

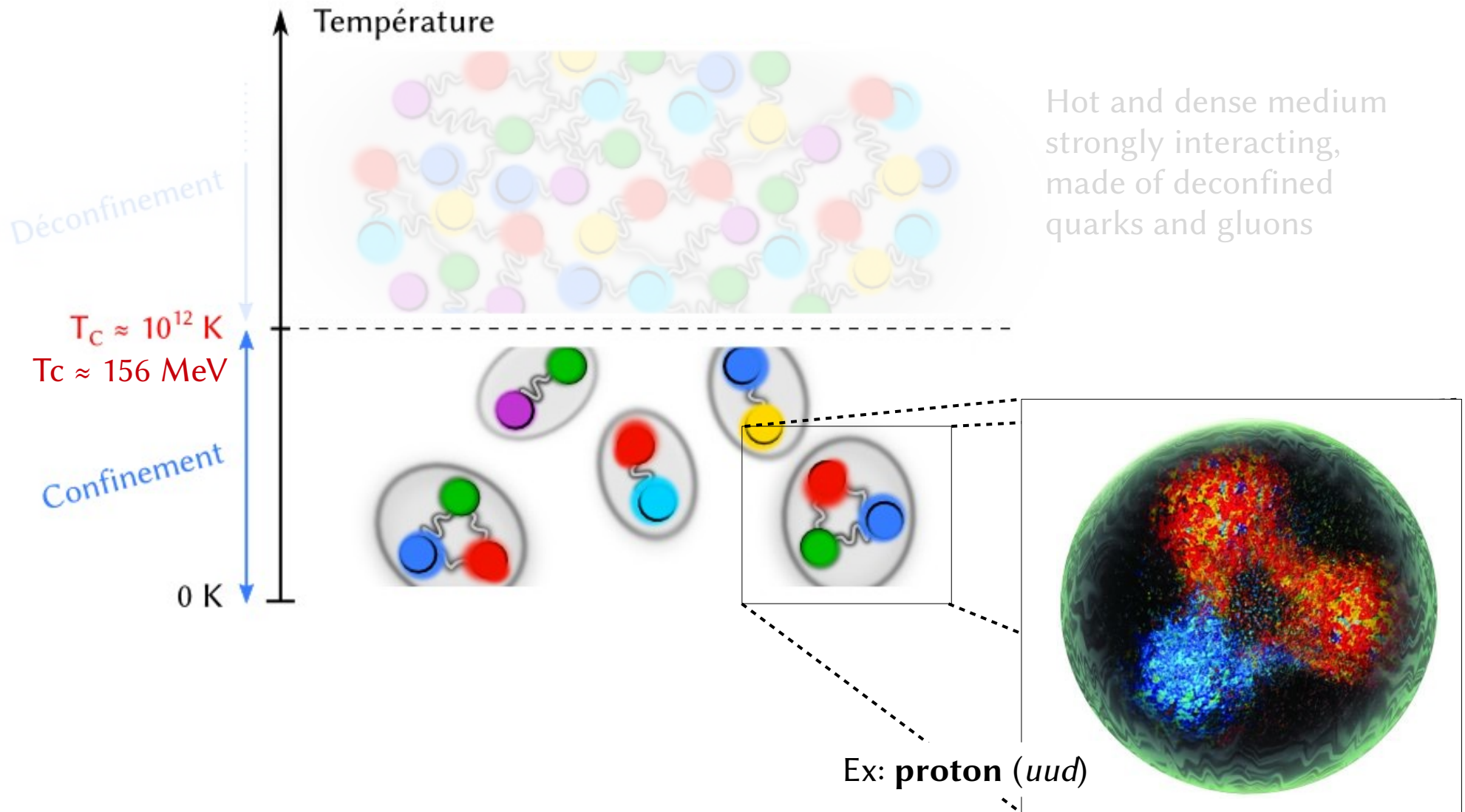
## ALICE group :

Strong interactions (QCD),  
Quark-Gluon Plasma,  
Strangeness, charm, beauty quarks

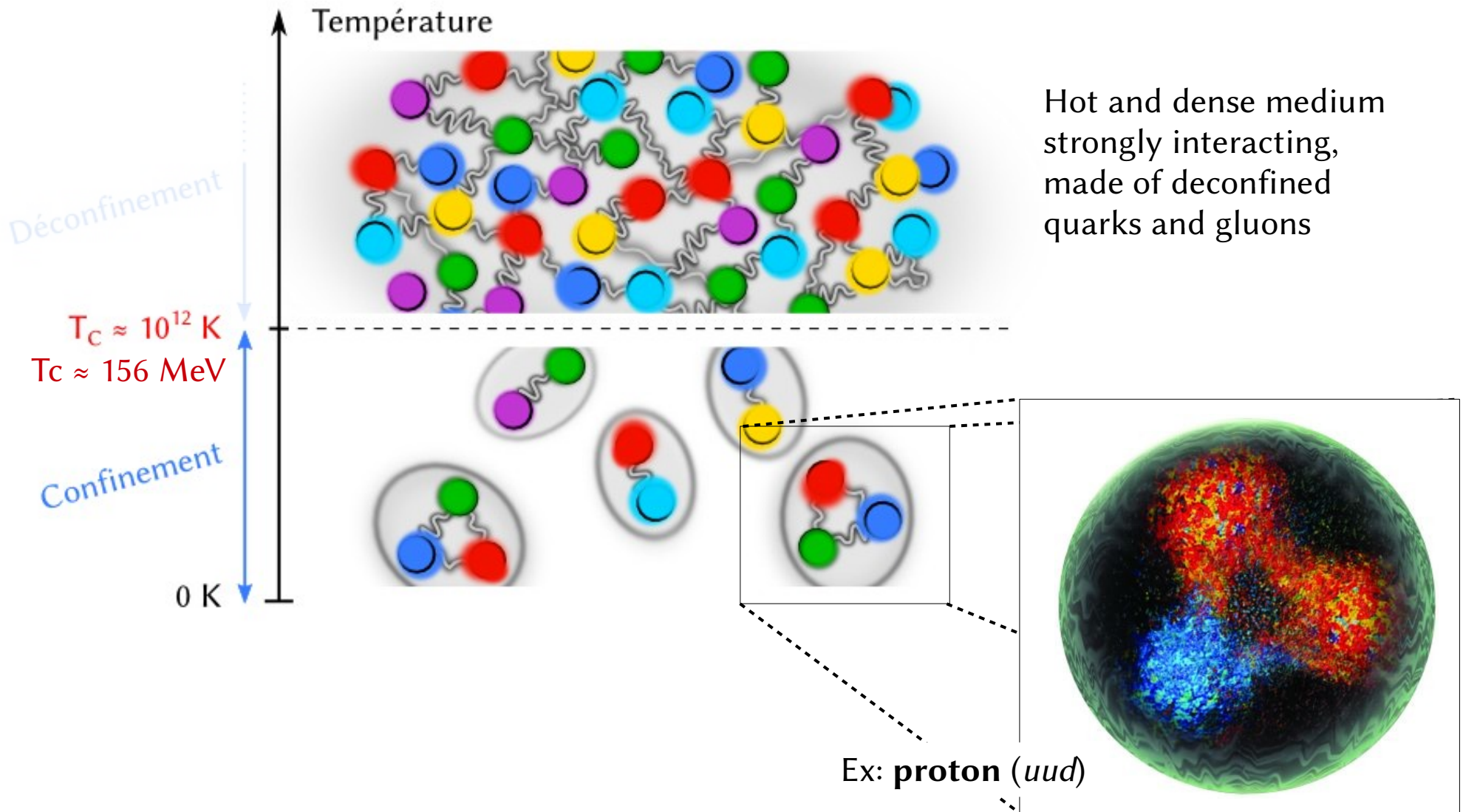
Pixel trackers,  
LHC pp, p-Pb, Pb-Pb



# I.1 – Introduction : QCD phase transition

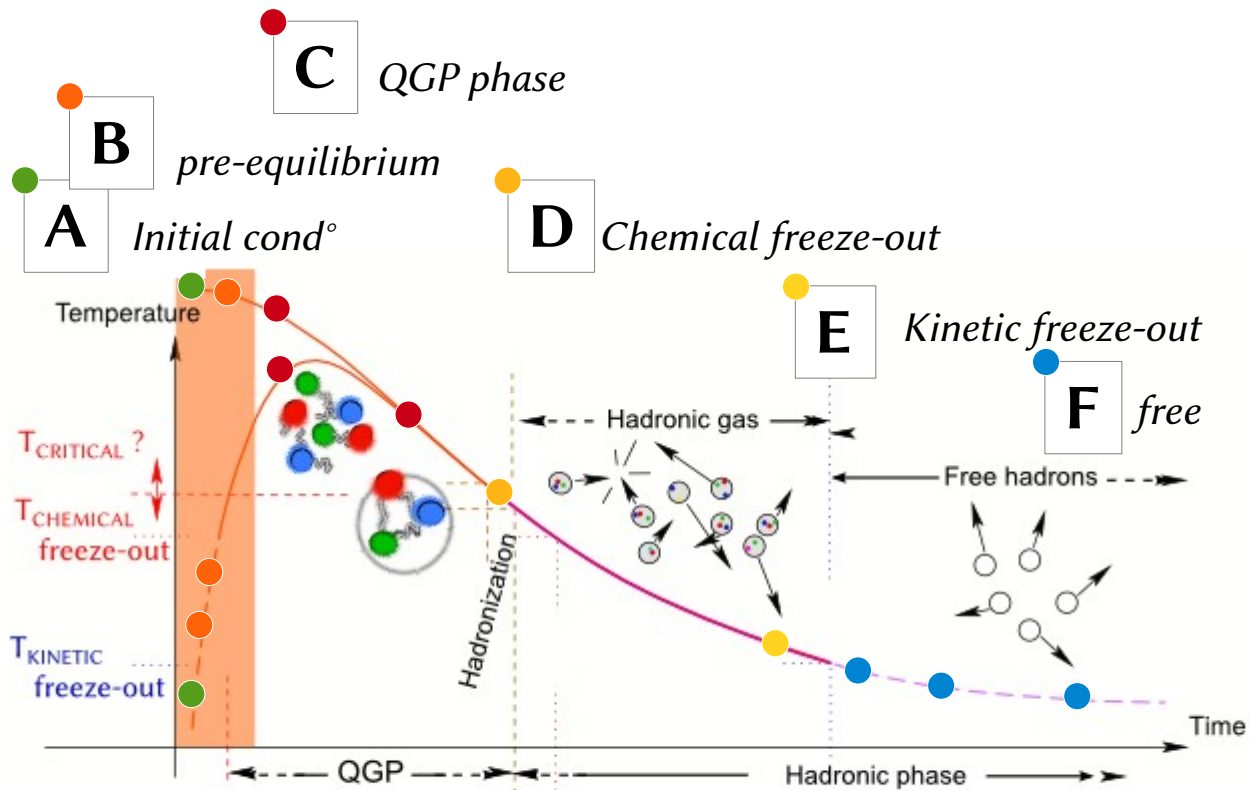
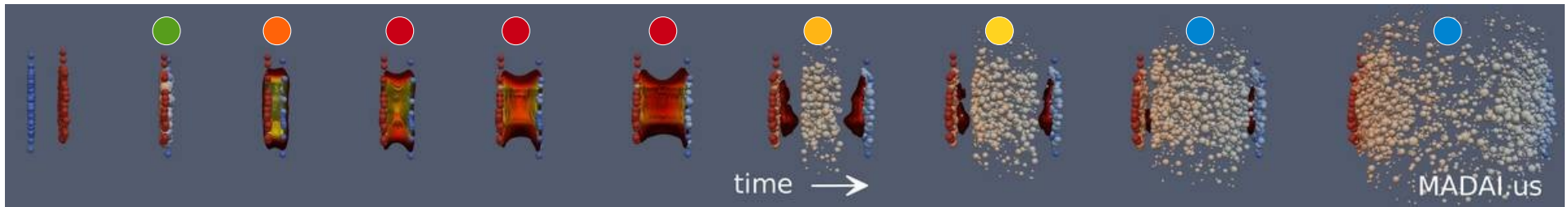


# I.1 – Introduction : QCD phase transition



# I.2 – Intro. : Bjorken scenario in heavy-ion collisions

Courtesy of [MADAI.us](http://MADAI.us) (see animation movie !)



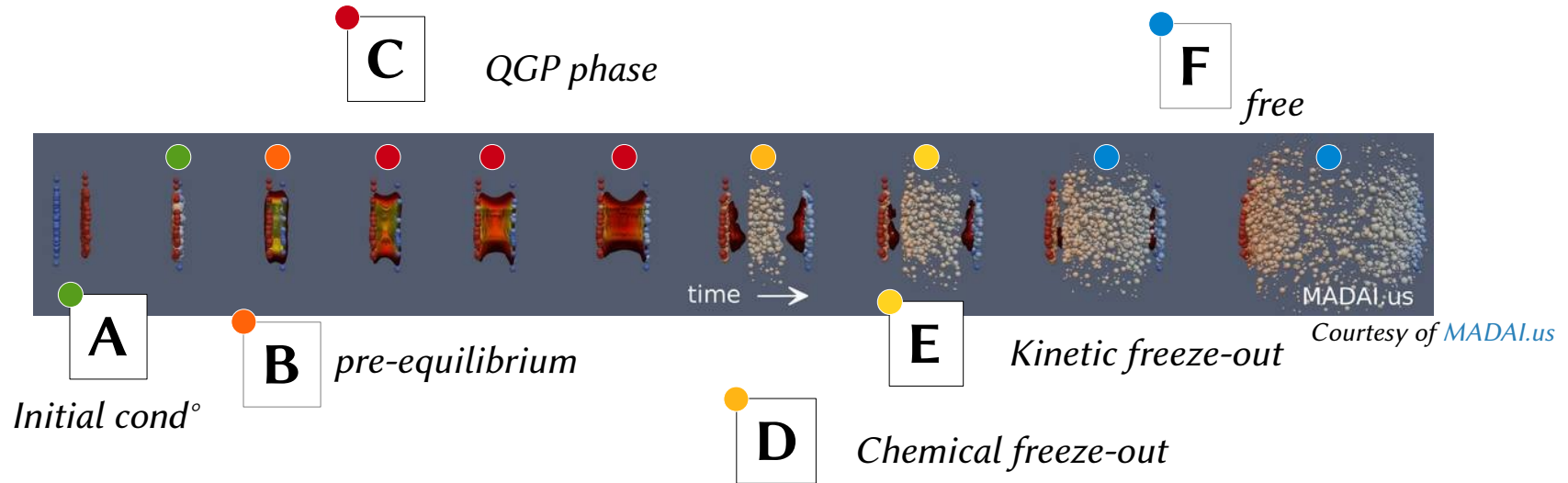
→ Remark :

No such thing as a live vision !  
but always, an observation based  
on remnants from  
the past ...

(NB : physics  $\sim 10^{-23}$  s  
/ electronic readout  $> 10^{-12}$  s)



# II.1 – $u, d, s, c, b$ : probes and flavours



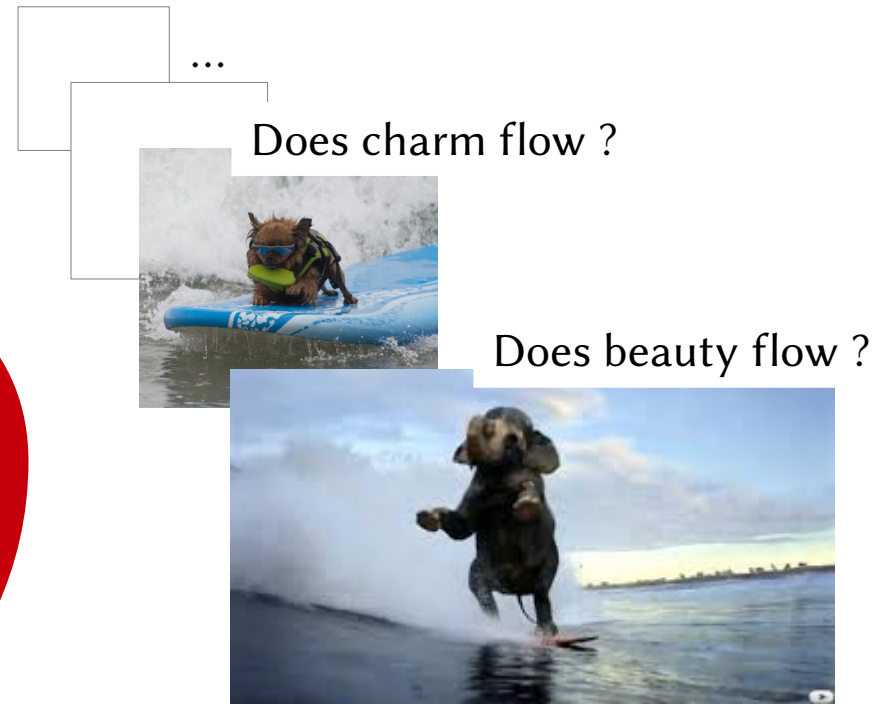
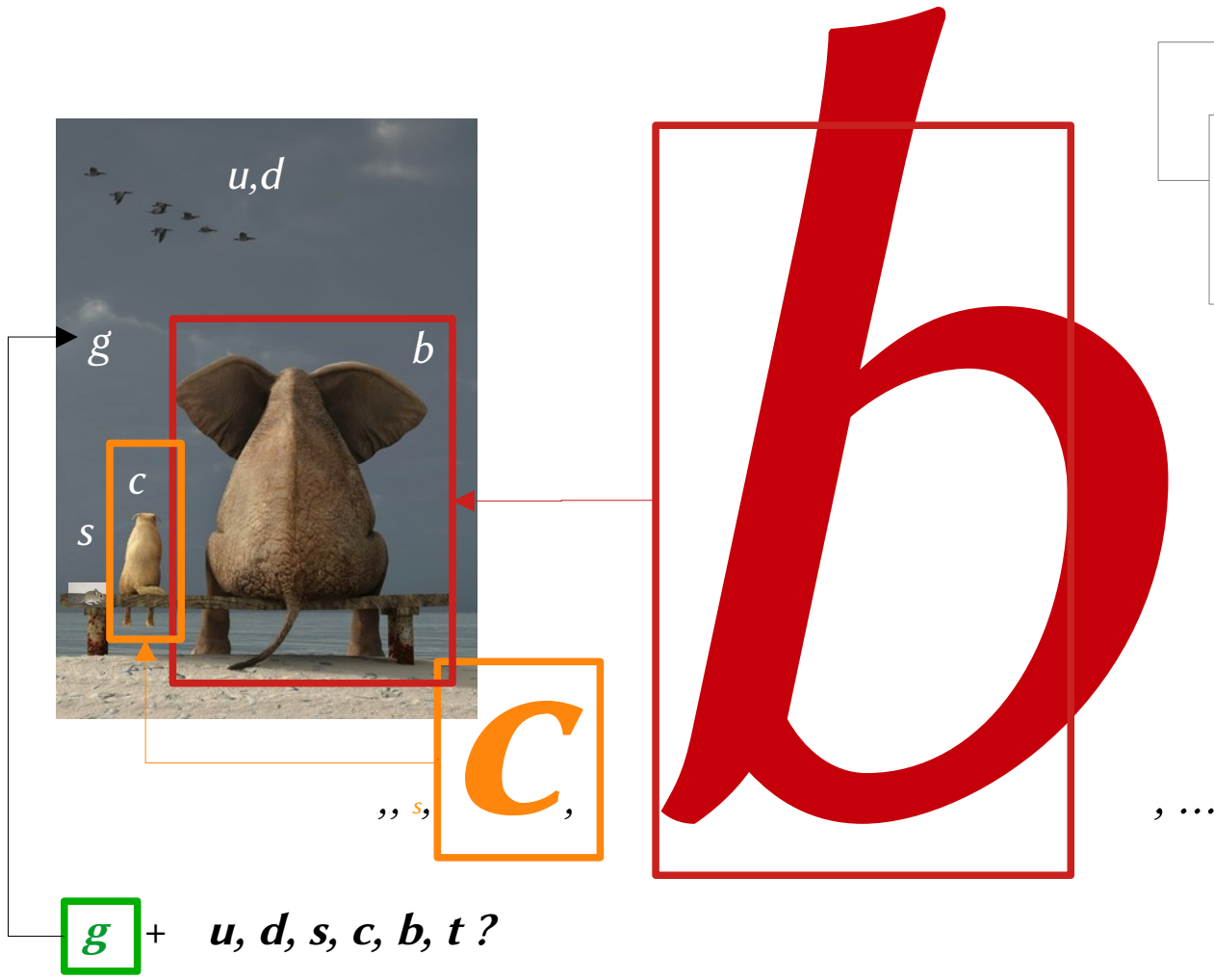
flavour physics :

$u, d, s, c, b (t) \Leftrightarrow$   $\pi^+ \pi^0 K^+ K_S^0 (d\bar{s}) \dots p \Lambda(uds) \Xi^-(dss) \Omega^-(sss) \dots \eta(547) \omega(782) K^0(892) \phi(1020)$   
 $\Sigma^\pm(1385) \Lambda(1520) \Xi^0(1530) d t \ ^3\text{He} \ ^4\text{He} \ ^3_\Lambda\text{H} \dots$   
 $(D^0 D^+ D^{*+} D_S^+) \dots J/\psi \chi_{c_i} \psi(2S) \dots \Lambda_C^+(udc), \Xi_C^+(usc), \Xi_C^0(dsc), \Omega_C^0(ssc) \dots$   
 heavy-flavour ( $\mu^\pm, e^\pm$ )  
 $B^0 B^\pm B_S^0 \Lambda_b^0 \dots Y(1S, 2S, 3S)$   
 $\gamma W^\pm Z$  + anti-particles

# II.2 – $u, d, s, c, b$ : example of hydrodynamics

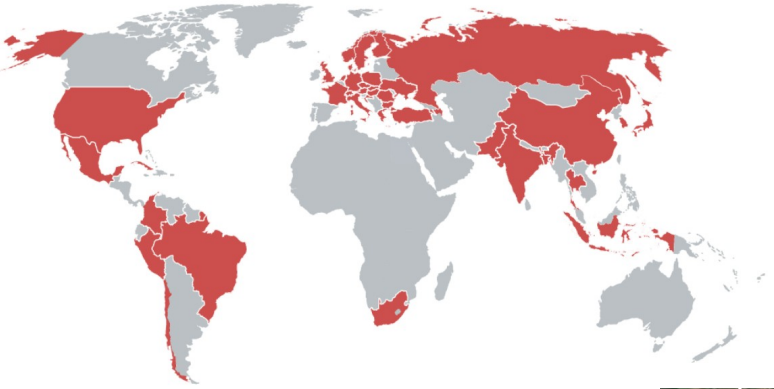
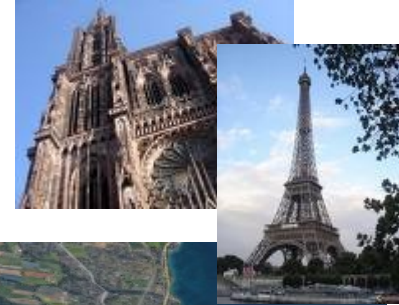


Courtesy of MADAI.us



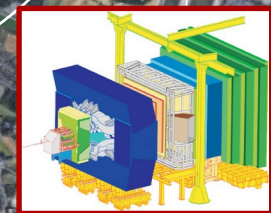
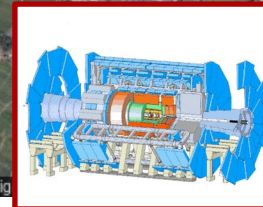
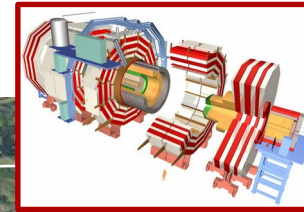
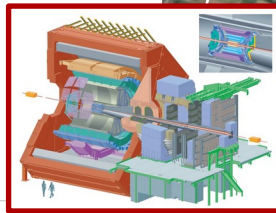
- LHC data :
- $c$  seem to flow with the tide !
  - not the case for  $b$ ...

# III.1 – ALICE : the experiment and the collaboration

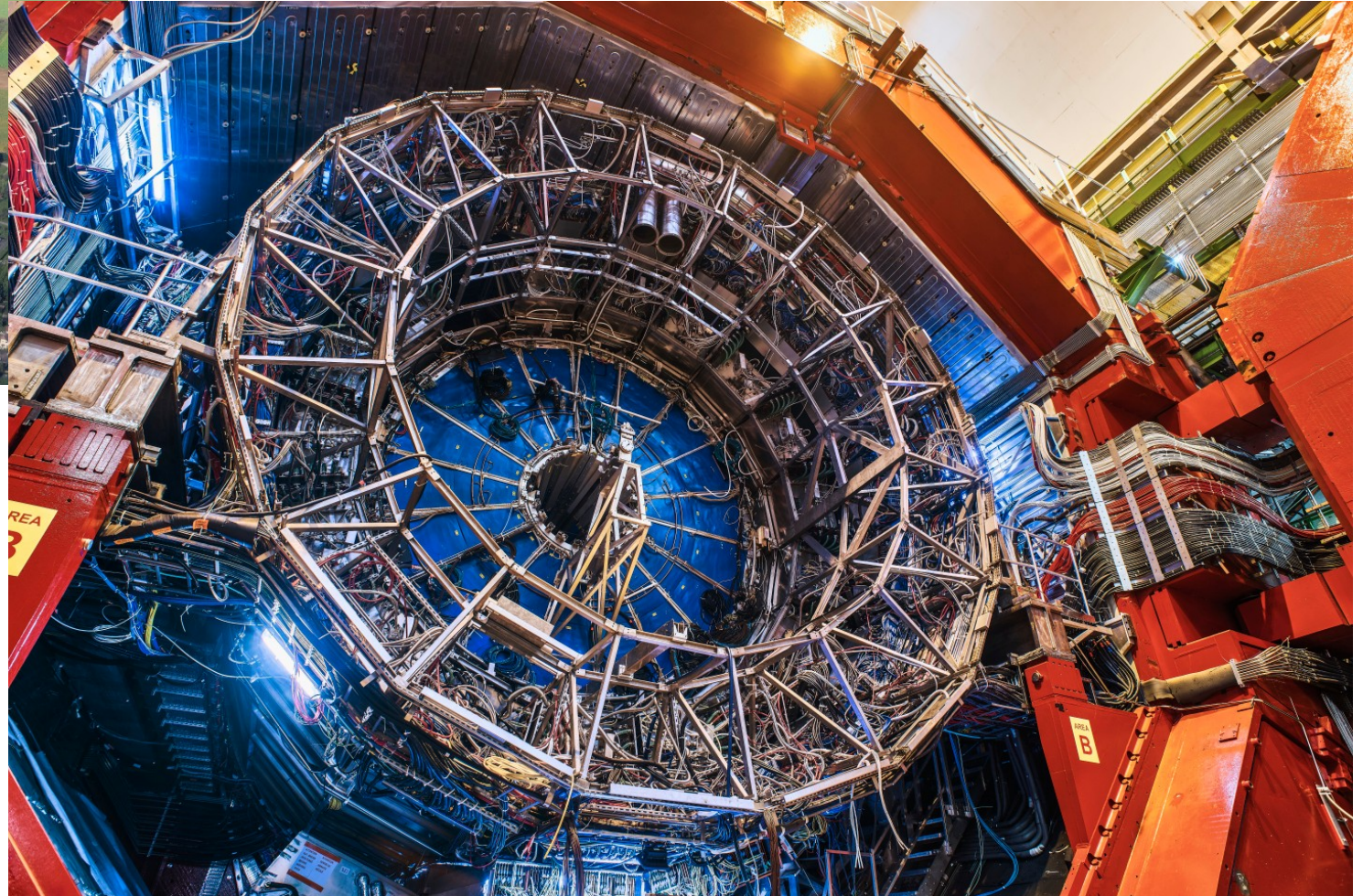
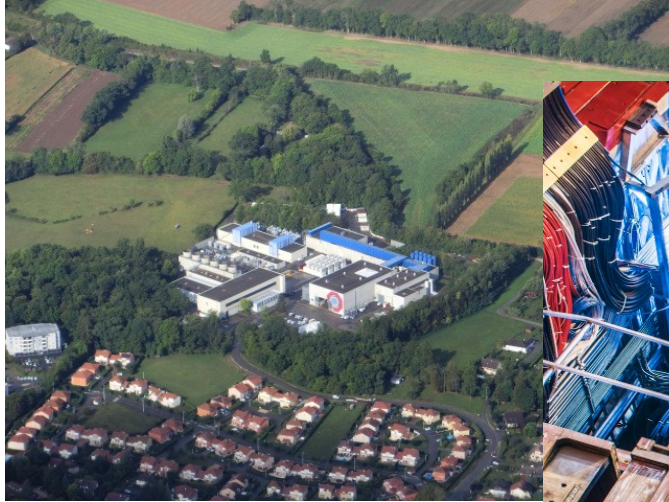


36 countries  
147 institutes  
 $\approx 2.8 \times 10^3$  members  
(1997-2023)  
 $\approx 1050$  authors  
(2023)

Dim :  $16 \times 16 \times 26 \text{ m}^3$   
Mass : 10 000 t  
Costs : 80 M€



## III.2 – ALICE : 15 sub-detectors



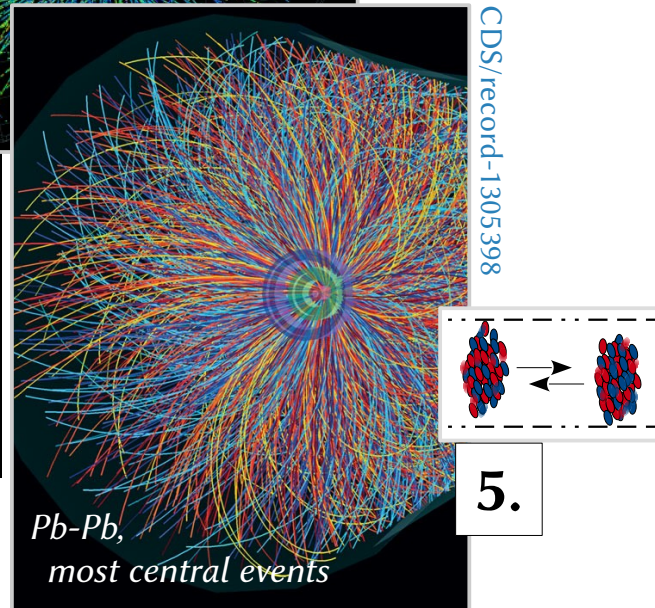
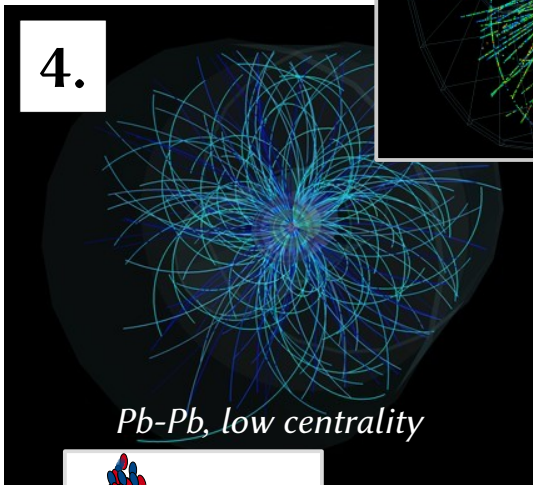
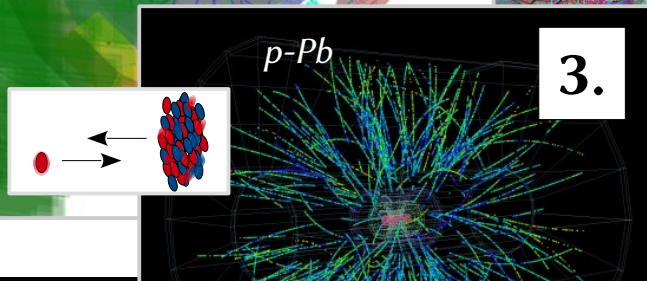
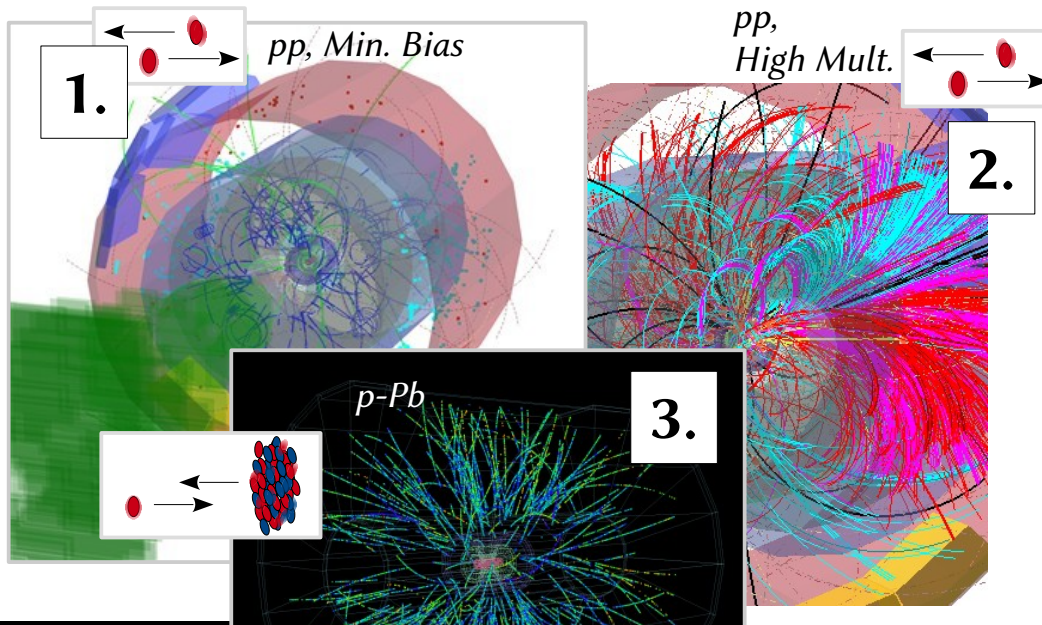
Here 2019-01, during Long Shutdown II, before LHC run III

<https://cds.cern.ch/record/2653650>.

<https://fr-fr.facebook.com/pg/ALICE.experiment/posts/>



# III.3 – ALICE : pp, pA, AA : continuum of physics ?



The starting plain question may be :  
at the same  $\sqrt{s_{NN}}$ ,

**“ 1 x (Pb-Pb)  $\neq$  n x (pp) ? ”**

Current stakes :

→ qualifying the binary answer

“ pp, p-Pb → no QGP. ”

“ Pb-Pb → QGP ! ”

# IV.1 – ALICE-IPHC : team (Nov. 2024)

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**Iouri BELIKOV (DR)**



**Boris HIPPOLYTE (Pr)**



**Marc IMHOFF (IR)**



**Christian KUHN (DR)**



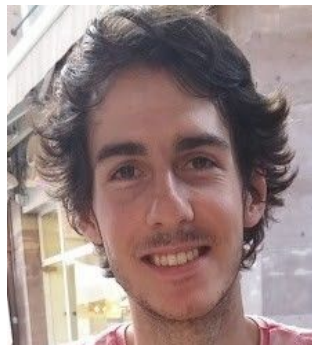
**Antonin MAIRE (CR)**



**Vamério di Bella (PhD Student)**



**(Serhiy  
SENYUKOV)  
(IR, PICSEL)**



**Alexandre BIGOT  
(PhD / ATER)**

# IV.2 – ALICE-IPHC : strange, charm, beauty, baryons

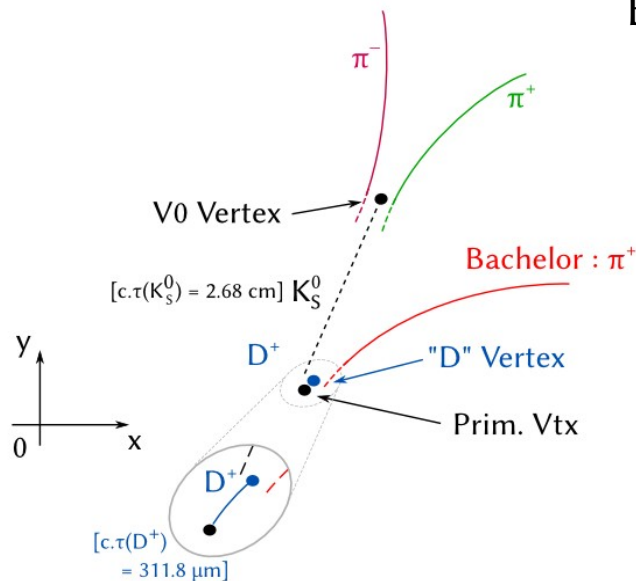
Local expertise : **topological hadronic reconstruction**

= unstable (rather) long-lived particles

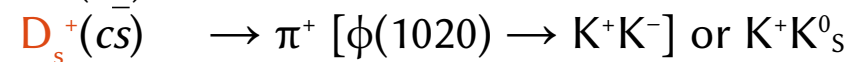
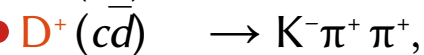
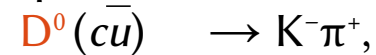
Strangeness :  $c\tau \approx \mathcal{O}(5 \text{ cm})$

Charm :  $c\tau \approx \mathcal{O}(10^2 \mu\text{m})$

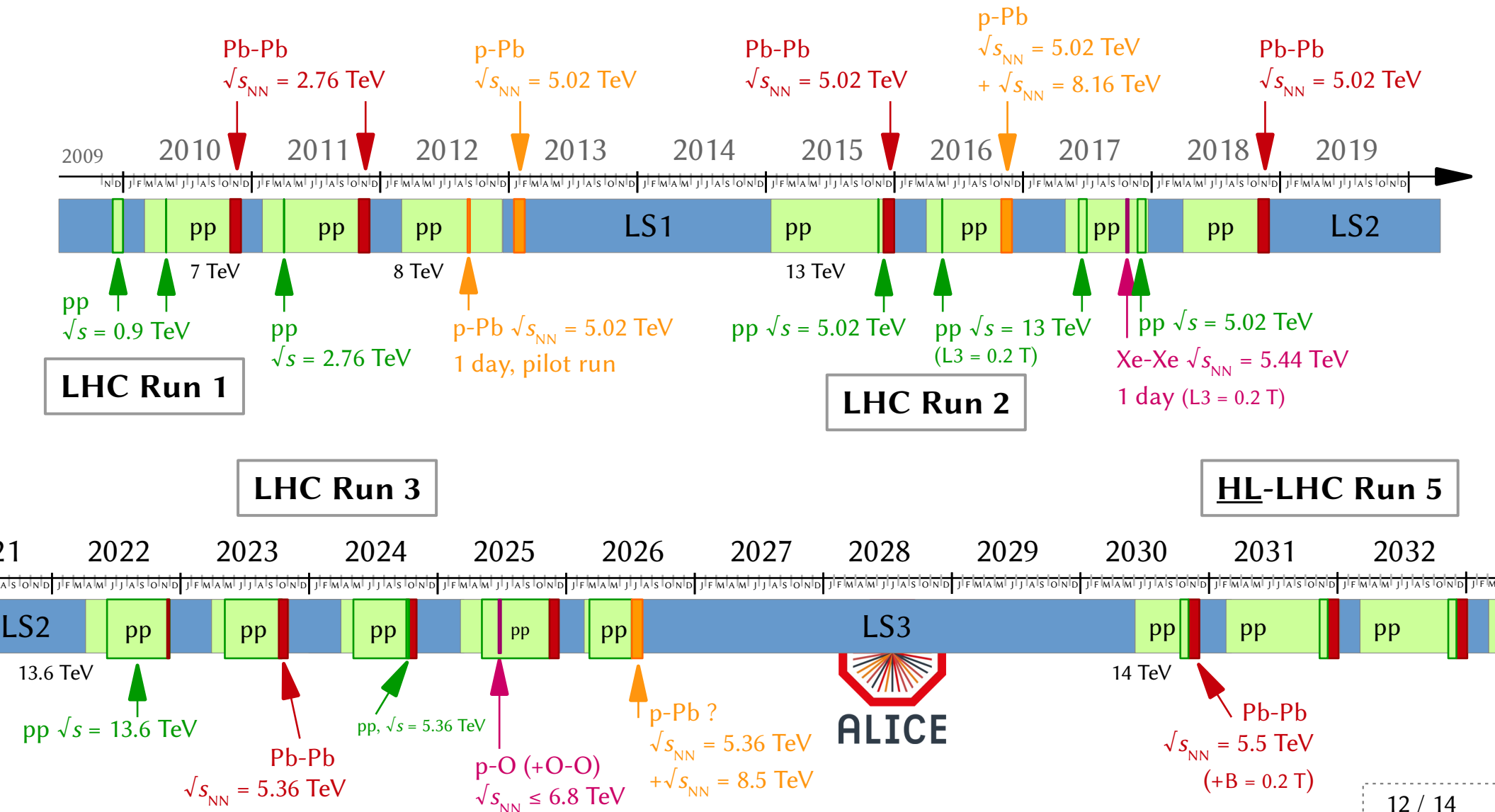
Beauty :  $c\tau \approx \mathcal{O}(5 \cdot 10^2 \mu\text{m})$



Example : some charm production

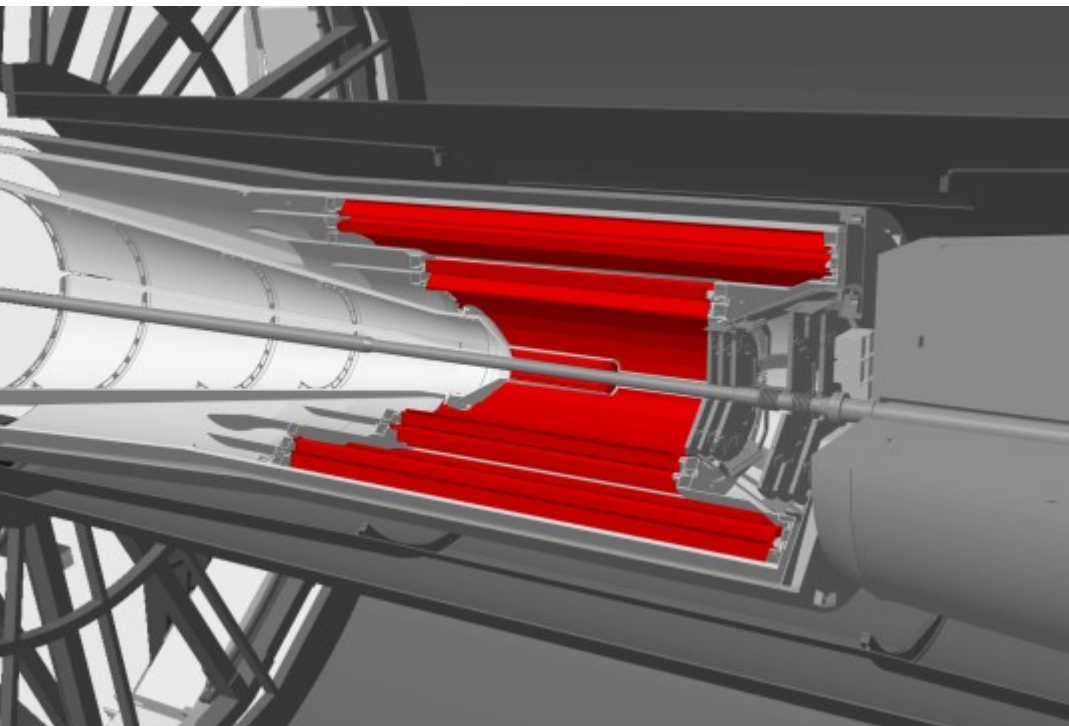


# V.1 – Upgrades : LHC data taking and shutdown



# V.2 – Upgrades : ITS-2, design and layout

See TDR ITS-2, [CERN-LHCC-2013-024](#)



ITS2 in operation (pp, Pb-Pb),  $\geq 2022$

$\eta$  coverage:  $|\eta| < 1.22$  (for 90% of luminous region)

$R$  coverage: 22 – 400 mm

$12.6 \times 10^9$  pixel camera

$\approx 10 \text{ m}^2$  of Si,  $\approx 15.4 \times 10^6$  CHF

7 layers of MAPS (Monolithic Active Pixel Sensor)  
= *ALPIDE* CMOS chips

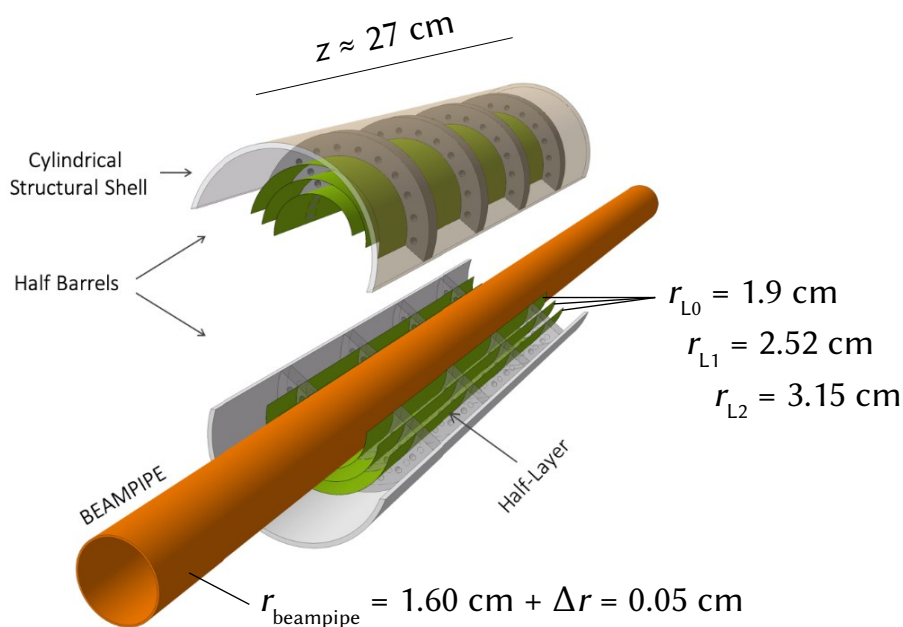


- ALPIDE*
- Space point resolution:  $\sim 5 \mu\text{m}$
  - Time resolution:  $\sim 2 \mu\text{s}$
  - Continuous readout

# V.3 – Upgrades : future challenges = ITS3, ALICE3

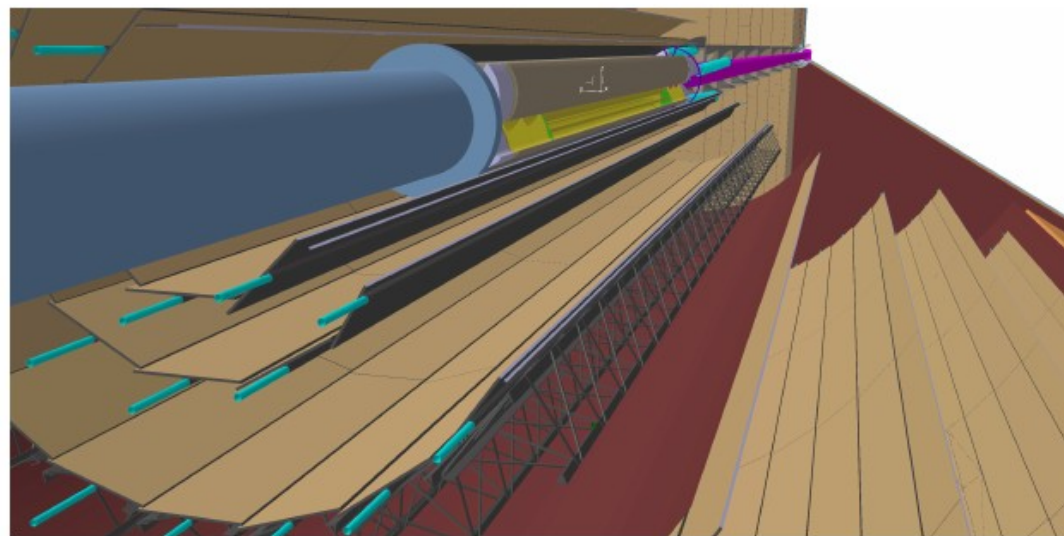
Next upgrade :  
**ITS-3** [HL-LHC Run IV = 2030-2033]

- Keywords :*
- ultra-light MAPS  
 → stitched + bent sensors
  - spatial resolution  $\sim 5 \mu\text{m}$
  - $r_{L0} = 1.9 \text{ cm}$
  - air cooling,  $+20^\circ\text{C}$



Next-to-Next upgrade :  
**Outer Tracker** [HL-LHC Run V  $\geq 2036$ ]  
 in the new experiment ALICE3

- Keywords :*
- light MAPS, planar,  $O[55 \text{ m}^2]$
  - spatial resolution  $\sim 10 \mu\text{m}$
  - time resolution  $< 100 \text{ ns}$
  - air cooling,  $+20^\circ\text{C}$



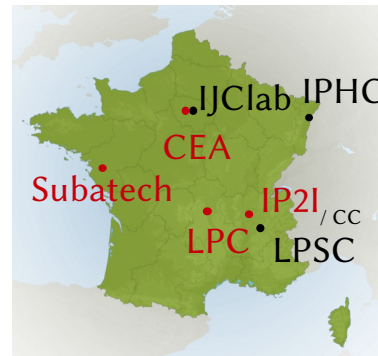
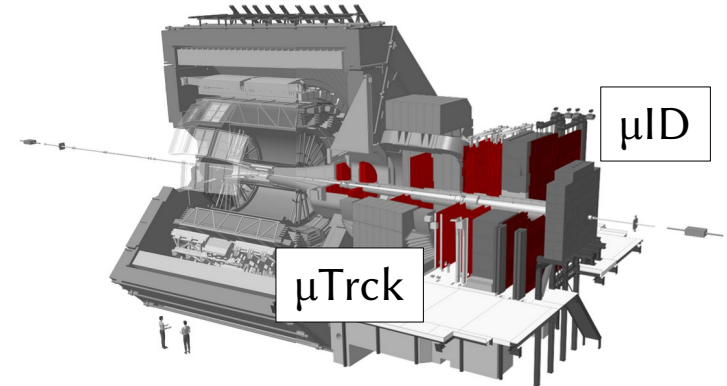
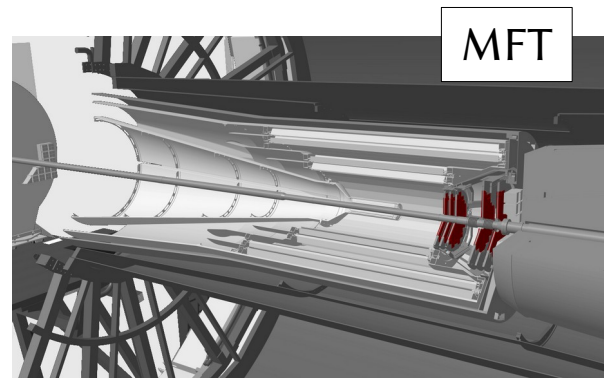
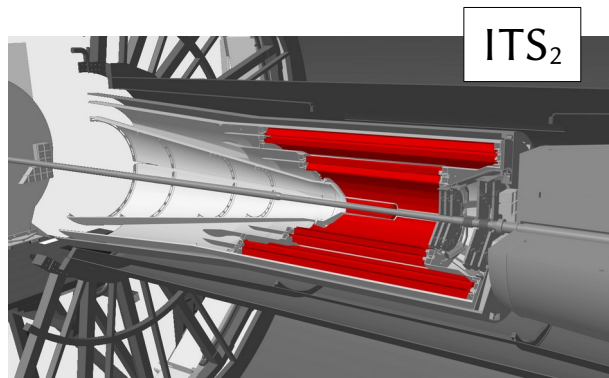
**Figure 83:** Sketch of the outer tracker mechanics. Modules assembled in staves structures are visible as well as services and power lines. Furthermore, the overlap of the staves can be seen.

# *Appendices*

*A – Upgrade Run 3 in IN2P3*

*B – Flavour physics : s,c,b*

# A.1 – LHC run III [2022-26]: ALICE-France commitments





# B.1 – Flavours : extend $(u,d,s)$ to $(c,b)$

- **Strangeness**  $(u,d +s)$  // **Open charm**  $(u,d,s +c)$

differential measurements ( $p_T$ , event activity) in run II, III, ...

- production cross-sections ( $d^2N/dp_T dy$ ,  $R_{AA}$ , particle ratios)
- hadronisation mechanisms (angular correlations),
- thermalisation, hydrodynamisation (radial flow,  $v_n$ )

... in various systems :

- pp Min. Bias
- pp High Multiplicity
- p-Pb
- Pb-Pb

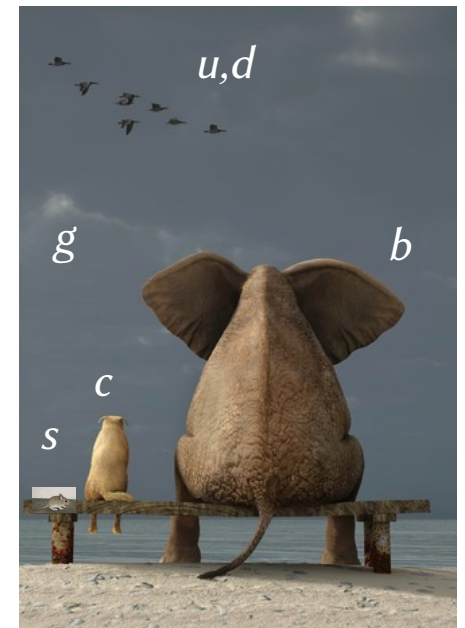
*Local expertise* : **topological hadronic reconstruction**

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Strangeness :  $c\tau \approx \mathcal{O}(5 \text{ cm})$

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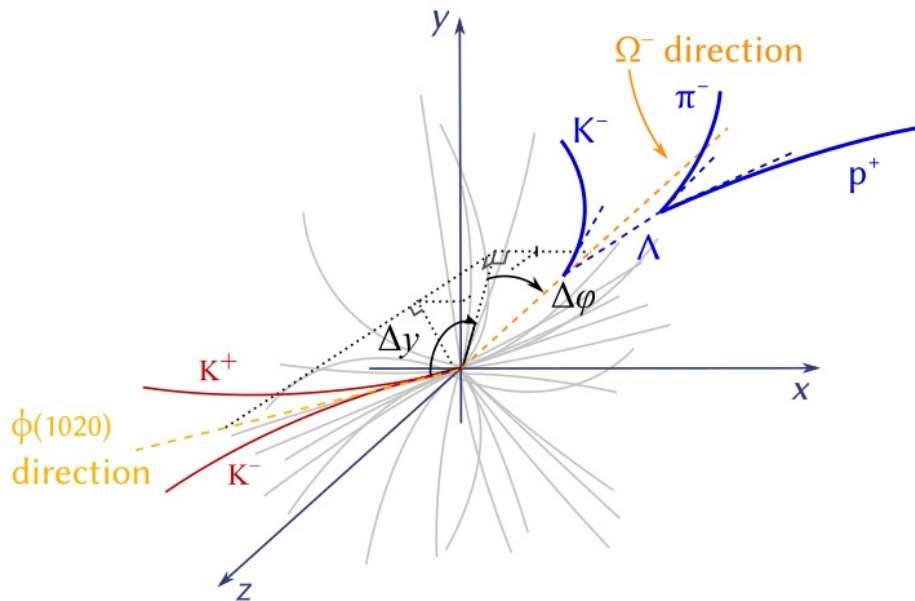
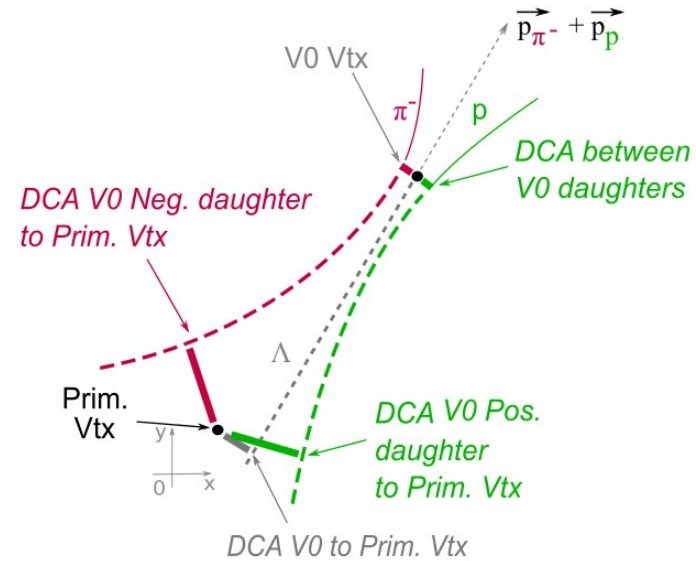
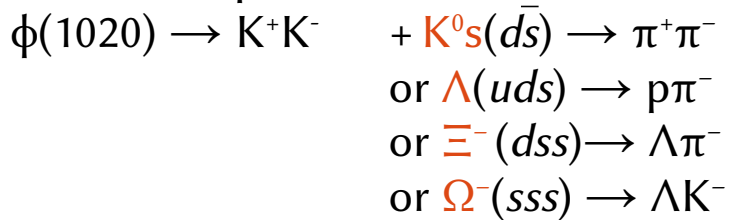
Beauty :  $c\tau \approx \mathcal{O}(5 \cdot 10^2 \mu\text{m})$



# B.2 – Flavours : HEP topics – strangeness = $f(dN_{ch}/d\eta)$

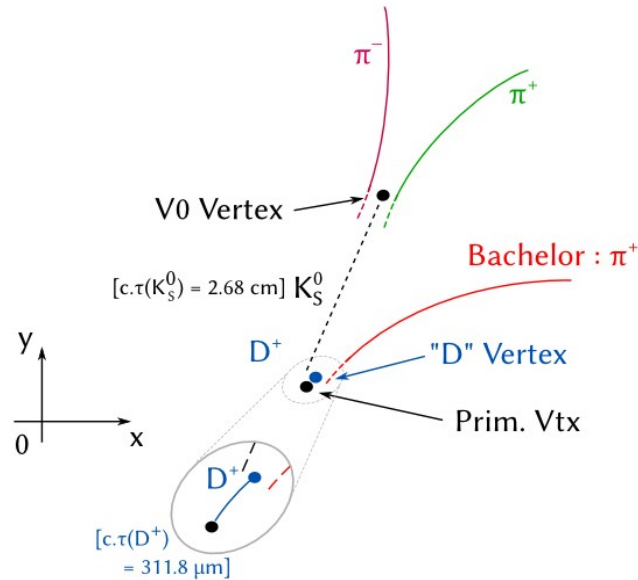
PDGlive.lbl.gov

Correlated production :

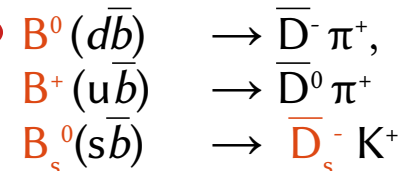
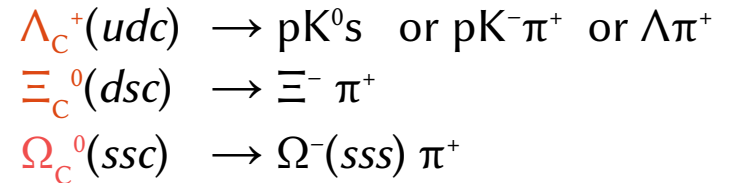
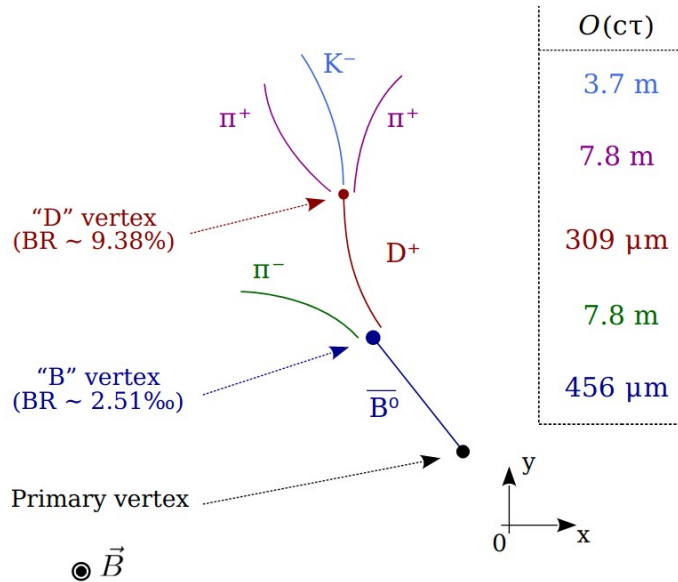
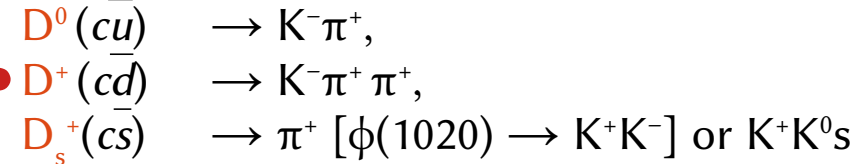


# B.2 – Flavours : HEP topics = charm, beauty, baryons

PDGLive.lbl.gov

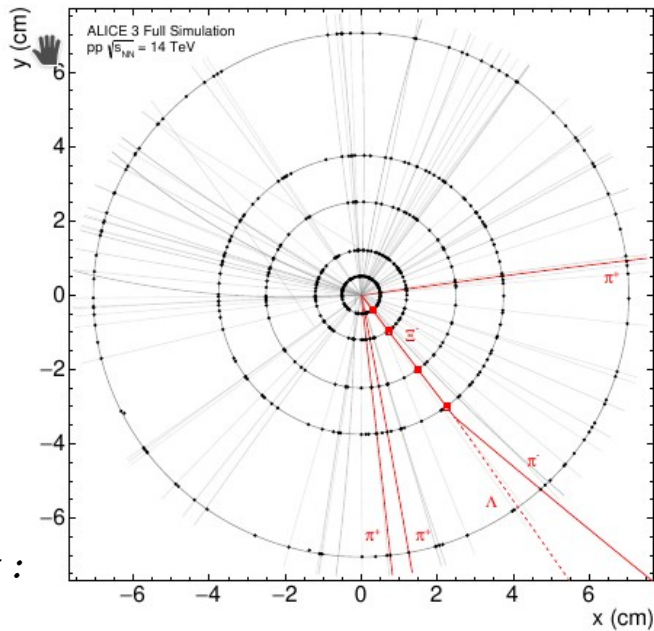


Charm and beauty production :



# B.3 – Flavours : HEP topics = charm, beauty, baryons

PDGLive.lbl.gov



On plot :

$\Xi_{cc}^{++}$

- $\Xi_c^+ \pi^+$
- $(\Xi^- \pi^+ \pi^+) \pi^+$
- $(\Lambda \pi^-) \pi^+ \pi^+ \pi^+$
- $(p \pi^-) \pi^- \pi^+ \pi^+ \pi^+$

in ALICE-3 (>2031)

Charm and beauty production :

- $D^0(c\bar{u}) \rightarrow K^- \pi^+$ ,
- $D_s^+(c\bar{s}) \rightarrow \pi^+ [\phi(1020) \rightarrow K^+ K^-] \text{ or } K^+ K^0_s$

- $\Lambda_c^+(udc) \rightarrow p K^0_s \text{ or } p K^- \pi^+ \text{ or } \Lambda \pi^+$
- $\Xi_c^0(dsc) \rightarrow \Xi^- \pi^+$
- $\Omega_c^0(ssc) \rightarrow \Omega^- (sss) \pi^+$

- $B^0(d\bar{b}) \rightarrow \bar{D}^- \pi^+$ ,
- $B^+(u\bar{b}) \rightarrow \bar{D}^0 \pi^+$
- $B_s^0(s\bar{b}) \rightarrow \bar{D}_s^- K^+$