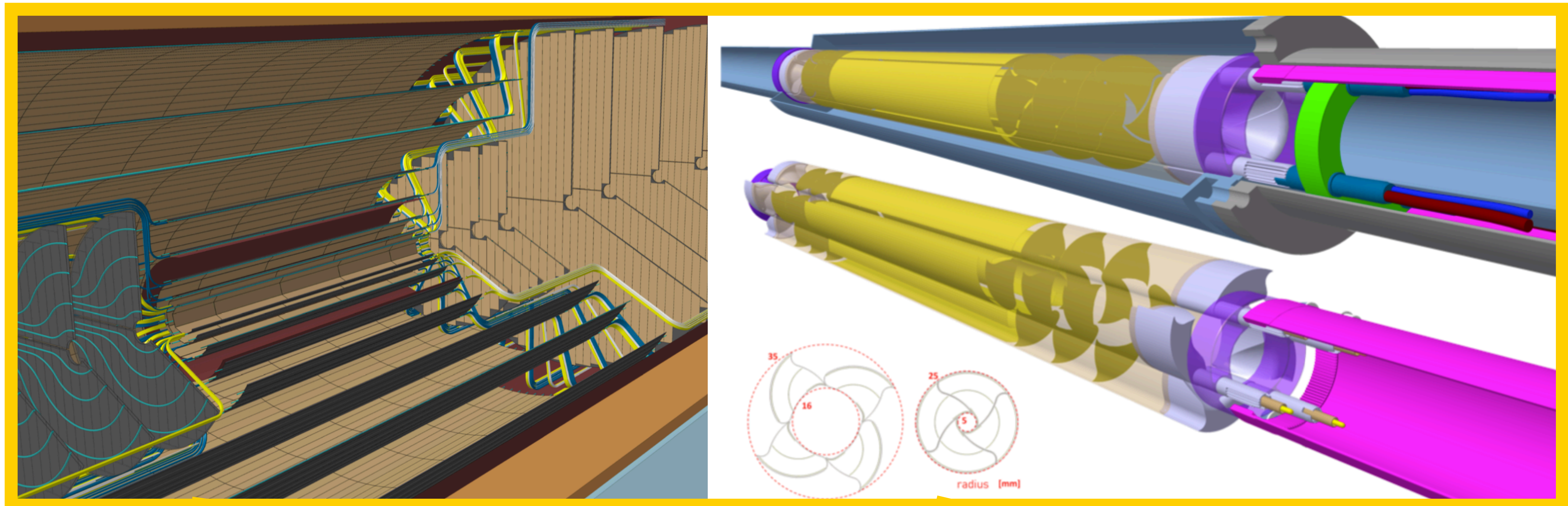
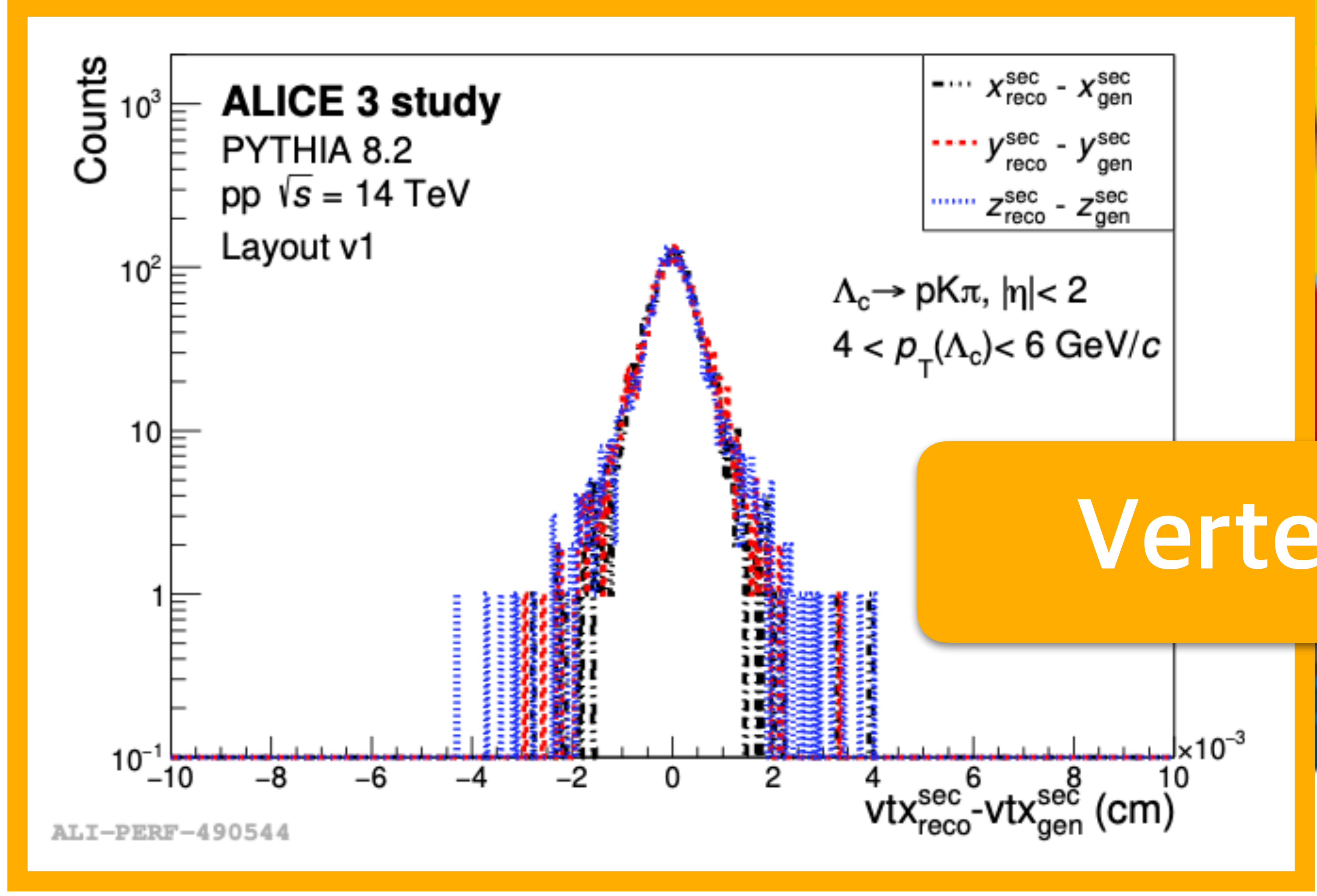
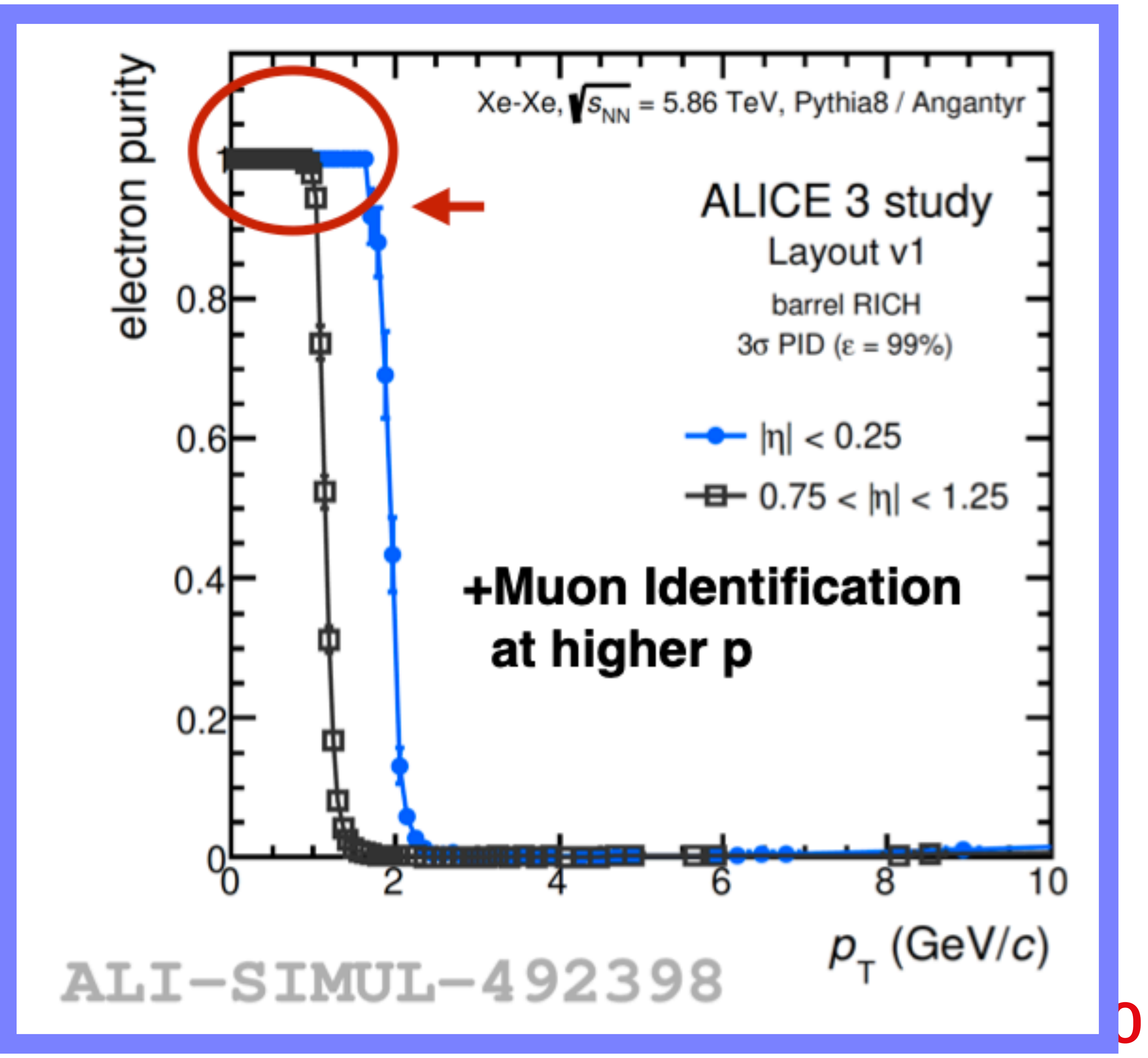


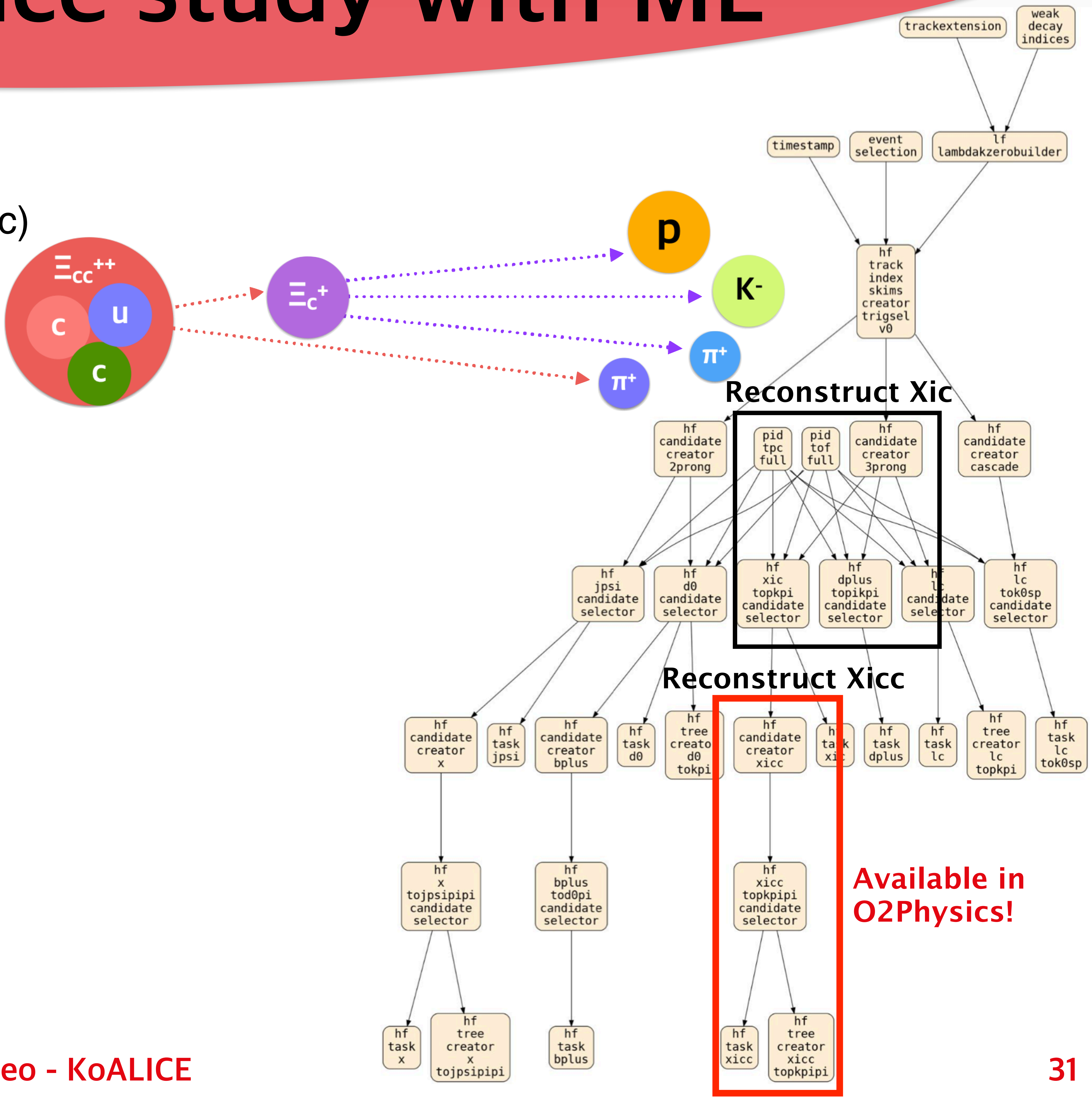






Ξ_{cc}^{++} Performance study with ML

- **Analysis Task**
  - **O2Physics :** hf-tree-creator-xicc-topkipipi (hf-task-xicc)



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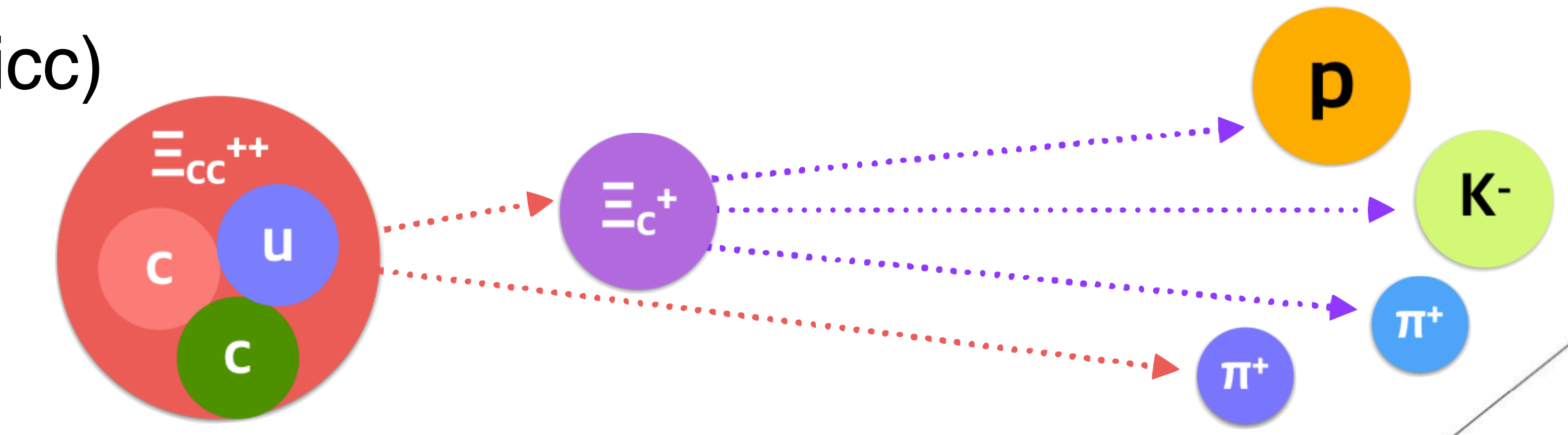
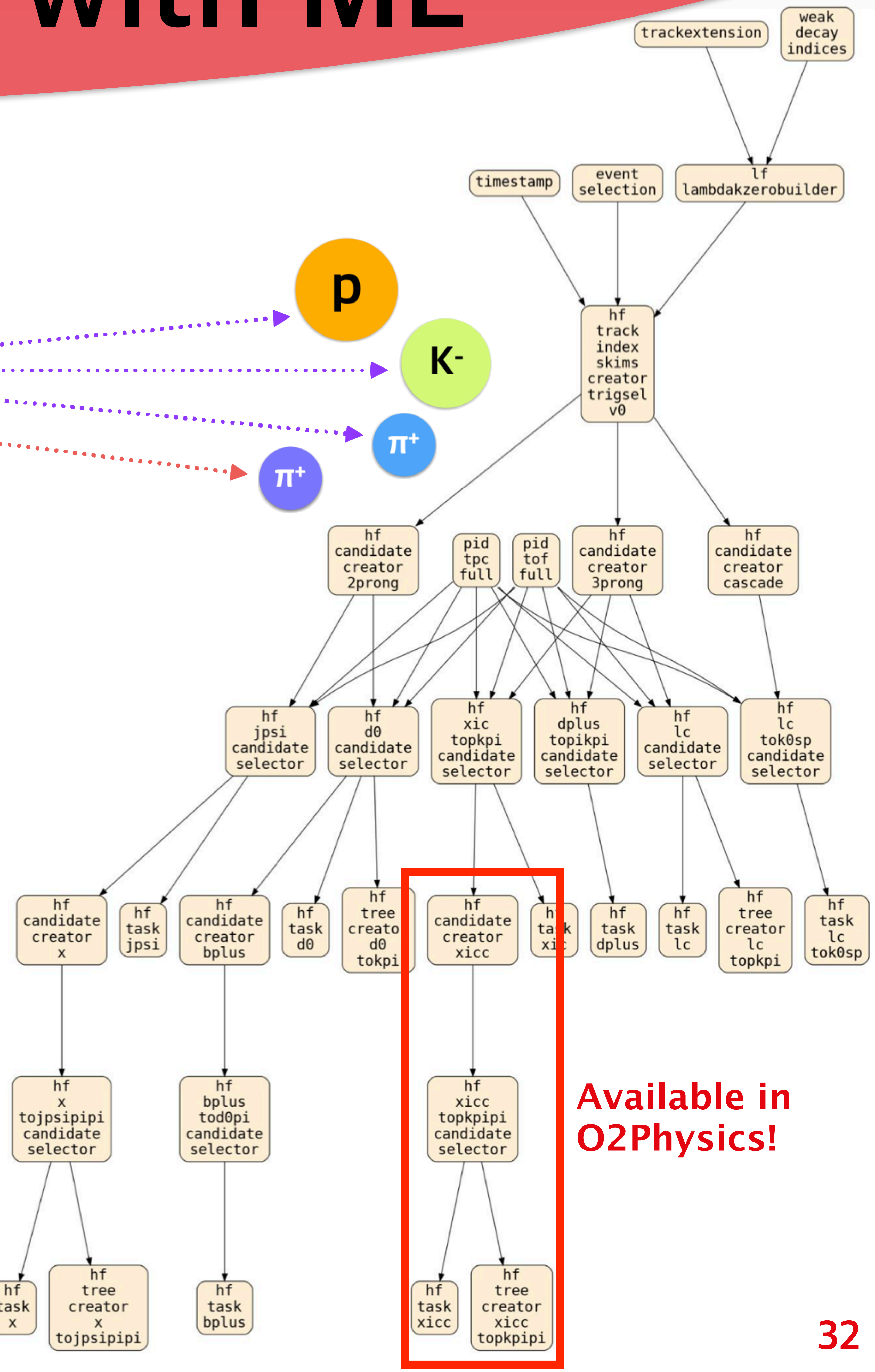
- **ML package**
  - **hipe4ml** : https://github.com/hipe4ml/hipe4ml
    - BDT algorithm : XGBoost





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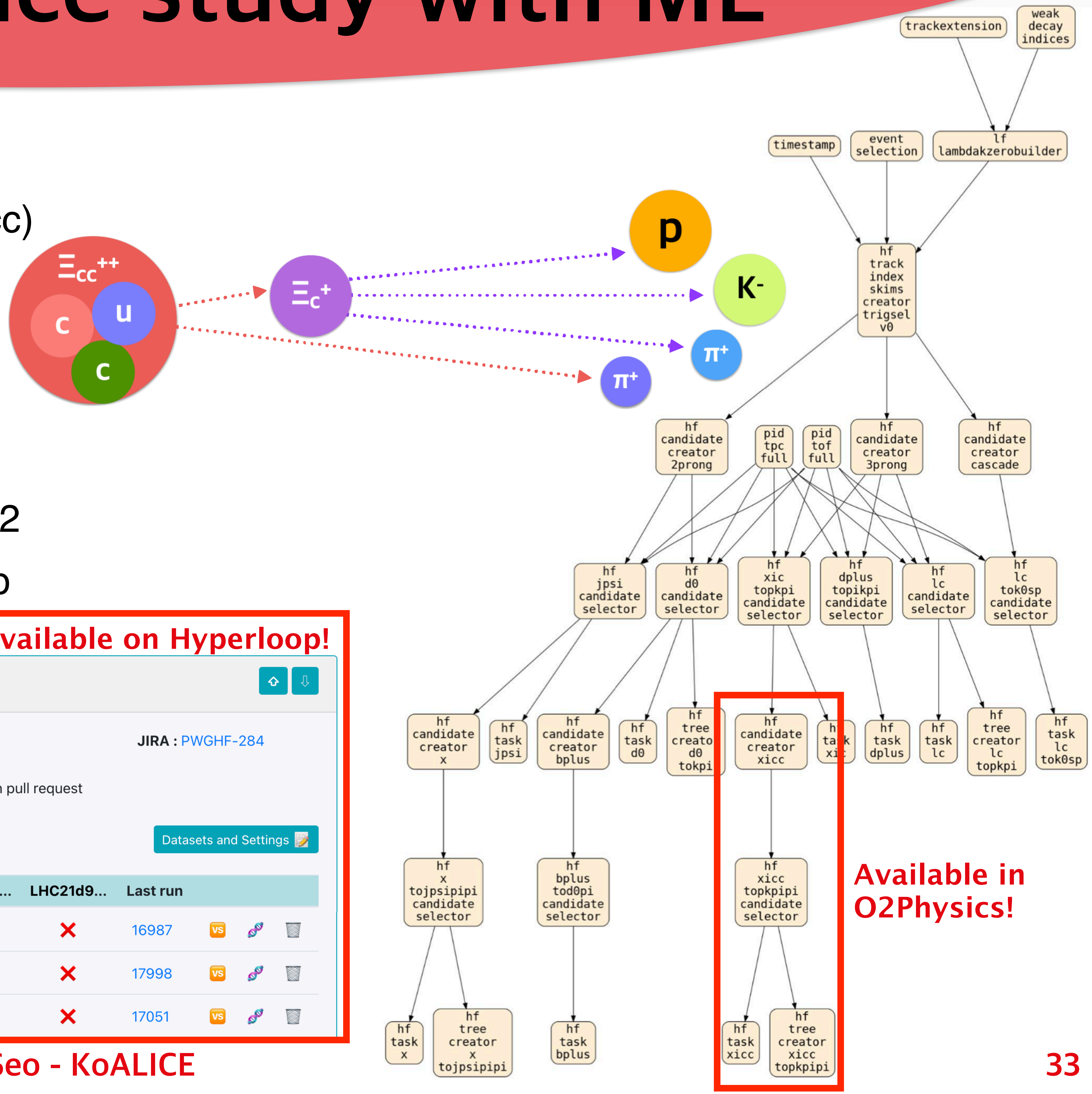
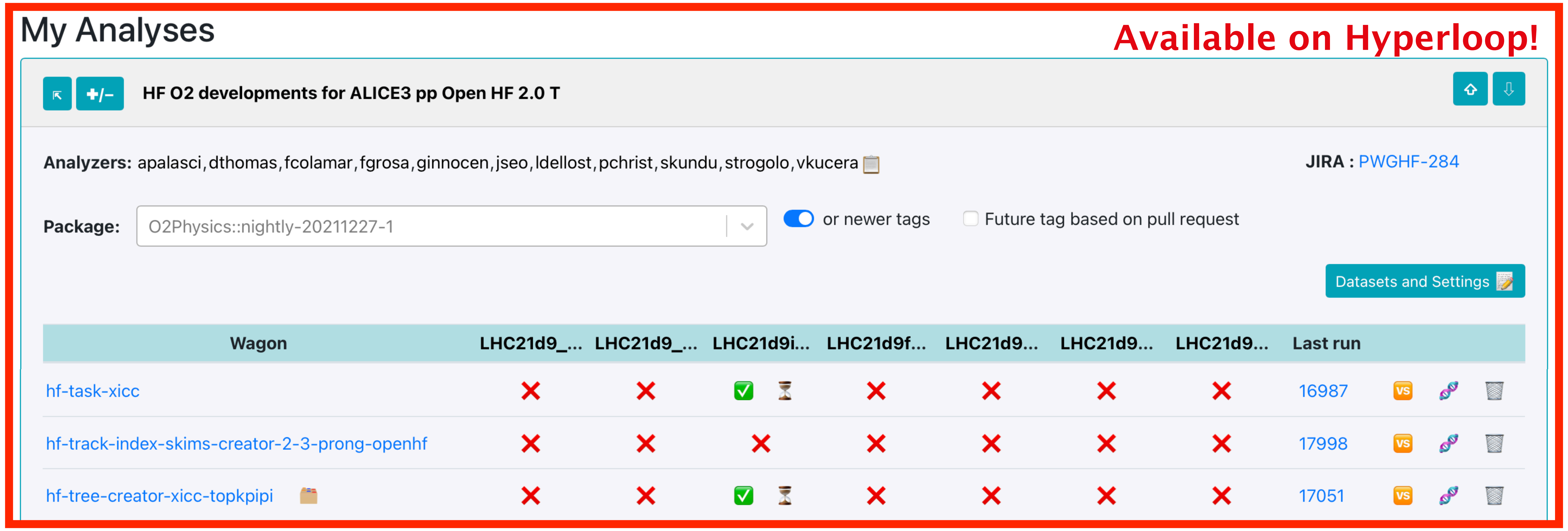
- **ML package**
  - **hipe4ml** : https://github.com/hipe4ml/hipe4ml
    - BDT algorithm : XGBoost
- **Input sample**
  - **Signal :** Ξ_{cc}^{++} enhanced MC; generated by DelphesO2
  - **Background :** pp 14TeV MB MC; on the AliHyperloop

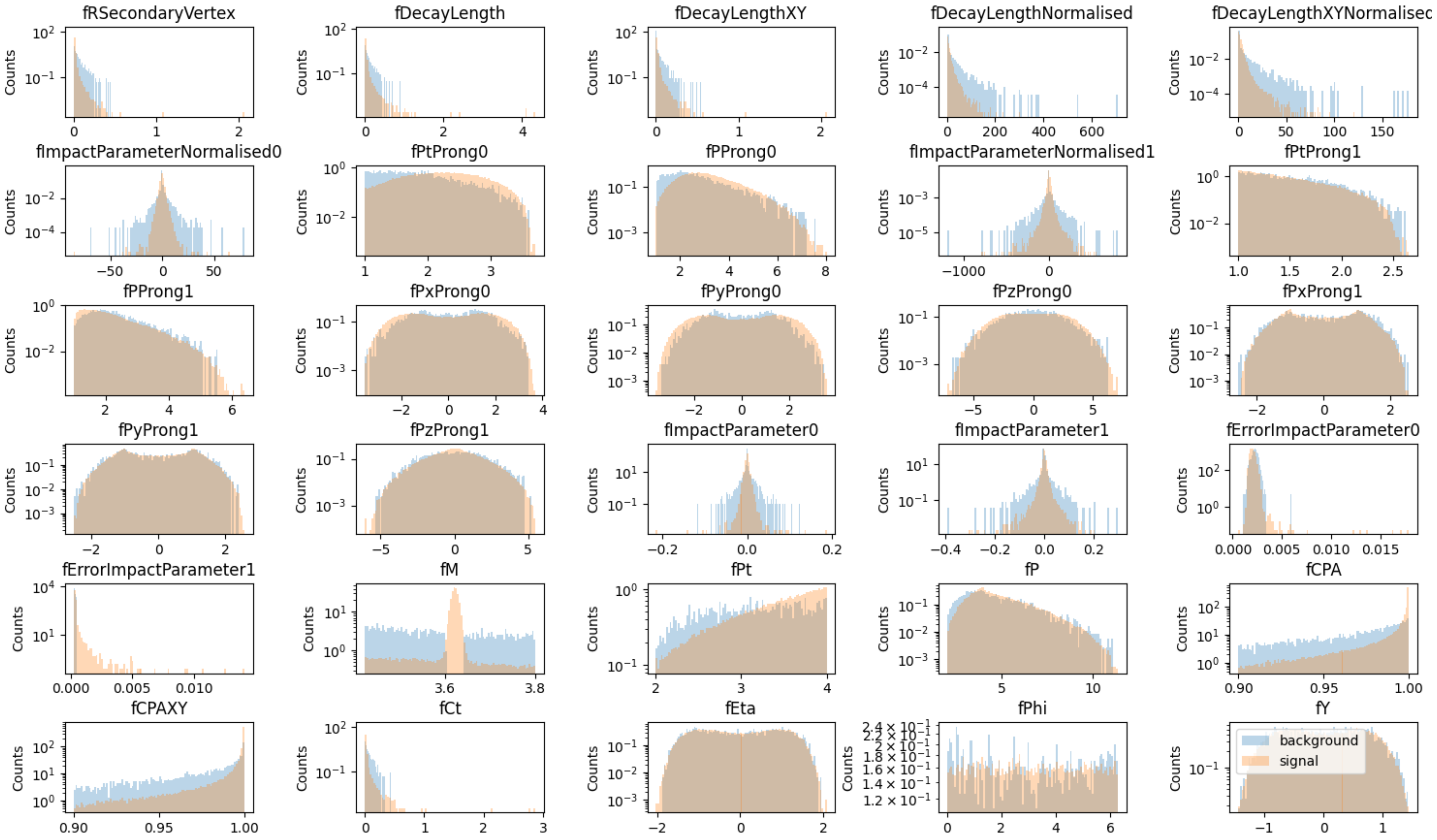




Wagon	LHC21d9_...	LHC21d9_...	LHC21d9i...	LHC21d9f...	LHC21d9...	LHC21d9...	LHC21d9...	Last run
hf-task-xicc	✗	✗	✅ ⏳	✗	✗	✗	✗	16987
hf-track-index-skims-creator-2-3-prong-openhf	✗	✗	✗	✗	✗	✗	✗	17998
hf-tree-creator-xicc-topkpipi	✗	✗	✅ ⏳	✗	✗	✗	✗	17051

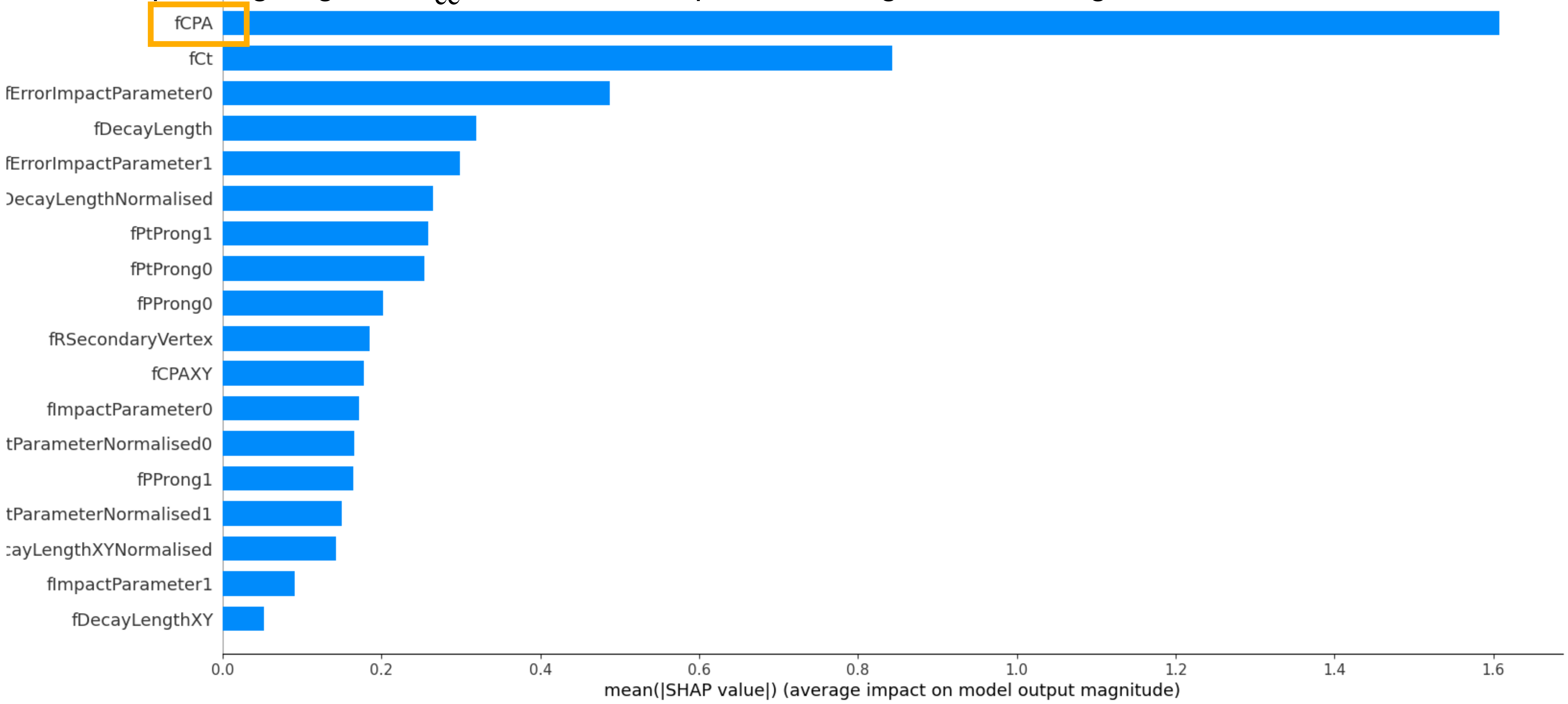
Signal vs Background

- **Signal vs background distribution** $(2 \leq p_{\mathrm{T}} < 4\,\mathrm{GeV}/c)$



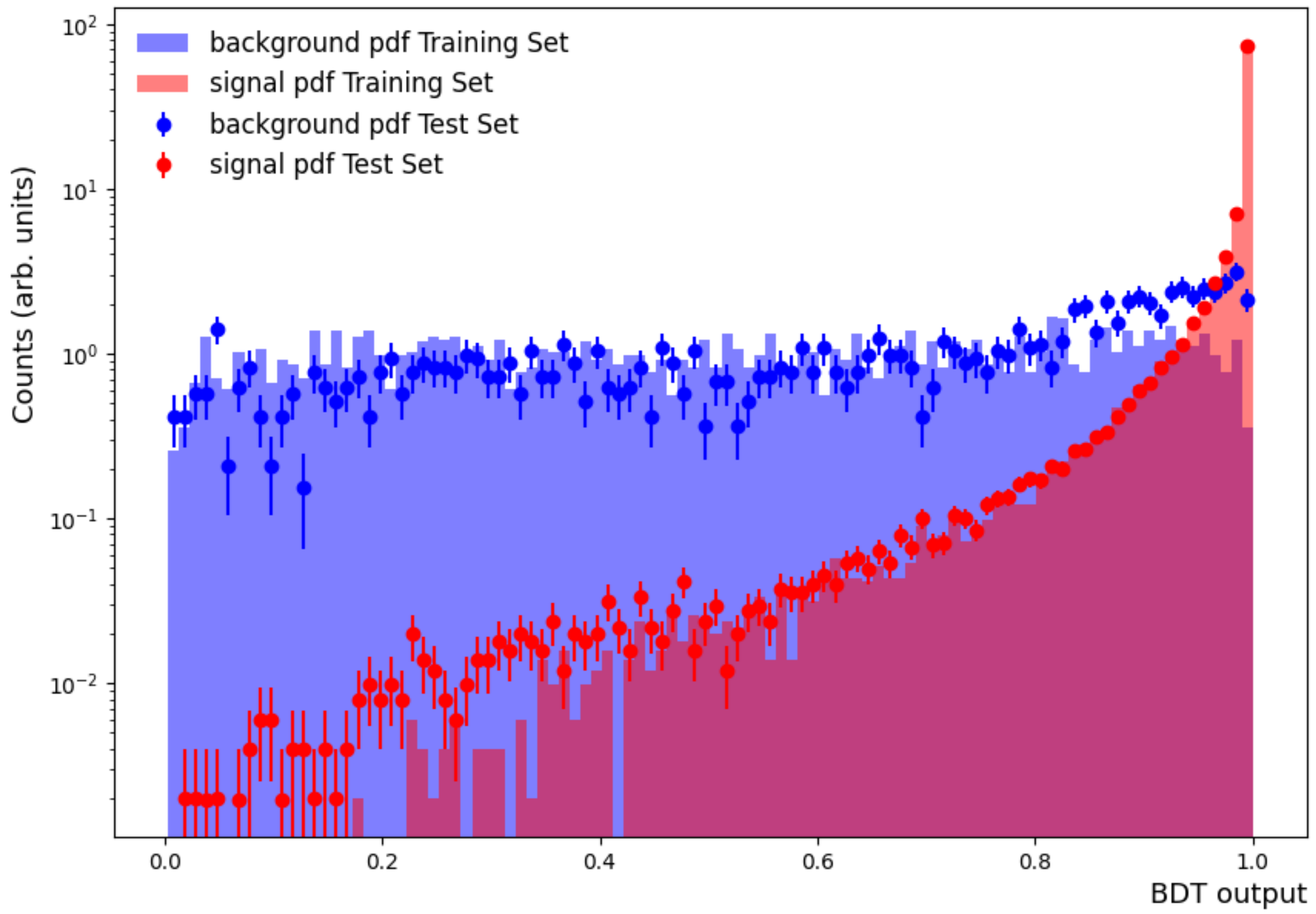
BDT model output

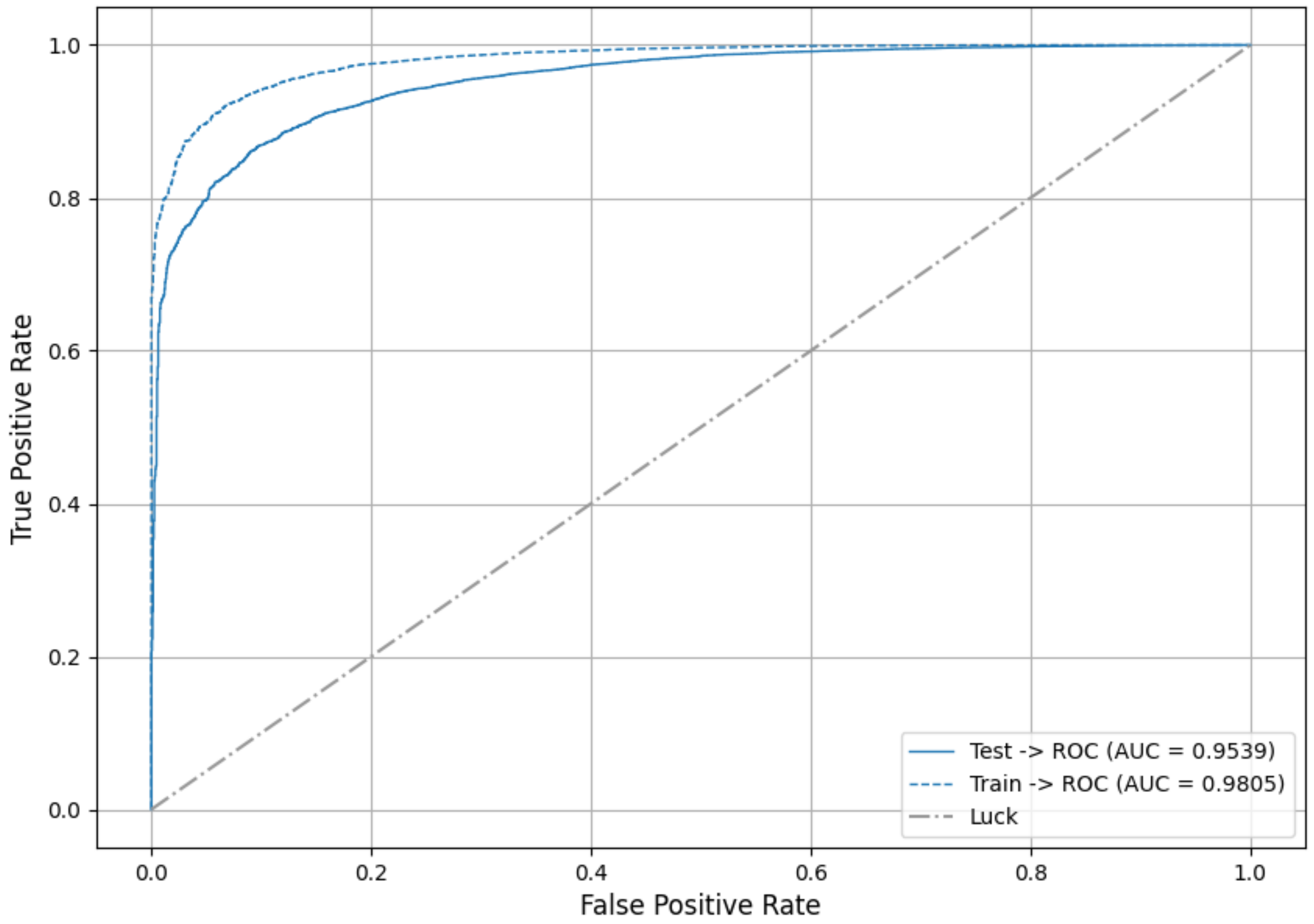
- **Feature importance** $(2 \leq p_{\mathrm{T}} < 4\,\mathrm{GeV}/c)$
  - Cosine of pointing angle of Ξ_{cc}^{++} is critical to separate the signal and background.



BDT model output

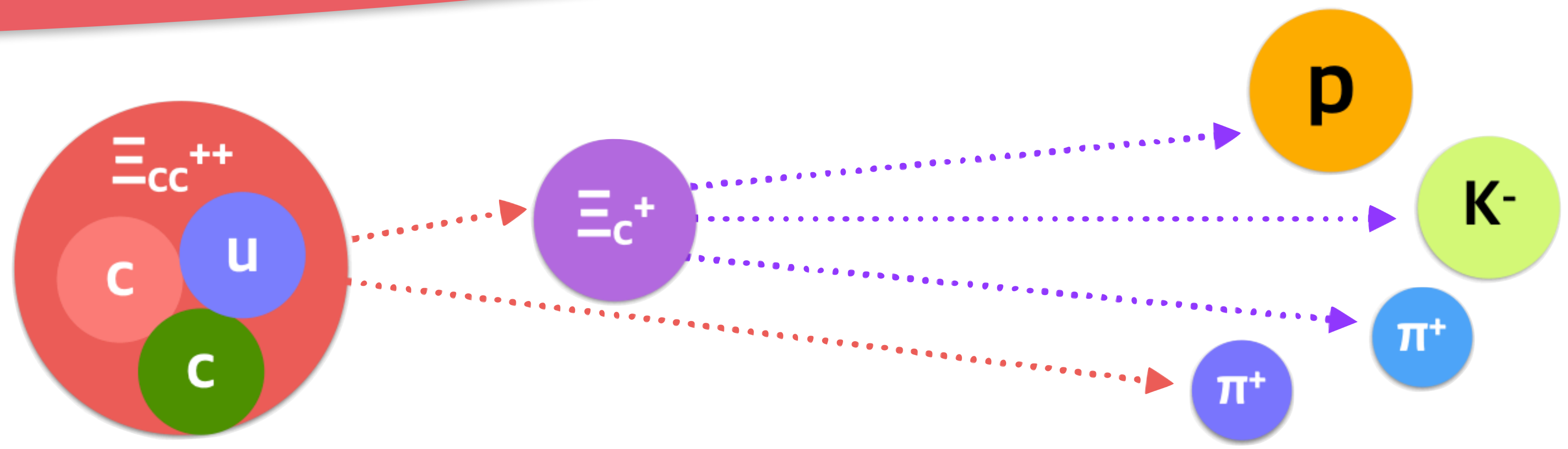
- **Model output** $(2 \leq p_{\mathrm{T}} < 4\,\mathrm{GeV}/c)$
  - **BDT output :** Kind of the probability of signal
    - 0.999 BDT output cut is applied to separate the signal and background.





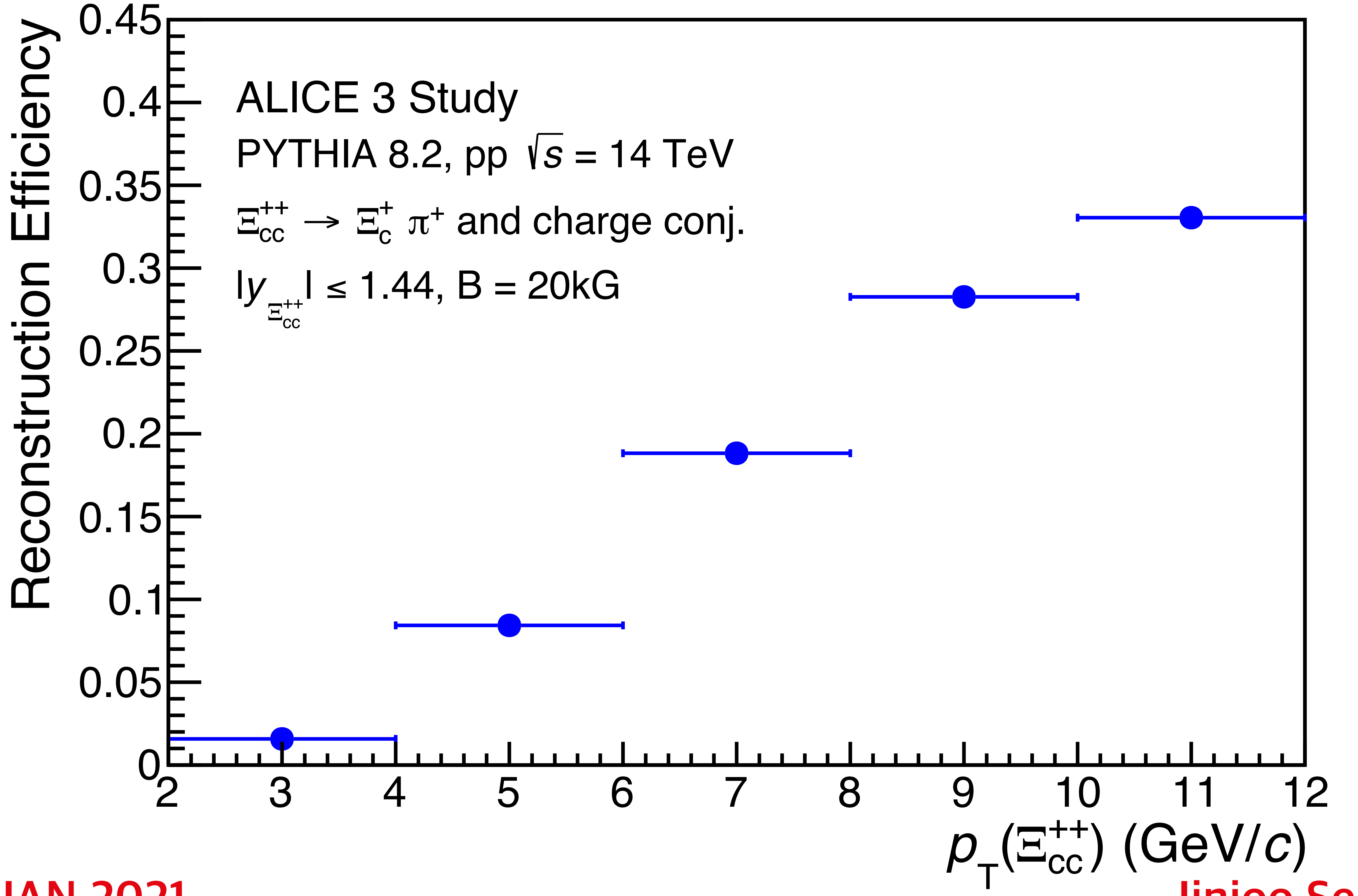
Results

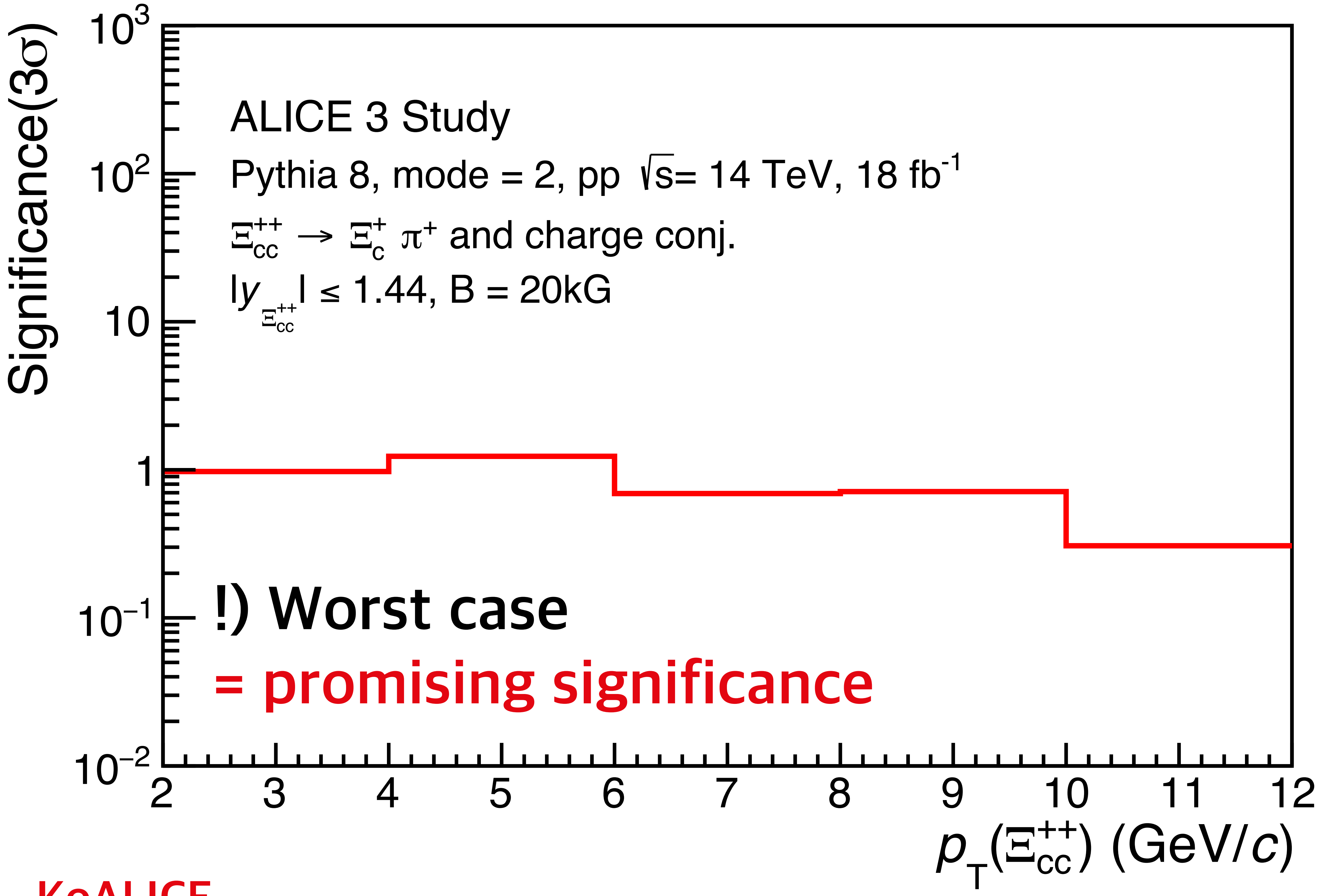
- **Performance study : Ξ_{cc}^{++} on non-strangeness decay**
  - **Efficiency** : Increases with p_T due to higher momentum π^+
  - **Significance**



arXiv:hep-ph/9710339

    - Signal/event : Theoretical expectation(cross section, 39 nb) + PYTHIA 8 (p_T shape) + efficiency + BR(0.03%)
    - Large uncertainty on production cross section(factor 200) and branching ratio(factor 5)





Summary of 2021 Activity

- $\Xi_c^{0,+}$ **production in pp collisions at 13 TeV**
  - Thanks a lot for all of your help!

PHYSICAL REVIEW LETTERS **127,** 272001 (2021)

Measurement of the Cross Sections of Ξ_c^0 and Ξ_c^+ Baryons and of the Branching-Fraction Ratio $\mathrm{BR}(\Xi_c^0 \to \Xi^- e^+ \nu_e)/\mathrm{BR}(\Xi_c^0 \to \Xi^- \pi^+)$ in *pp* Collisions at $\sqrt{s} = 13$ TeV

S. Acharya *et al.*[*]
(A Large Ion Collider Experiment Collaboration)

(Received 2 August 2021; revised 18 October 2021; accepted 19 November 2021; published 28 December 2021)

The p_T-differential cross sections of prompt charm-strange baryons Ξ_c^0 and Ξ_c^+ were measured at midrapidity ($|y| < 0.5$) in proton-proton (pp) collisions at a center-of-mass energy $\sqrt{s} = 13$ TeV with the ALICE detector at the LHC. The Ξ_c^0 baryon was reconstructed via both the semileptonic decay ($\Xi^- e^+ \nu_e$) and the hadronic decay ($\Xi^- \pi^+$) channels. The Ξ_c^+ baryon was reconstructed via the hadronic decay ($\Xi^- \pi^+ \pi^+$) channel. The branching-fraction ratio $\mathrm{BR}(\Xi_c^0 \to \Xi^- e^+ \nu_e)/\mathrm{BR}(\Xi_c^0 \to \Xi^- \pi^+) = 1.38 \pm 0.14(\mathrm{stat}) \pm 0.22(\mathrm{syst})$ was measured with a total uncertainty reduced by a factor of about 3 with respect to the current world average reported by the Particle Data Group. The transverse momentum (p_T) dependence of the Ξ_c^0- and Ξ_c^+-baryon production relative to the D^0 meson and to the $\Sigma_c^{0,+,++}$- and Λ_c^+-baryon production are reported. The baryon-to-meson ratio increases toward low p_T up to a value of approximately 0.3. The measurements are compared with various models that take different hadronization mechanisms into consideration. The results provide stringent constraints to these theoretical calculations and additional evidence that different processes are involved in charm hadronization in electron-positron (e^+e^-) and hadronic collisions.

DOI: 10.1103/PhysRevLett.127.272001

Measurements of heavy-flavor hadron production in high-energy proton-proton (pp) collisions provide important tests of quantum chromodynamics (QCD). The cross sections of heavy-flavor hadrons are usually computed using the factorization approach as a convolution of three factors [1]: (i) the parton distribution functions of the incoming protons, (ii) the hard-scattering cross section at partonic level, and (iii) the fragmentation function of heavy quarks into a given heavy-flavor hadron. The D- and B-meson cross sections in pp collisions at several center-of-mass energies at the LHC [2–7] are described within uncertainties by perturbative QCD calculations [8–12], which use fragmentation functions tuned on e^+e^- data, over a wide range of transverse momentum (p_T). Measurements of Λ_c^+-baryon production at midrapidity in pp collisions at the center-of-mass energy $\sqrt{s} = 5.02$ and 7 TeV were reported by the ALICE and CMS Collaborations in Refs. [13–15]. The measured Λ_c^+/D^0 ratio is higher than previous measurements in e^+e^- [16–18] and e^-p [19,20] collisions. A similar observation was drawn from the measurement of the inclusive Ξ_c^0-baryon production at midrapidity in pp collisions at $\sqrt{s} = 7$ TeV [21].

PYTHIA8.2 tunes including string formation beyond the leading-color approximation [22] and a statistical hadronization model (SHM) [23] including a set of higher-mass charm-baryon states as prescribed by the relativistic quark model (RQM) and from lattice QCD [24,25] qualitatively describe the measured $\Sigma_c^{0,+,++}/D^0$ and Λ_c^+/D^0 cross section ratios [15,26], but underestimate the Ξ_c^0/D^0 ratio [21]. The observed enhancement of the charm-baryon production can also be explained by model calculations considering hadronization of charm quarks via coalescence in addition to the fragmentation in pp collisions [27,28]. The increased yield of charm baryons makes it mandatory to include their contribution for an accurate measurement of the $c\bar{c}$ production cross section in pp collisions at the LHC [29].

In this Letter, the measurements of the cross sections of the prompt (i.e., produced directly in the hadronization of charm quarks and in the decays of directly produced excited charm states) charm-strange baryons Ξ_c^0 and Ξ_c^+ at midrapidity ($|y| < 0.5$) in pp collisions at $\sqrt{s} = 13$ TeV are reported. The Ξ_c^0 baryon was reconstructed via the decay channels $\Xi^- e^+ \nu_e$, $\mathrm{BR} = (1.8 \pm 1.2)\%$ and $\Xi^- \pi^+$, $\mathrm{BR} = (1.43 \pm 0.32)\%$ [30] together with their charge conjugates in the interval $1 < p_T < 12$ GeV/c. The Ξ_c^+ baryon was reconstructed via the decay channel $\Xi^- \pi^+ \pi^+$, $\mathrm{BR} = (2.86 \pm 1.21 \pm 0.38)\%$ [31], together with its charge conjugate, in the interval $4 < p_T < 12$ GeV/c.

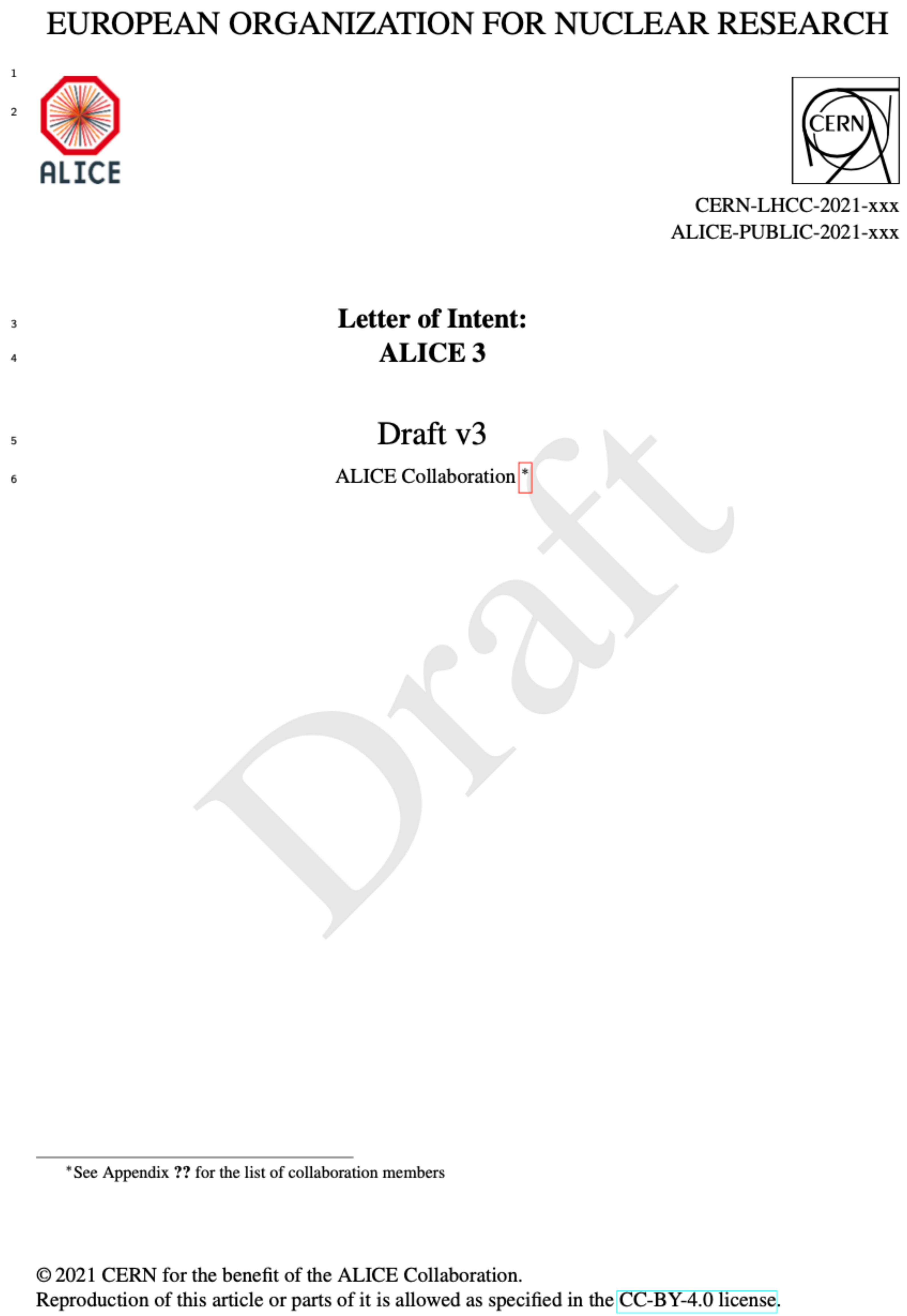
[*]Full author list given at the end of the article.

0031-9007/21/127(27)/272001(13) 272001-1

Summary of 2021 Activity

- $\Xi_c^{0,+}$ **production in pp collisions at 13 TeV**
  - Thanks a lot for all of your help!

- Ξ_{cc}^{++} **Performance study**
  - **O2Physics**
    - Develop analysis workflow
  - **ALICE 3 LoI**
    - Still working on until final review
    - Open for comments: until 21 January
    - Final LHCC Review : 21 February


EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-LHCC-2021-xxx
ALICE-PUBLIC-2021-xxx

Letter of Intent:
ALICE 3

Draft v3

ALICE Collaboration[*]

Draft

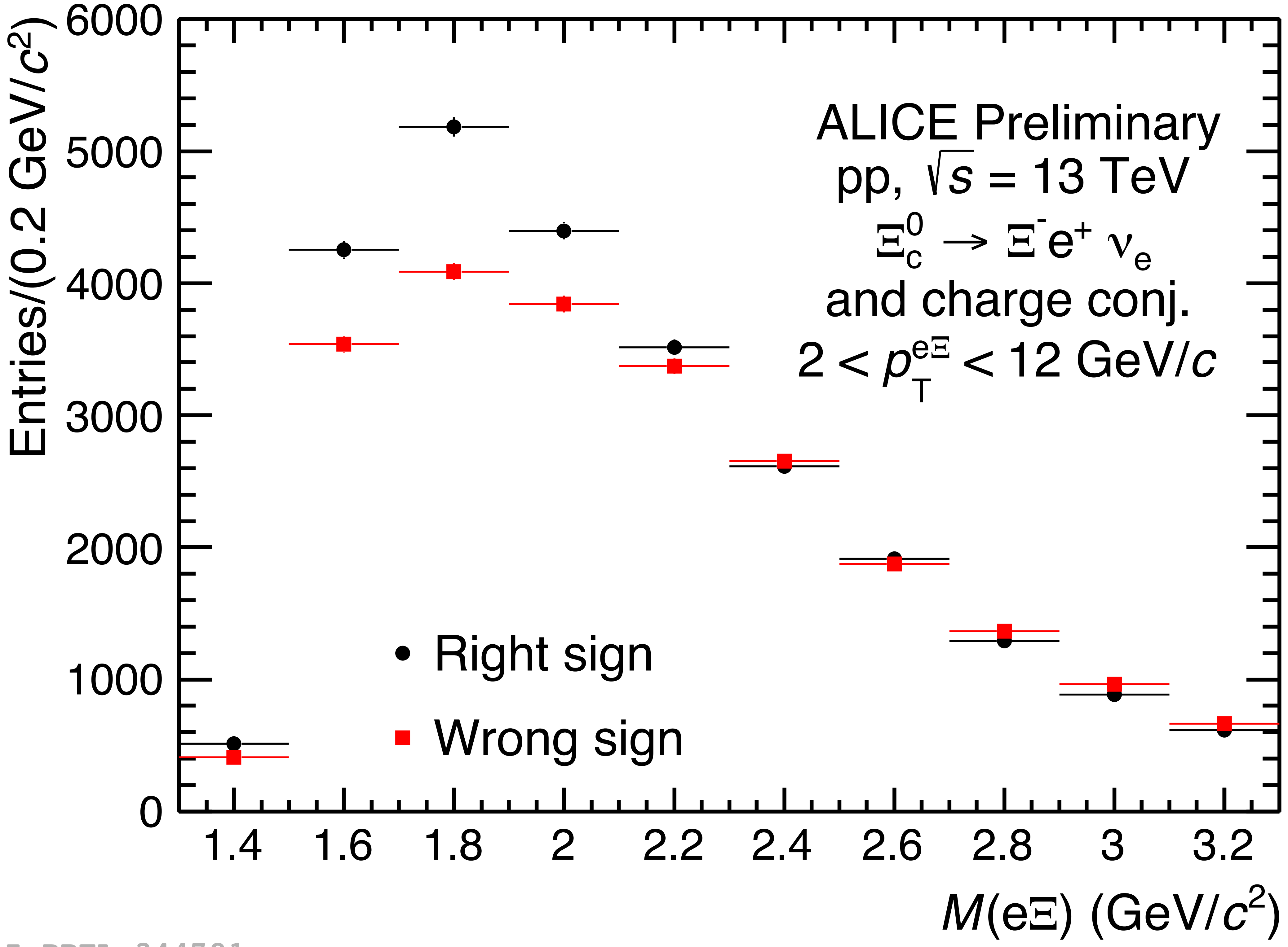
[*]See Appendix ?? for the list of collaboration members

Back up

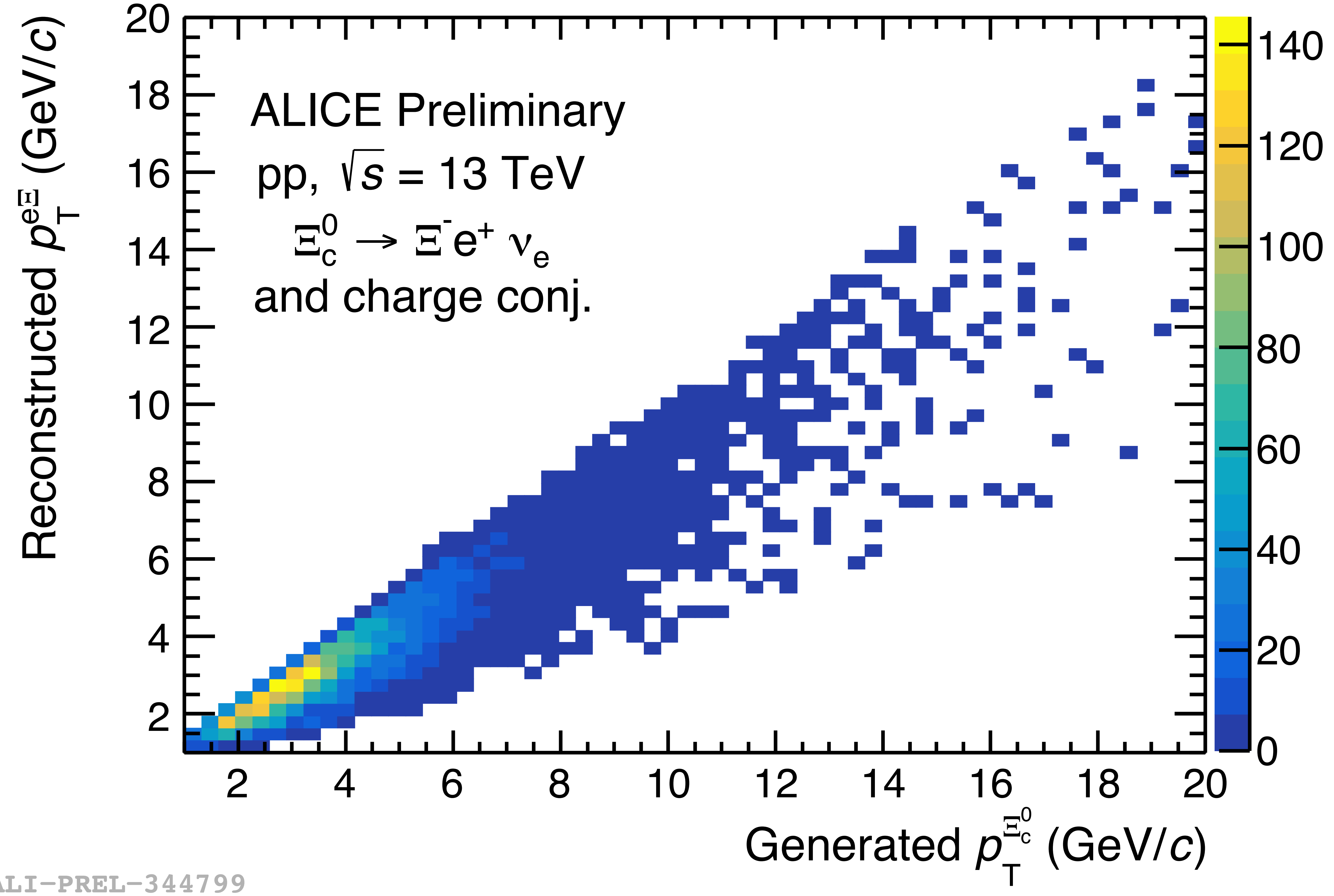
$\Xi^0_c \rightarrow e^+\Xi^-\nu_e$

- Unfolding

- **Unfolding**
  - The p_T of eΞ pairs is corrected for the missing momentum of the neutrino using unfolding techniques.
  - Convergence of the Bayesian unfolding is achieved after three iterations.

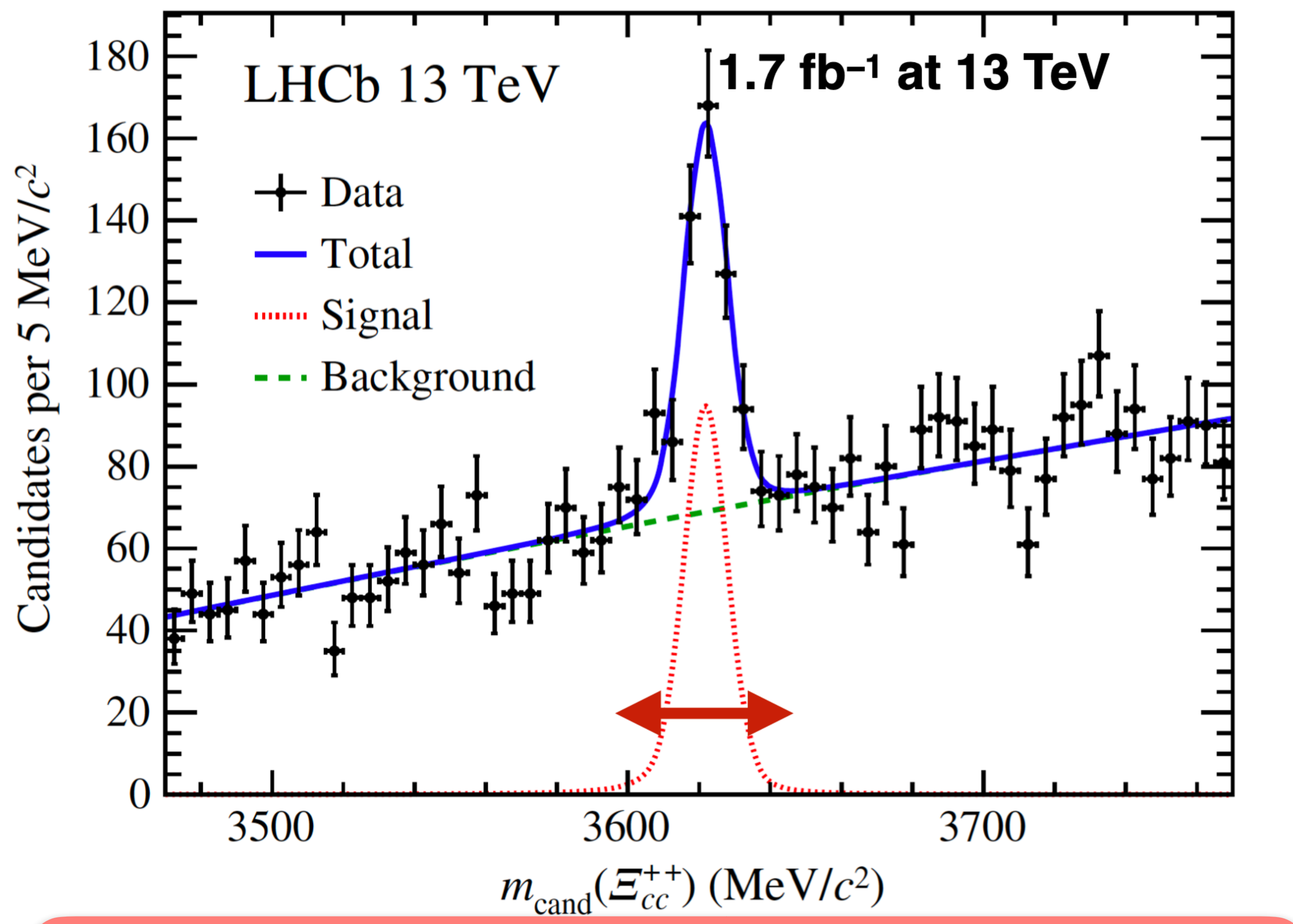


ALI-PREL-344791

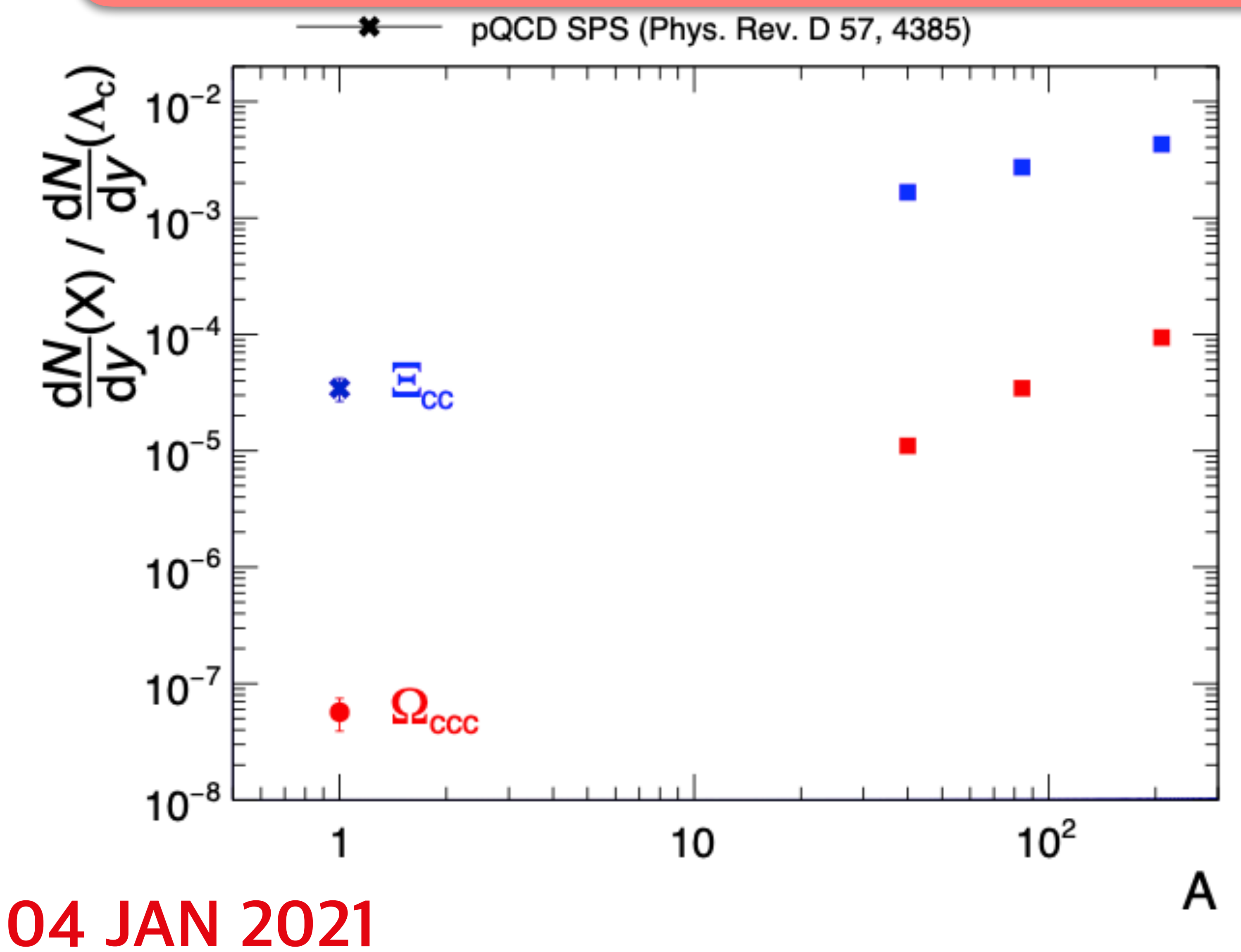


ALI-PREL-344799

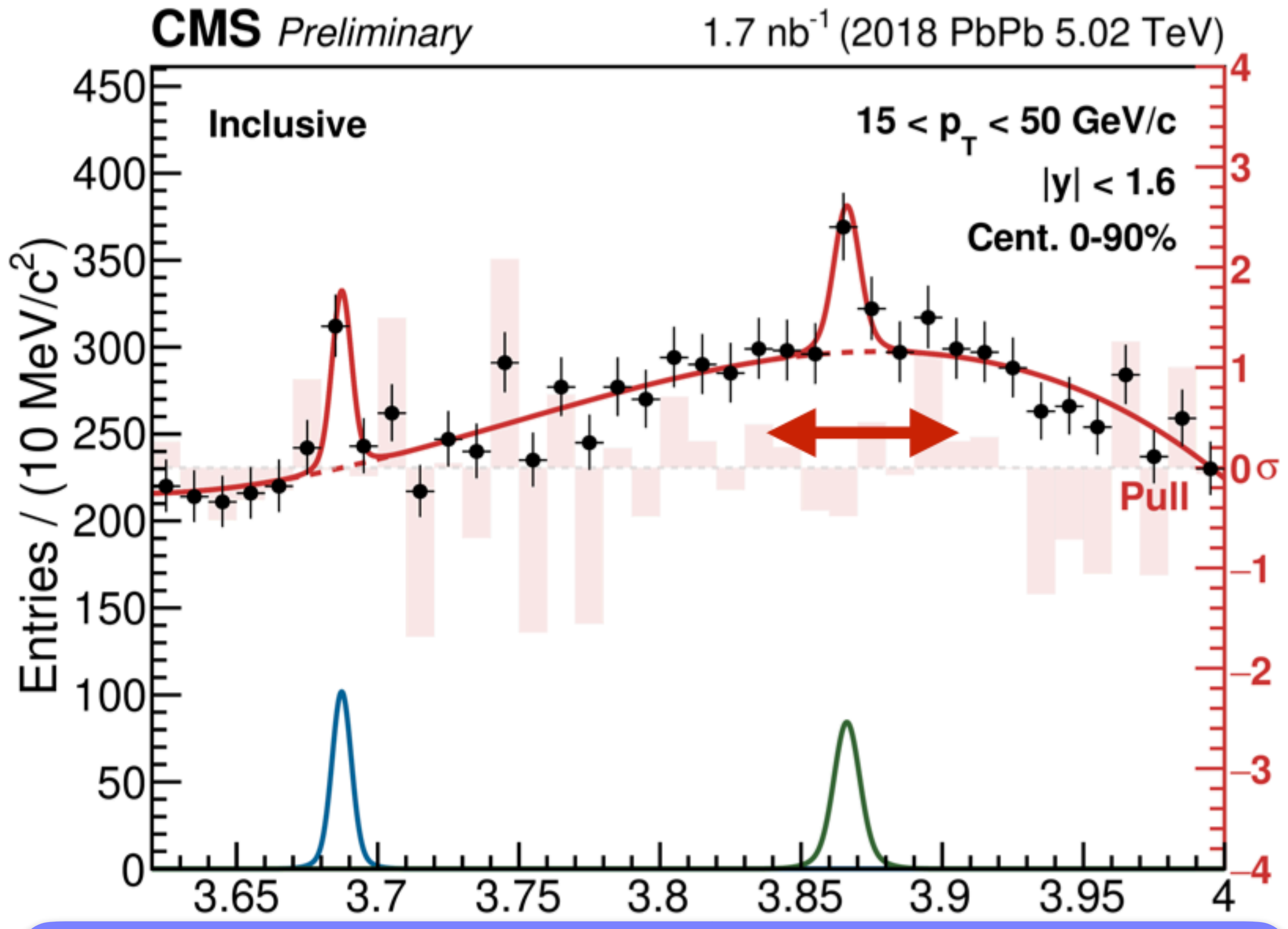
ALICE 3 Physics needs



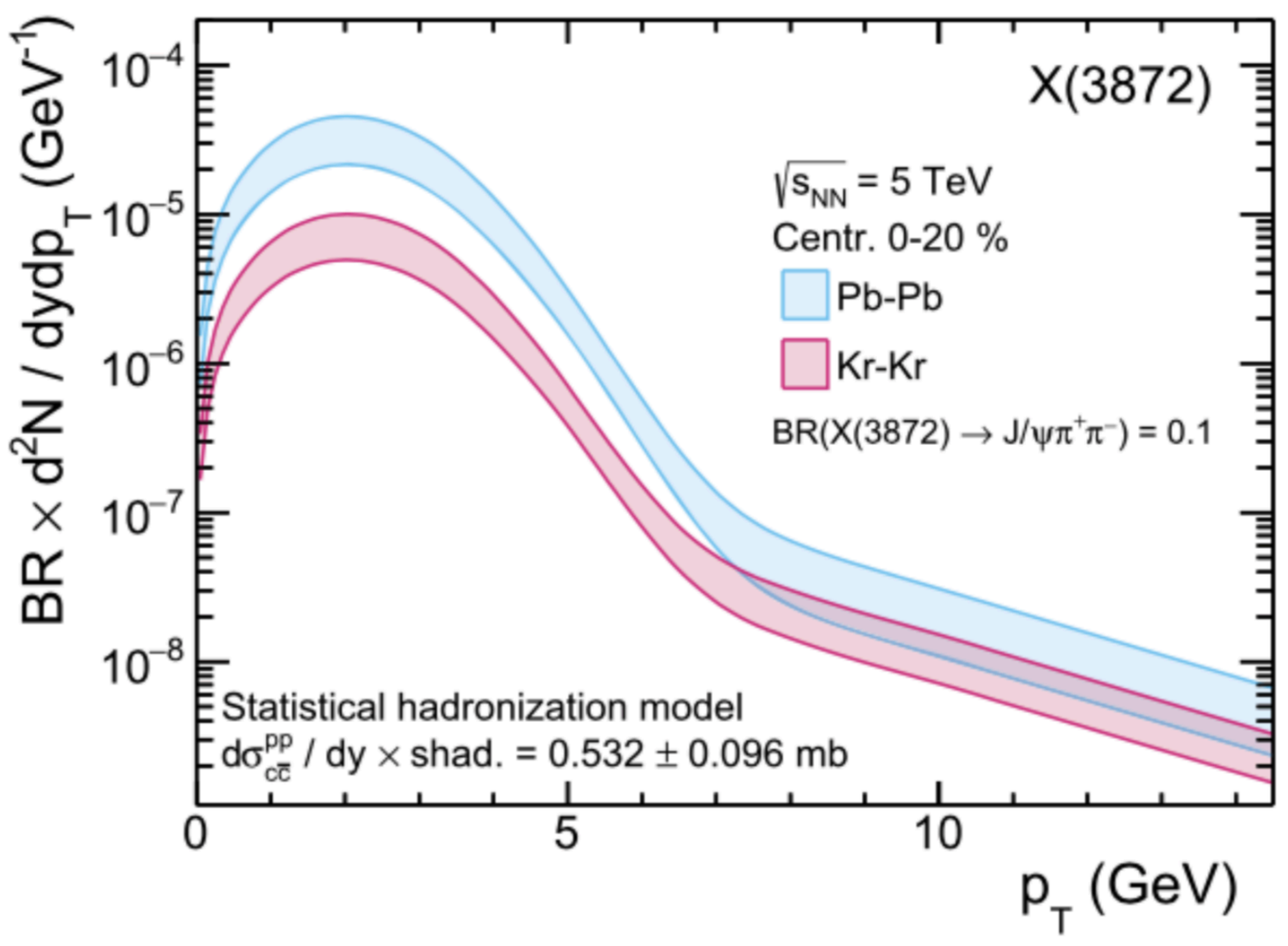
Multi-charm baryons



- **Luminosity**
  - In pp collisions : O(10-100) fb^{-1}
  - In AA collision : O(10) fb^{-1}
- **Tracking/Vertexing**
  - Primary/secondary vertex resolution and d_0 : O (1) μm
  - p_T reach down to ~ 100 MeV
    - **Both $\sigma(p_T)$ and $\sigma(d_0)$ matters!**
  - J/ψ reconstruction down to 0 GeV
    - **$\sigma(p_T)$ is probably critical here!**
- **Particle Identification**
  - **Hadron PID : p ~ 0.1 to 2-3 GeV/*c***
  - **Lepton PID : p ~ 0.7-1 to 5-10 GeV/*c***

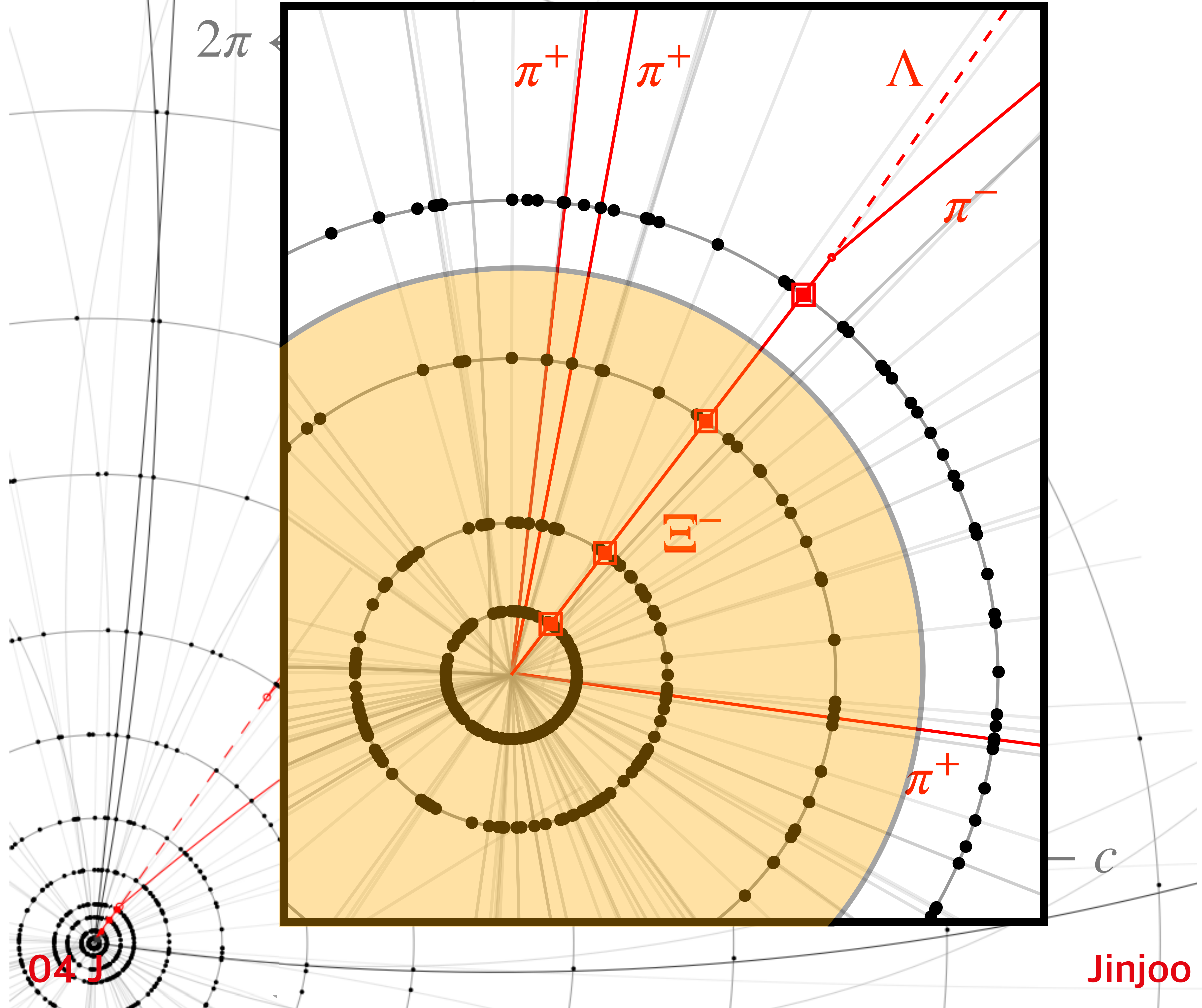


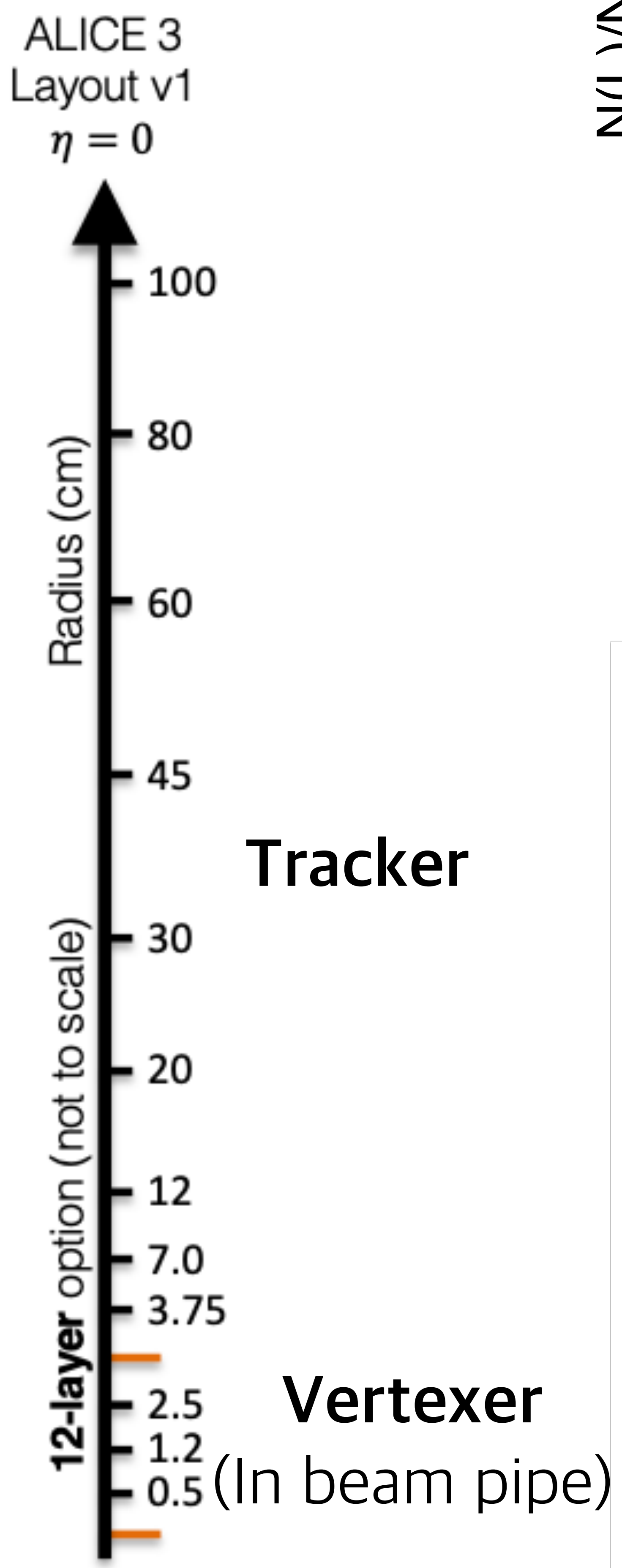
Quarkonia and exotica

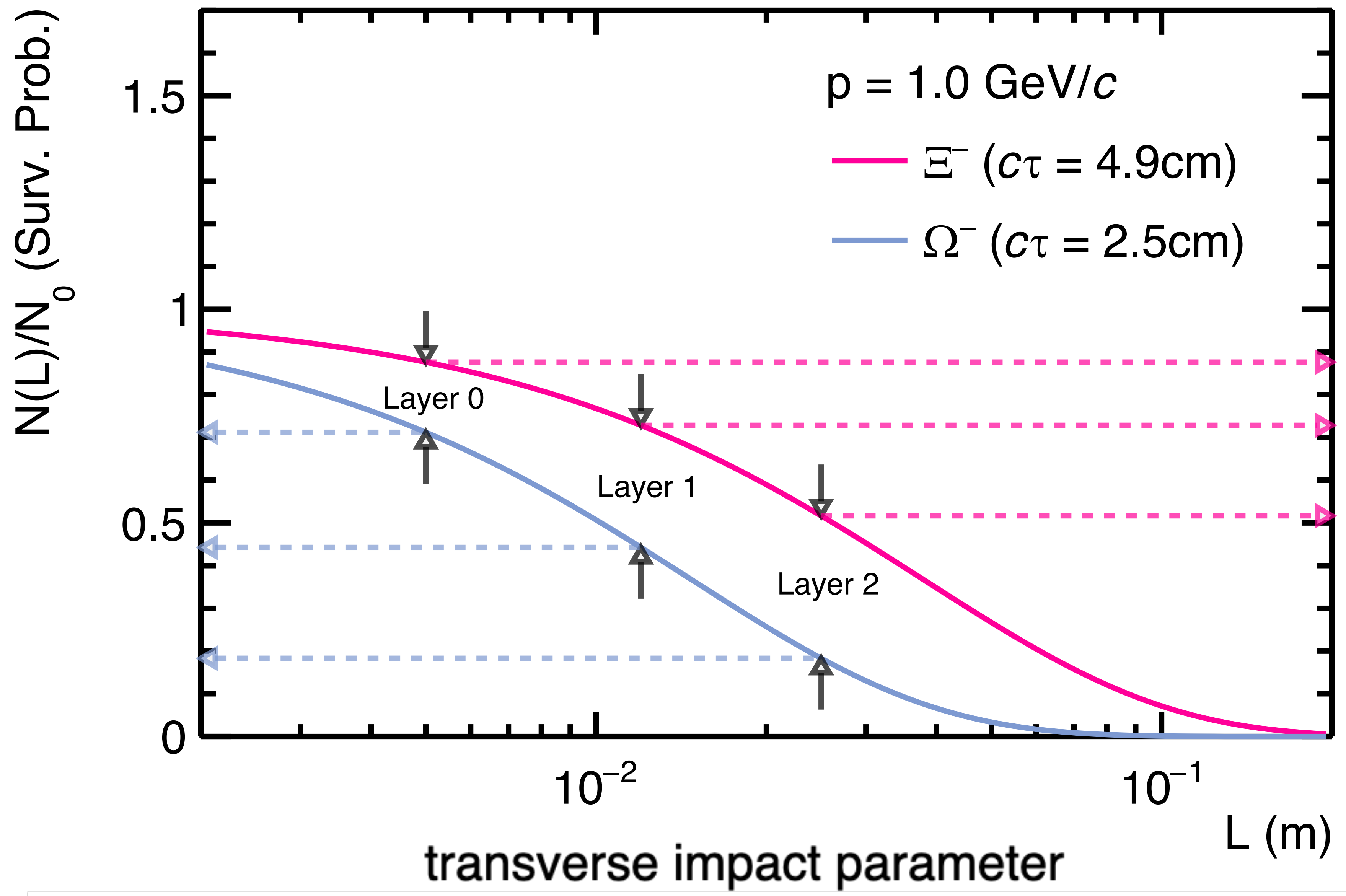


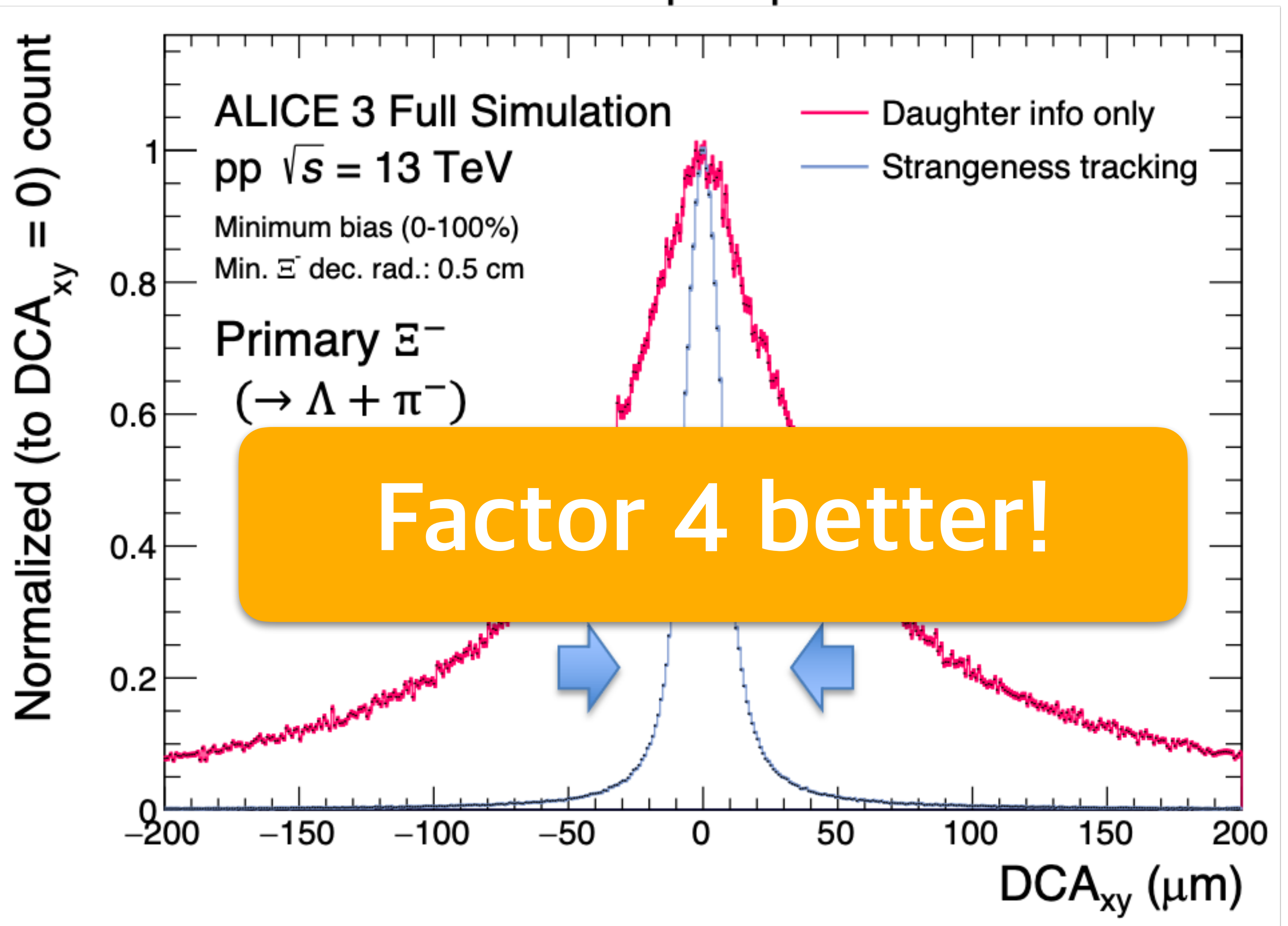
Multi-Charm baryon

- **Performance study : strangeness-tracking**
  - $\Xi_{cc}^{++} \rightarrow \Xi_c^{+}\pi^{+} \rightarrow (\Xi^{-}\pi^{+}\pi^{+})\pi^{+}$ and $\Omega_{cc}^{+} \rightarrow \Omega_c^{0}\pi^{+} \rightarrow (\Omega^{-}\pi^{+})\pi^{+}$









ML Preselection & Training variable

- **Pre-selection and Training variable**
  - Very loose cuts
    - |nSigmaTOF| < 3 & |nSigmaTOFCombined| < 5 are already applied to reduce the tree output size
      - NOT considered nSigmaTOF and nSigmaTOFCombined as training variable -> will be added

Preselection

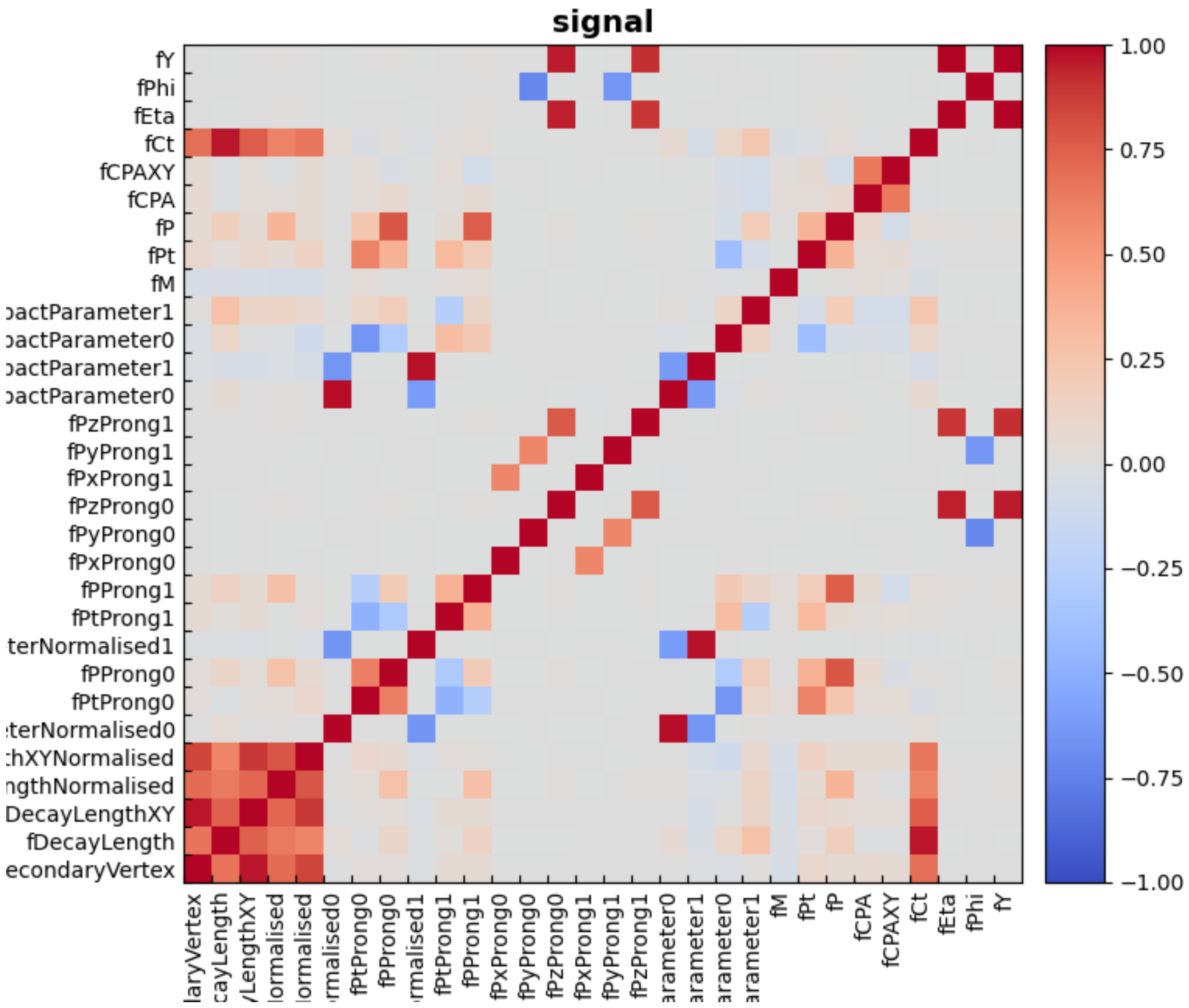
```
#loose preslection
preselection = [
        '-1.44 < fY < 1.44',
        '0.00 < fDecayLength < 10',
        '-10 < fImpactParameter0 < 10',
        '-10 < fImpactParameter1 < 10',
        '0.5 < fPtProng0 < 20',
        '1 < fPtProng1 < 20',
        '0.90 < fCPA < 1',
        '0.90 < fCPAXY < 1',
        '3.4 < fM < 3.8',
        '0 < fPt < 16'
]
```

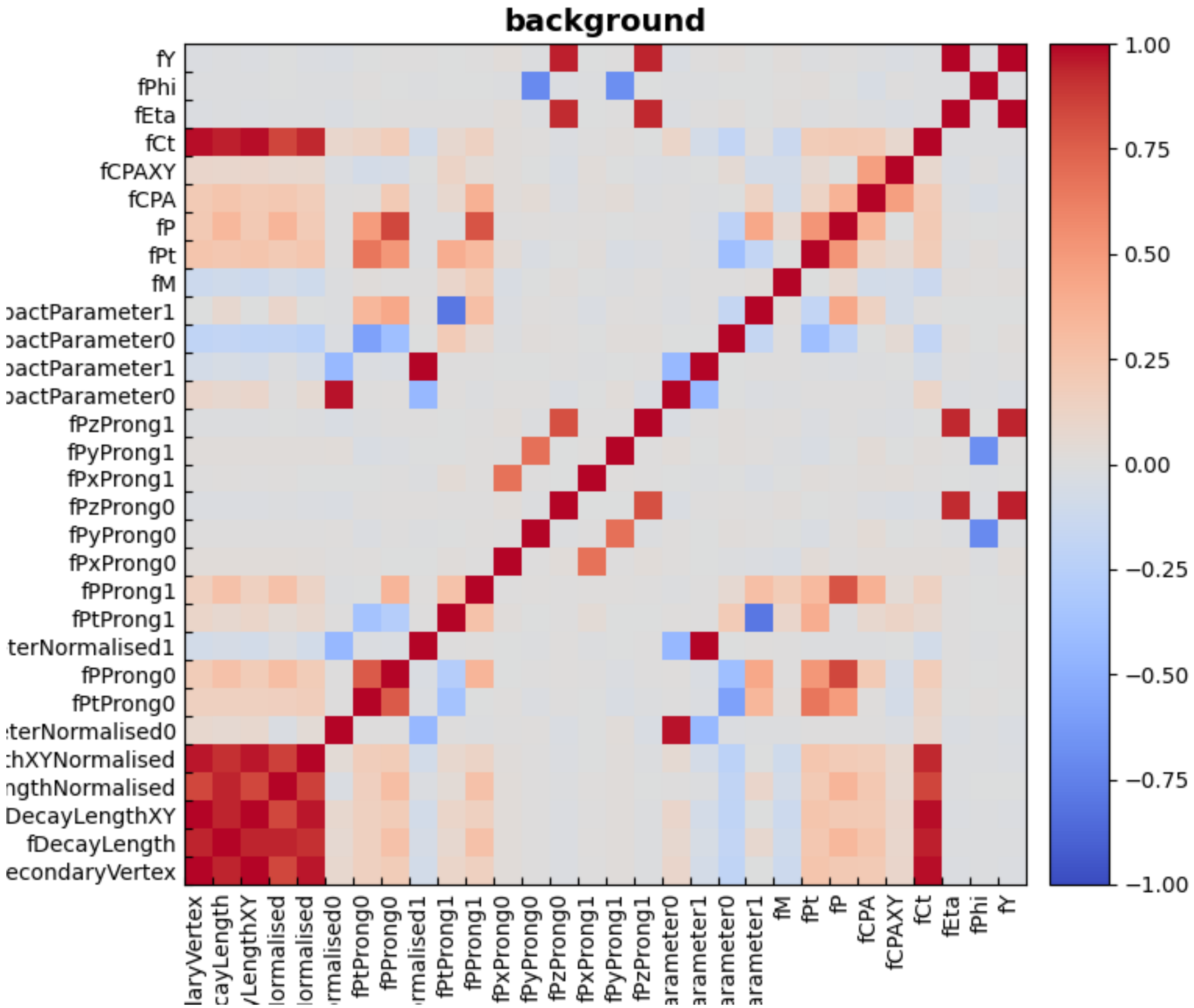
Training variable

```
("fDecayLength", &fDecayLength);
("fDecayLengthXY", &fDecayLengthXY);
("fDecayLengthNormalised", &fDecayLengthNormalised);
("fDecayLengthXYNormalised", &fDecayLengthXYNormalised);
("fImpactParameterNormalised0", &fImpactParameterNormalised0);
("fPtProng0", &fPtProng0);
("fPProng0", &fPProng0);
("fImpactParameterNormalised1", &fImpactParameterNormalised1);
("fPtProng1", &fPtProng1);
("fPProng1", &fPProng1);
("fImpactParameter0", &fImpactParameter0);
("fImpactParameter1", &fImpactParameter1);
("fErrorImpactParameter0", &fErrorImpactParameter0);
("fErrorImpactParameter1", &fErrorImpactParameter1);
("fCPA", &fCPA);
("fCPAXY", &fCPAXY);
```

Signal vs Background

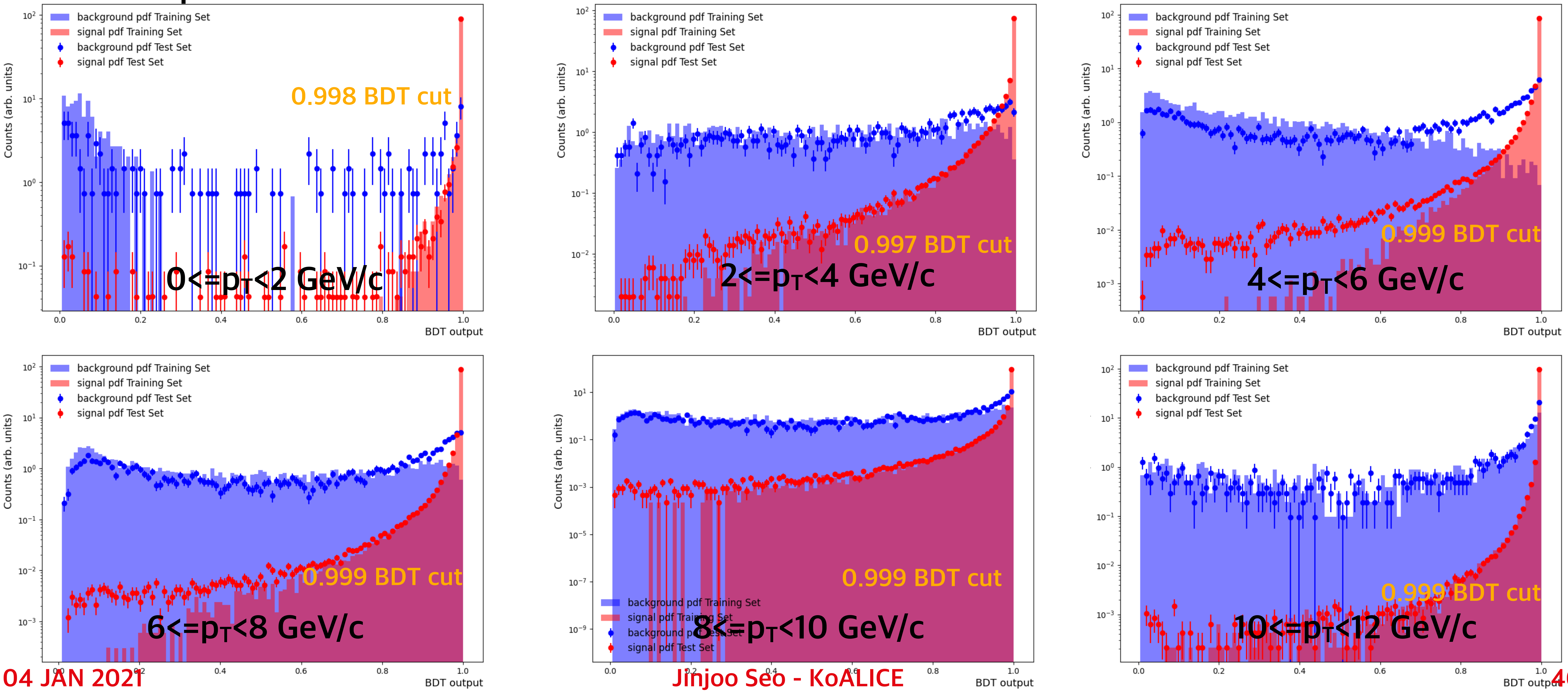
- **Signal vs background distribution** $(2 \leq p_{\mathrm{T}} < 4\,\mathrm{GeV}/c)$





BDT model output

- **Model output**



ROC curve

- **ROC curve**

Multi-HF hadron

	B.R.
$\Xi_{cc}^{++} \rightarrow \Lambda_c^+ + K^- + \pi^+ + \pi^-$	5%
$\Lambda_c^+ \rightarrow p + K^- + \pi^+$	6.35%
	0.32%

	B.R.
$\Xi_{cc}^{++} \rightarrow \Xi_c^+ + \pi^+$	5%
$\Xi_c^+ \rightarrow p + K^- + \pi^+$	2.2 ± 0.8% [1]
	0.11%

Ξ_{cc} decays: BR from 1703.09086 (authors claim ~1% < BR < ~10%)

	B.R.
$\Omega_{ccc}^{++} \rightarrow \Xi_{cc}^{++} + \overline{K}^0$	5% x 0.5
$\Xi_{cc}^{++} \rightarrow \Lambda_c^+ + K^- + \pi^+ + \pi^-$	5%
$\Lambda_c^+ \rightarrow p + K^- + \pi^+$	6.35%
$\overline{K}^0 : 50\,\%\, K_s^0 \rightarrow \pi^+ + \pi^-$	70%
	0.0055%

	B.R.
$\Omega_{ccc}^{++} \rightarrow \Xi_{cc}^{++} + \overline{K}^0$	5% x 0.5
$\Xi_{cc}^{++} \rightarrow \Xi_c^+ + \pi^+$	5%
$\Xi_c^+ \rightarrow p + K^- + \pi^+$	2.2 ± 0.8% [1]
$\overline{K}^0 : 50\,\%\, K_s^0 \rightarrow \pi^+ + \pi^-$	70%
	0.0019%

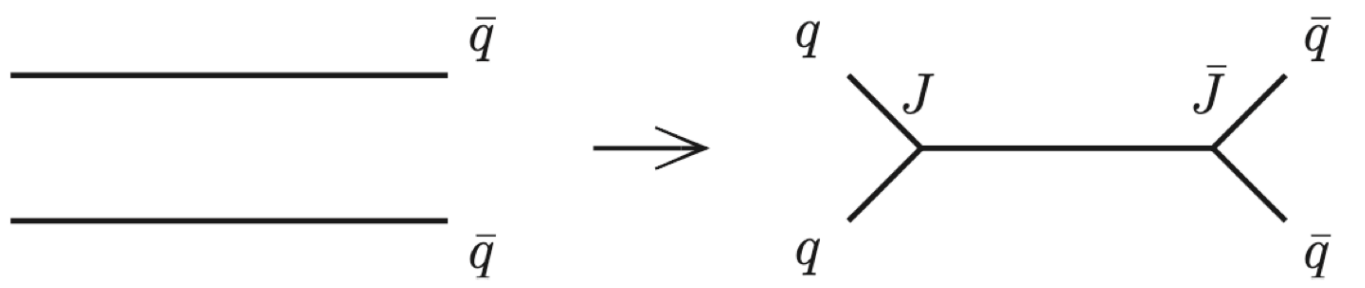
	B.R.
$\Omega_{ccc}^{++} \rightarrow \Xi_c^+ + \mathrm{D}^+$	5%
$\Xi_c^+ \rightarrow p + K^- + \pi^+$	2.2 ± 0.8% [1]
$\mathrm{D}^+ \rightarrow K^- + \pi^+ + \pi^-$	9%
	0.0099%

	B.R.
$\Omega_{ccc}^{++} \rightarrow \Omega_{cc}^+ + \pi^+$	5%
$\Omega_{cc}^+ \rightarrow \Omega_c^0 + \pi^+$	5%
$\Omega_c^0 \rightarrow \Omega^- + \pi^+$	5%
$\Omega^- \rightarrow \Lambda + K^-$	67.8%
$\Lambda \rightarrow p + \pi^-$	63.9%
	0.0054%

[1]Belle, B.R. = 0.45 ± 0.22%, PRD 100 (2019) 031101

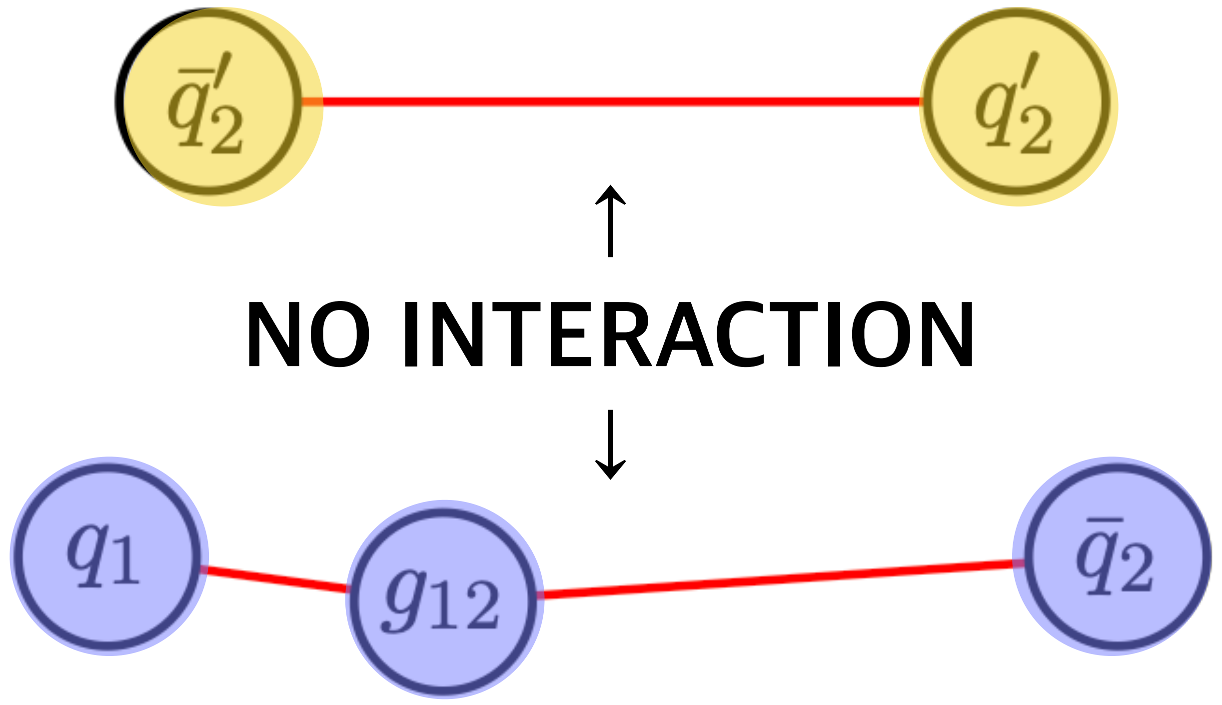
HF baryon enhance mechanism

- **PYTHIA 8 with Colour Reconnection (CR) tunes** JHEP 08 (2015) 003
  - Colour reconnection mode with QCD SU(3) algebra + string-length minimization
  - Junction connection topologies enhance baryon formation
  - Mode parameters : string reconnection, connection causality of dipoles, time dilation



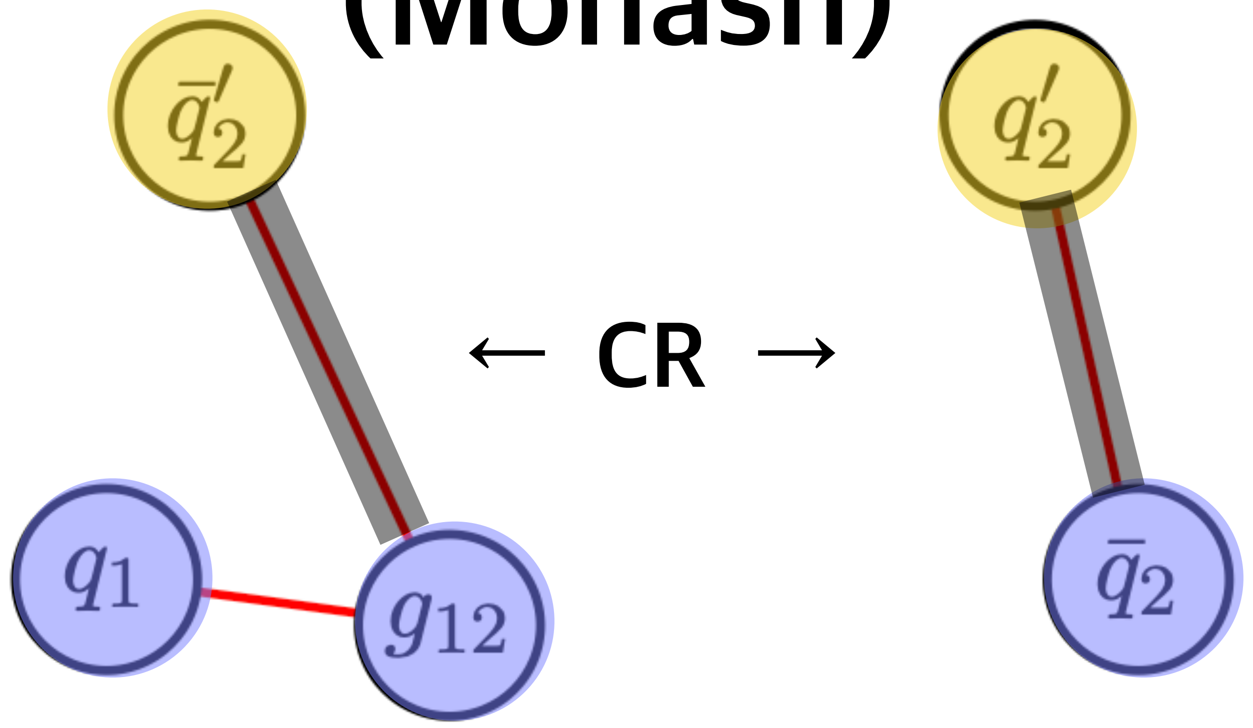
(b) Type II: junction-style reconnection

No CR



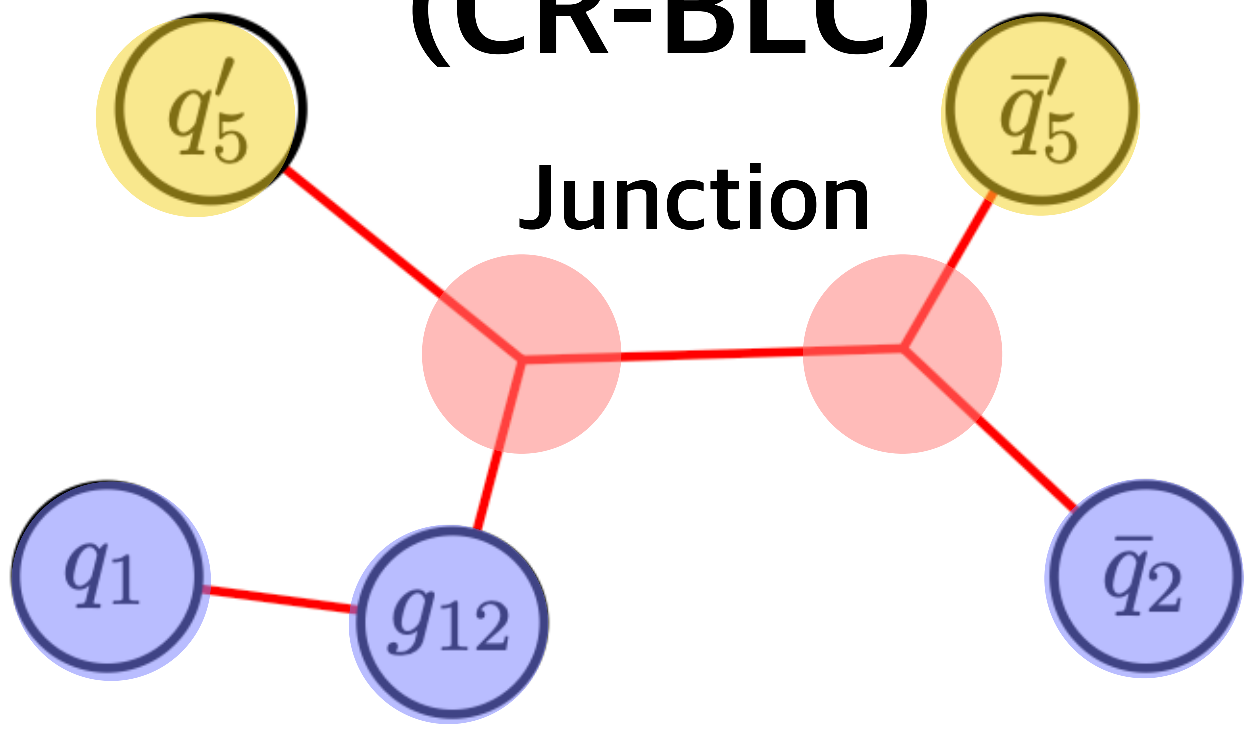
- Partons created in different MPIs do not interact each other

Old CR (Monash)



- CR allowed between partons from different MPIs to minimize the string length
- Used in Monash tune

New CR (CR-BLC)



- Minimization of string length over all possible configurations
- Enhancement of hadrons
- Used in CR mode X tunes

HF baryon enhance mechanism

- **PYTHIA 8 with Colour Reconnection (CR) tunes** JHEP 08 (2015) 003
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- **Statistical Hadronisation Model (SHM) + additional baryon states** PLB 795 (2019) 117-121
  - **PDG :** 5 Λ_c (I=0), 3 Σ_c (I=1), 8 Ξ_c (I=1/2), 2 Ω_c (I=0)
  - **RQM (Relativistic Quark Model) :** Add 18 Λ_c, 42 Σ_c, 62 Ξ_c, 34 Ω_c PRD 84 (2011) 014025

n_i $(\cdot 10^{-4}$ fm$^{-3})$	D^0	D^+	D^{*+}	D_s^+	Λ_c^+	$\Xi_c^{+,0}$	Ω_c^0
PDG(170)	1.161	0.5098	0.5010	0.3165	0.3310	0.0874	0.0064
PDG(160)	0.4996	0.2223	0.2113	0.1311	0.1201	0.0304	0.0021
RQM(170)	1.161	0.5098	0.5010	0.3165	0.6613	0.1173	0.0144
RQM(160)	0.4996	0.2223	0.2113	0.1311	0.2203	0.0391	0.0044

HF baryon enhance mechanism

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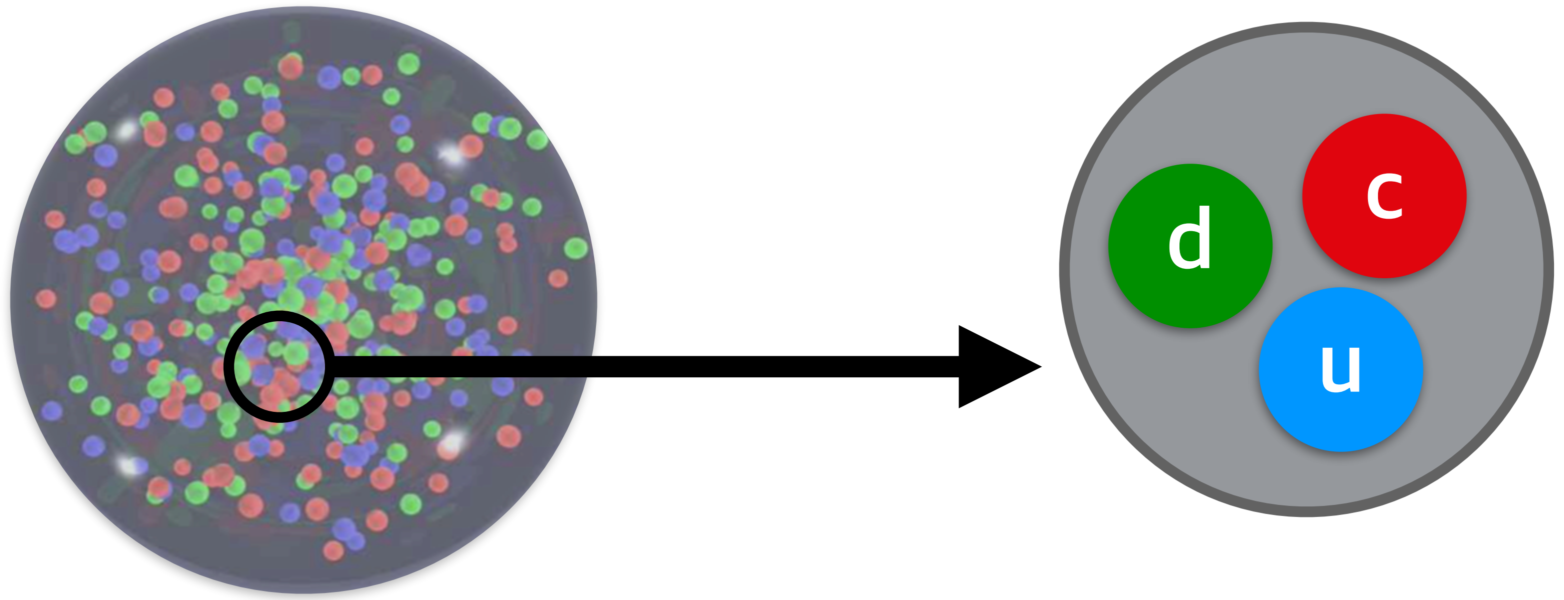
- **Quark Recombination Mechanism (QCM)** EPJC 78 no.4, (2018) 344
  - Combination of charm quarks with co-moving light quarks



HF baryon enhance mechanism

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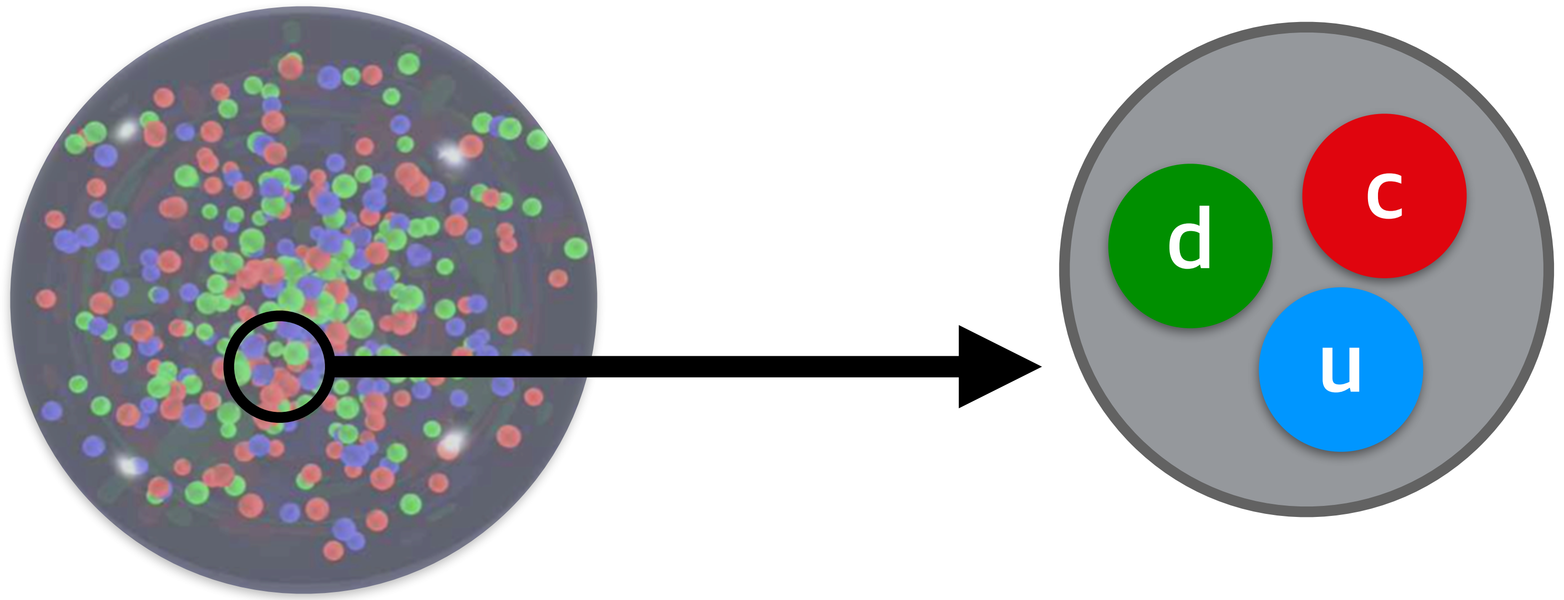

- **Catania model** arXiv:2012.12001
  - Coalescence process of heavy quarks with light quark based on the Wigner formalism + fragmentation process
  - Blast wave parametrization for light quarks spectra, FONLL calculation for heavy quarks spectra

PYTHIA

Parameter	Monash	Mode 0	Mode 2	Mode 3
StringPT:sigma	= 0.335	= 0.335	= 0.335	= 0.335
StringZ:aLund	= 0.68	= 0.36	= 0.36	= 0.36
StringZ:bLund	= 0.98	= 0.56	= 0.56	= 0.56
StringFlav:probQQtoQ	= 0.081	= 0.078	= 0.078	= 0.078
StringFlav:ProbStoUD	= 0.217	= 0.2	= 0.2	= 0.2
StringFlav:probQQ1toQQ0join	= 0.5, 0.7, 0.9, 1.0	= 0.0275, 0.0275, 0.0275, 0.0275	= 0.0275, 0.0275, 0.0275, 0.0275	= 0.0275, 0.0275, 0.0275, 0.0275
MultiPartonInteractions:pT0Ref	= 2.28	= 2.12	= 2.15	= 2.05
BeamRemnants:remnantMode	= 0	= 1	= 1	= 1
BeamRemnants:saturation	-	= 5	= 5	= 5
ColourReconnection:mode	= 0	= 1	= 1	= 1
ColourReconnection:allowDoubleJunRem	= on	= off	= off	= off
ColourReconnection:m0	-	= 2.9	= 0.3	= 0.3
ColourReconnection:allowJunctions	-	= on	= on	= on
ColourReconnection:junctionCorrection	-	= 1.43	= 1.20	= 1.15
ColourReconnection:timeDilationMode	-	= 0	= 2	= 3
ColourReconnection:timeDilationPar	-	-	= 0.18	= 0.073

JHEP 08 (2015) 003, arXiv:1505.01681v1