

Alice l'esperimento e la fisica

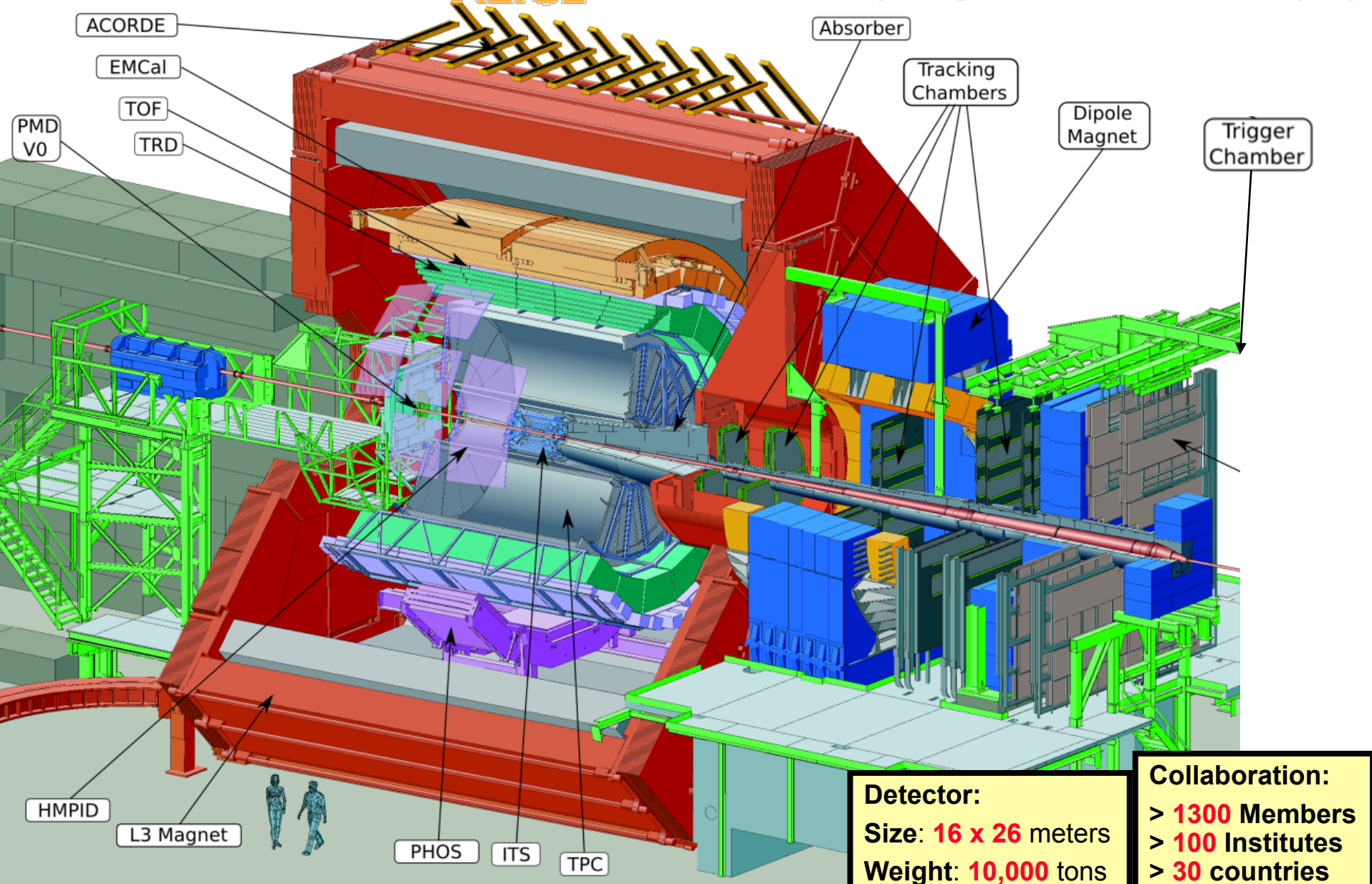


Pasquale Di Nezza

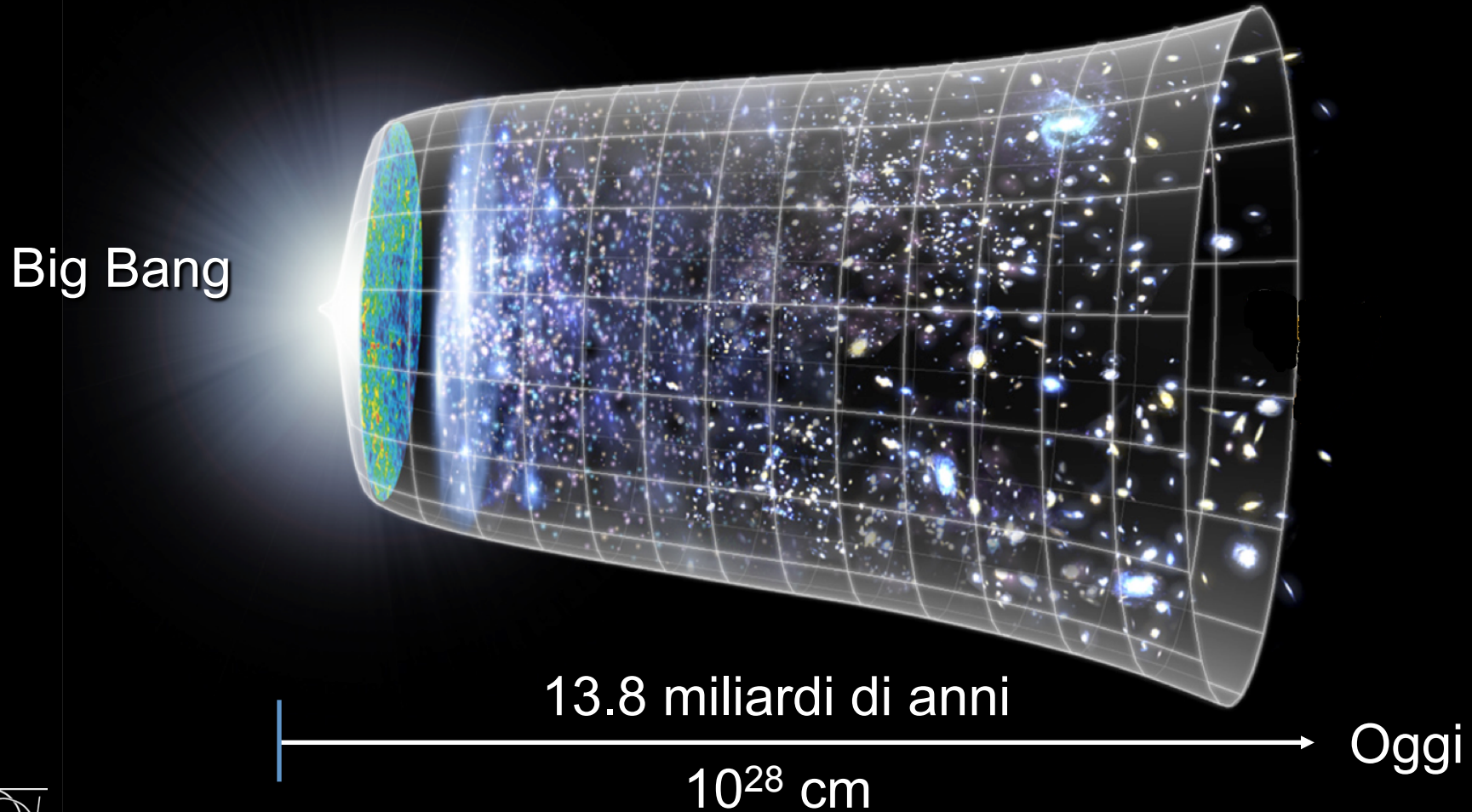


A Large Ion Collider Experiment

European Organisation for Nuclear Research



Comprendere i primissimi istanti di vita del nostro Universo dopo il Big Bang





Per capire la natura intima della materia bisogna essere in grado di:

ricreare le condizioni dei primi istanti dell'Universo

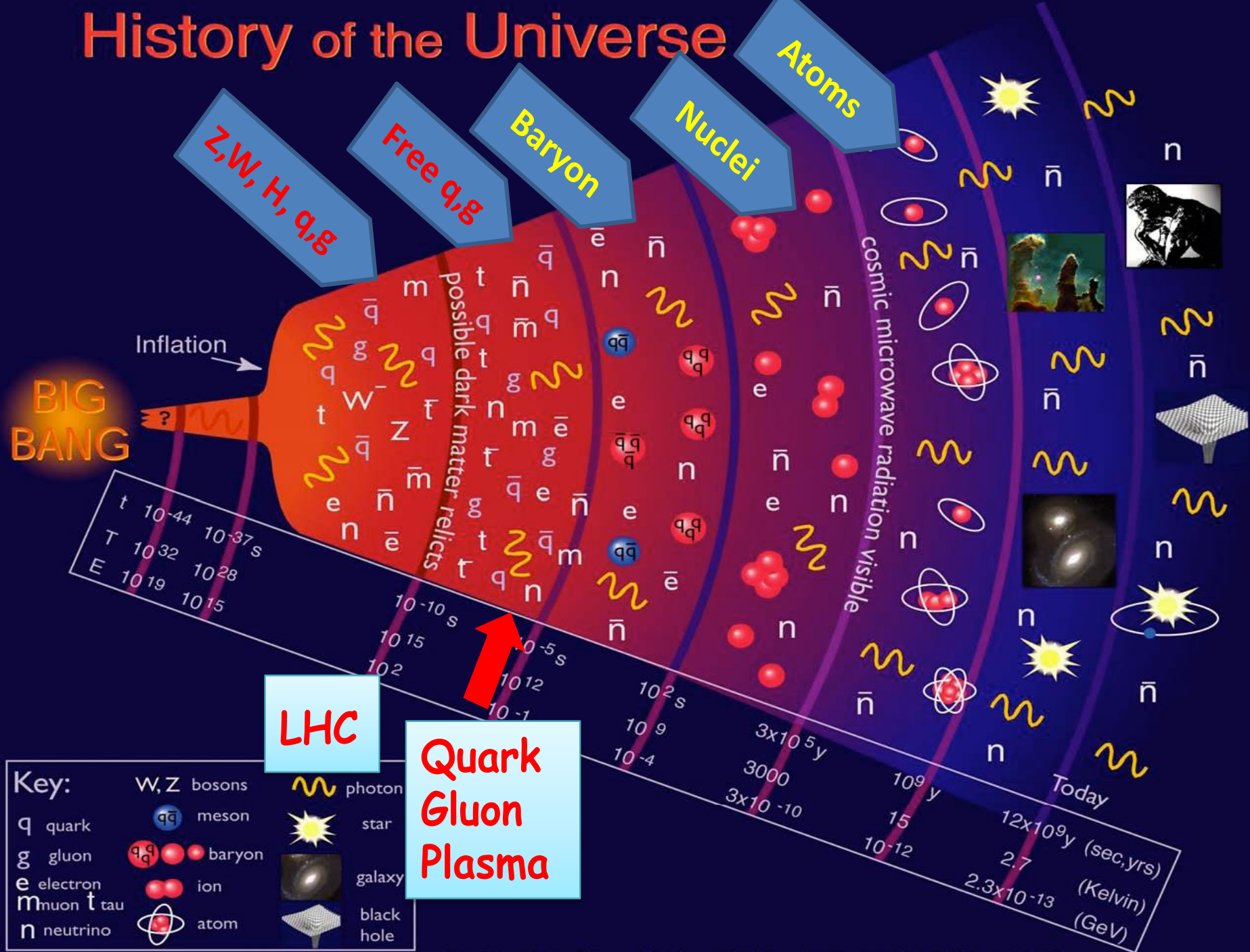
ricreare i portatori d'informazione

ricreare le particelle

Alice ... in viaggio nel tempo



History of the Universe

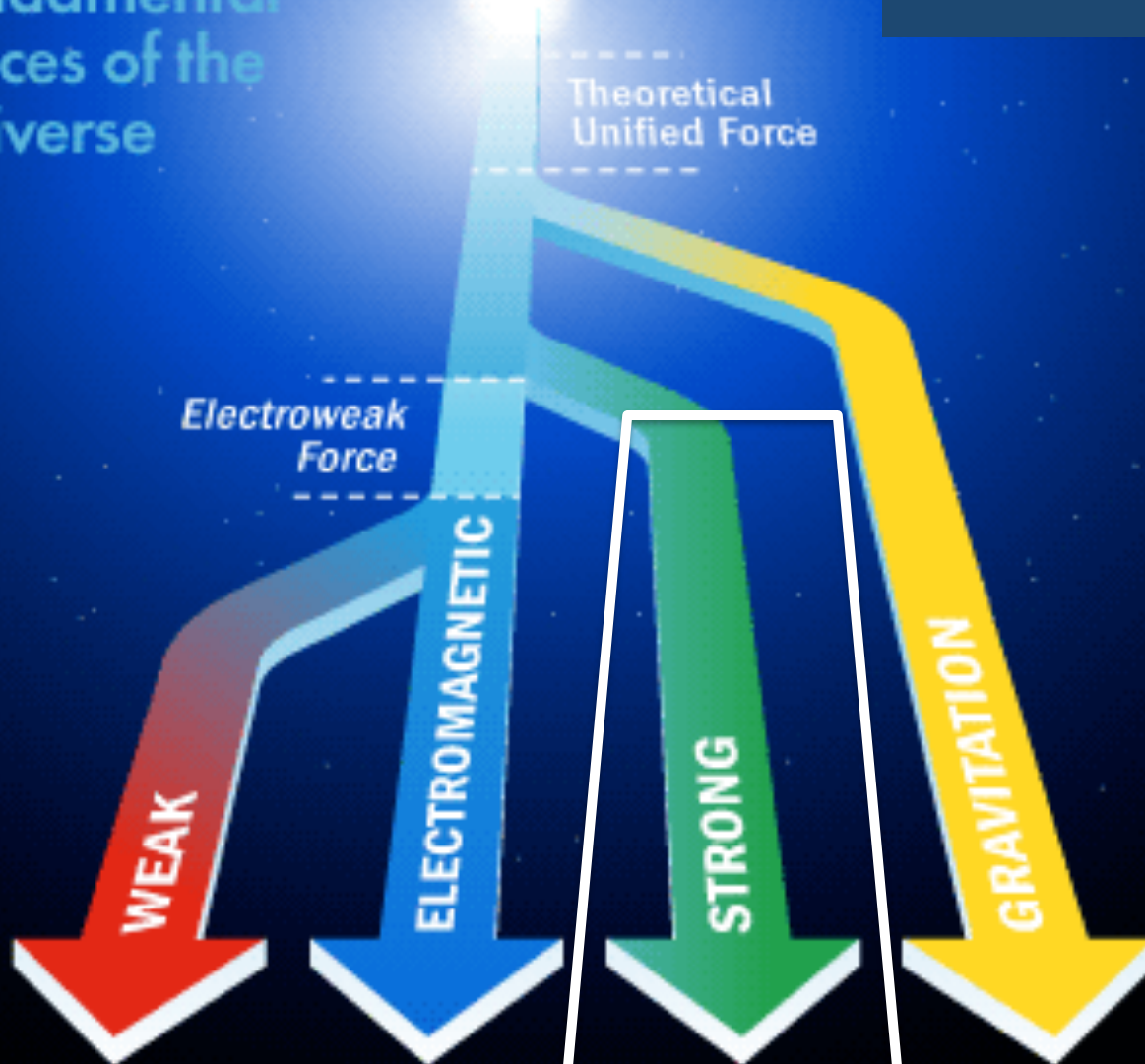


Fino a circa un centomillesimo di secondo dal Big Bang ($10^{-37} - 10^{-5}$ s) l'Universo era formato da una "zuppa" di quark e gluoni ... il Quark Gluon Plasma (QGP)

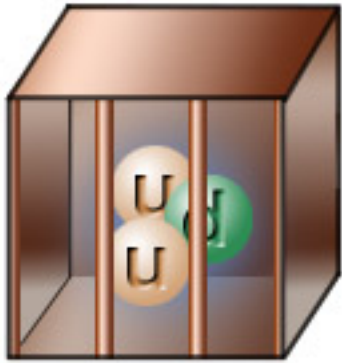


- Perché studiare il QGP?
- Quali sono le caratteristiche del QGP?
- E' possibile riprodurlo in laboratorio?

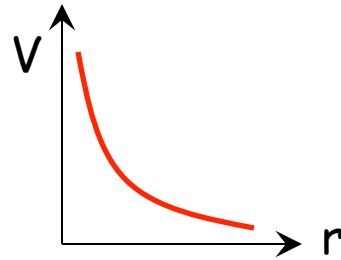
Fundamental Forces of the Universe



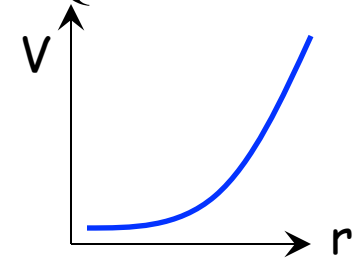
Liberta' Asintotica \rightarrow Confinamento



$$V_{\text{Coulomb}} \propto \frac{q_1 q_2}{r}$$

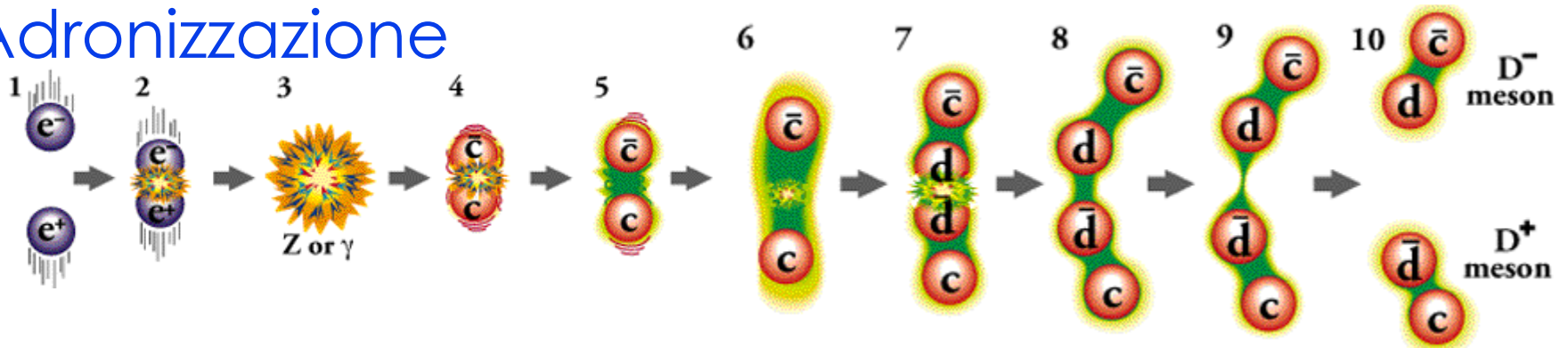


$$V_{\text{QCD}} \propto e^{k \cdot r}$$

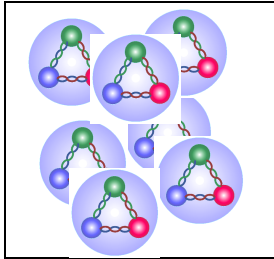


Allontanando i quark, si crea una tensione con energia sufficiente a creare altre particelle (1000 MeV / fm)

Adronizzazione



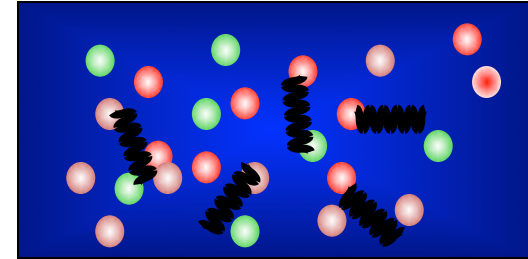
Bisogna creare un sistema che abbia una densità enorme (ptc a distanza infinitesima) tale da rendere trascurabile l'interazione forte



adroni



ENERGIA



Quark Gluon Plasma

Nobel Prize 2005

**D. Gross
H.D. Politzer
F. Wilczek**

QCD Asymptotic Freedom (1973)



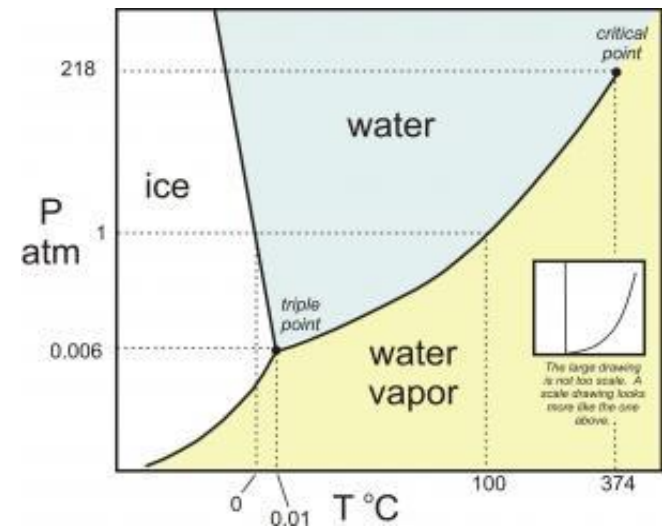
"Before [QCD] we could not go back further than 200,000 years after the Big Bang. Today...since QCD simplifies at high energy, we can extrapolate to very early times when nucleons melted...to form a quark-gluon plasma."

David Gross, Nobel Lecture (RMP 05)

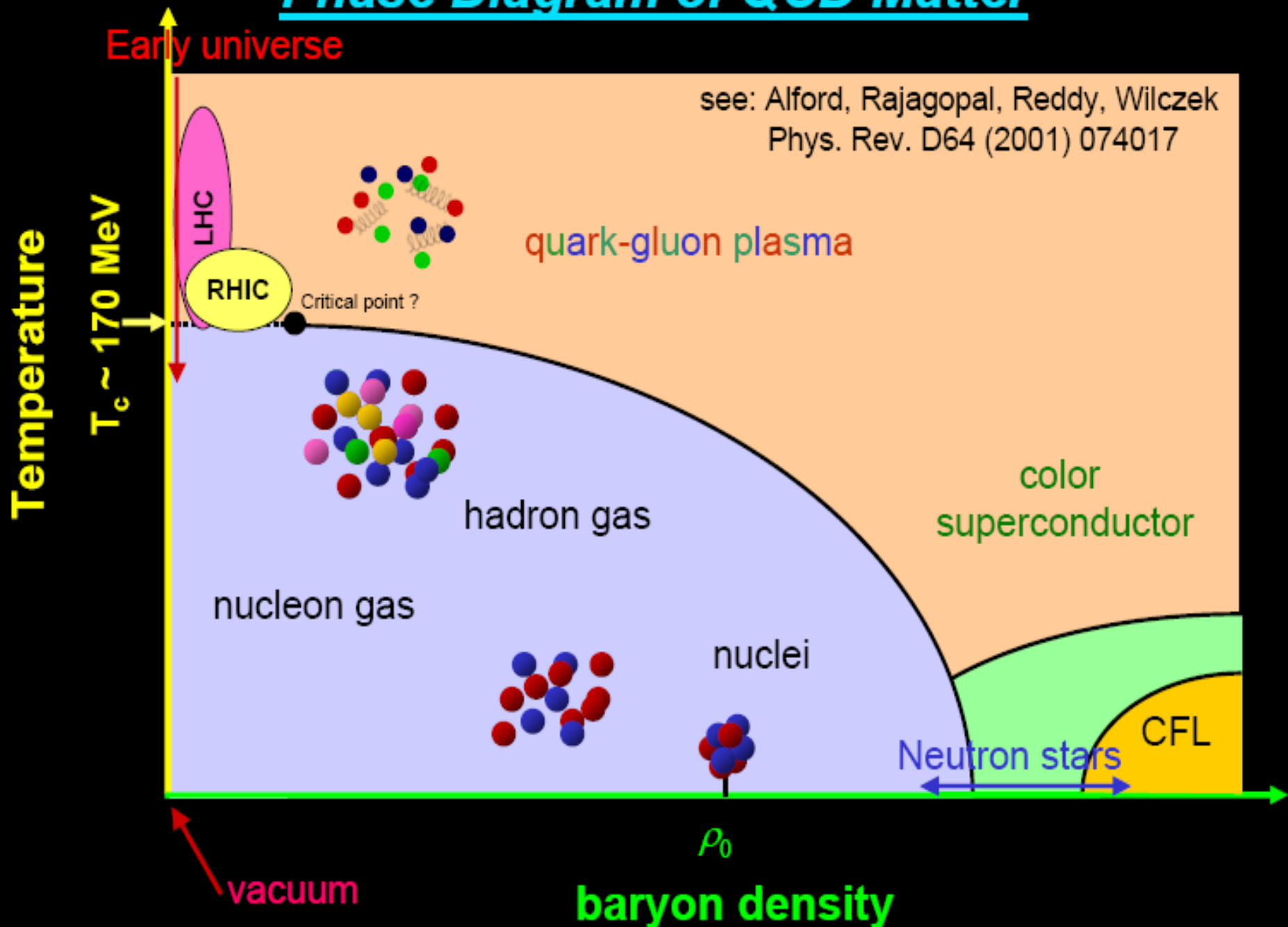


Temperature decreases

Fasi della materia
“normale”



Phase Diagram of QCD Matter



Il QGP: una "zuppa" ricca di informazioni

Flusso ellittico

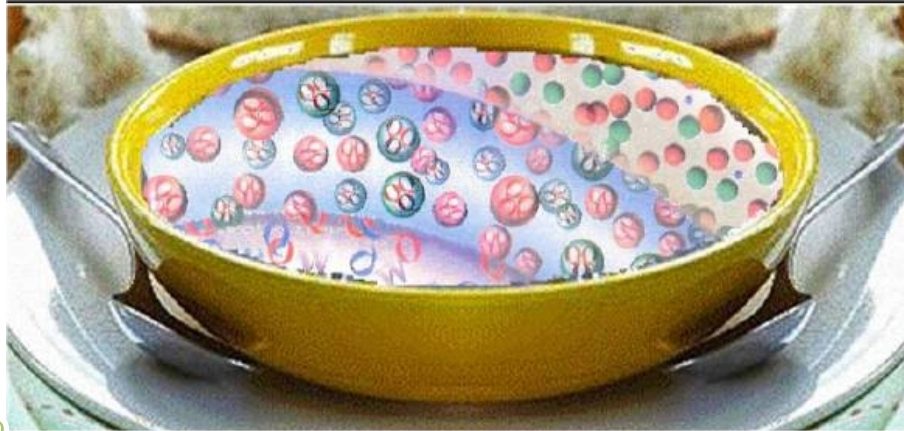
Evoluzione spazio-temporale della nascita di un adrone

Proprietà della QCD ad alte temperature: gradi di libertà, viscosità, conduttività, ...

Restaurazione della simmetria chirale

Freezout

Puzzle barionico



*Instabilità di plasma,
caos di colore*

Transizione di fase q-g nelle teorie cosmologiche dell'Universo primordiale

Equazione di stato della QCD

Perdita di energia partonica

Composizione chimica

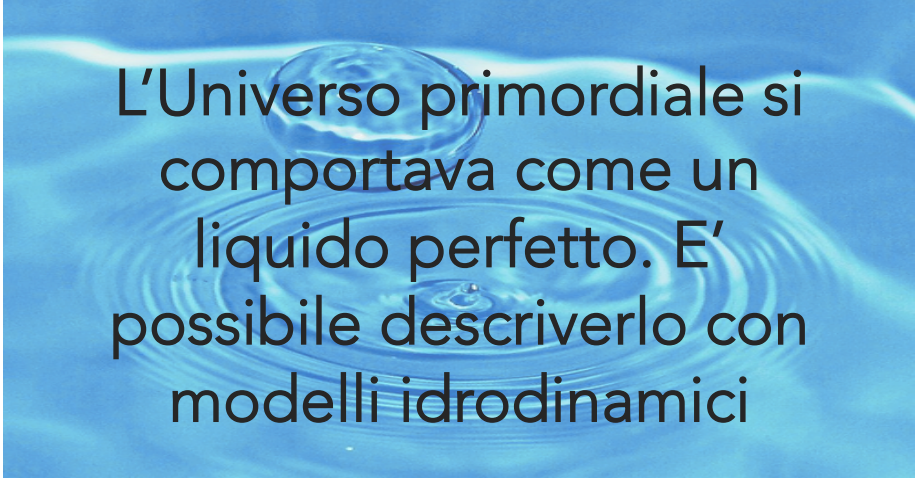
Il QGP: una "zuppa" ricca di informazioni

Flusso ellittico

Evoluzione spazio-temporale della nascita di un adrone

Proprietà della QCD ad alte temperature: gradi di libertà, viscosità, conduttività, ...

Restaurazione della simmetria chirale



L'Universo primordiale si comportava come un liquido perfetto. E' possibile descriverlo con modelli idrodinamici

Instabilità di plasma, caos di colore

Freezout
Puzzle barionico

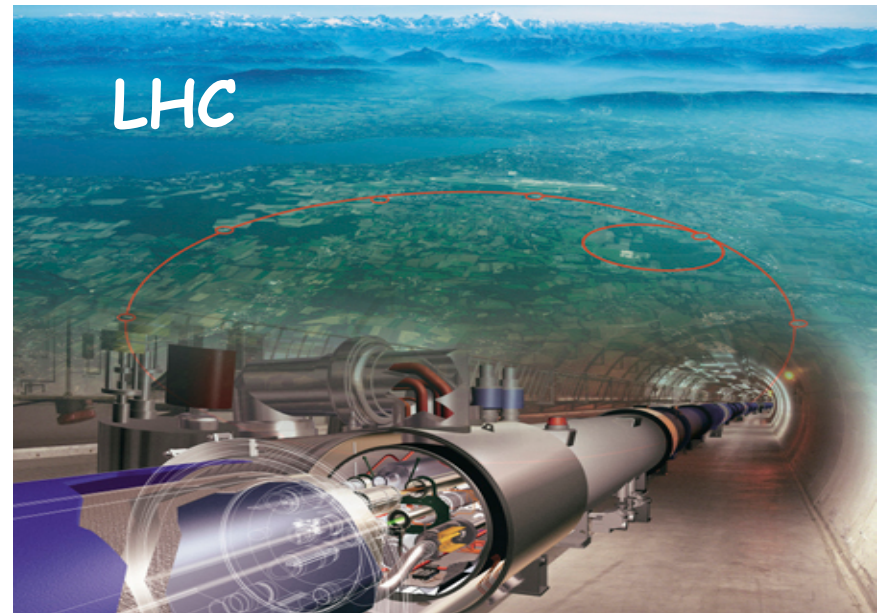
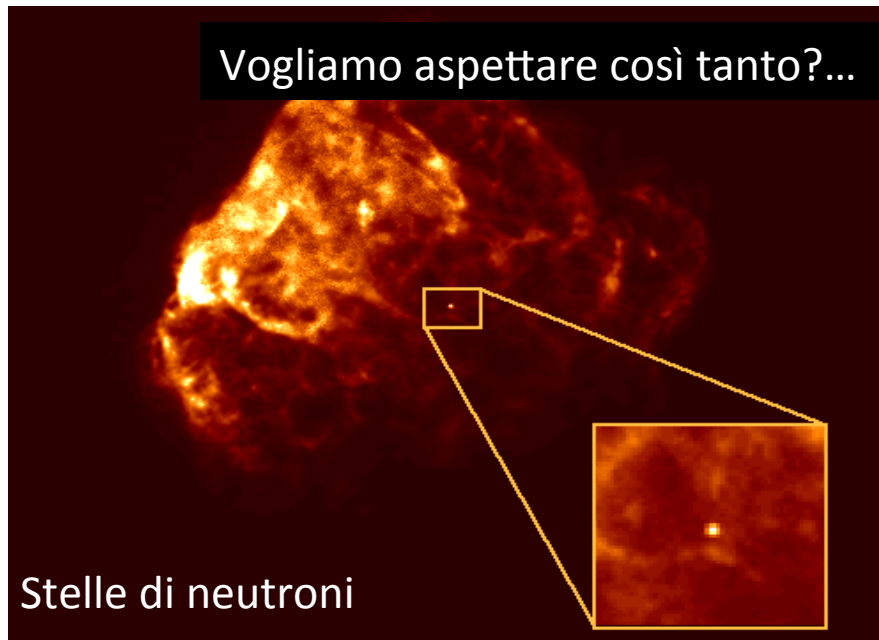
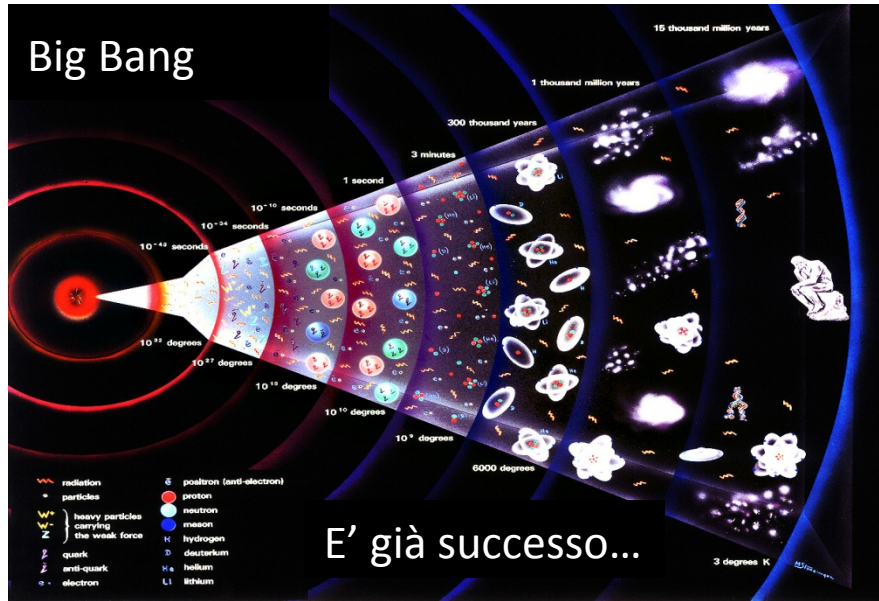
Transizione di fase q-g nelle teorie cosmologiche dell'Universo primordiale

Equazione di stato della QCD

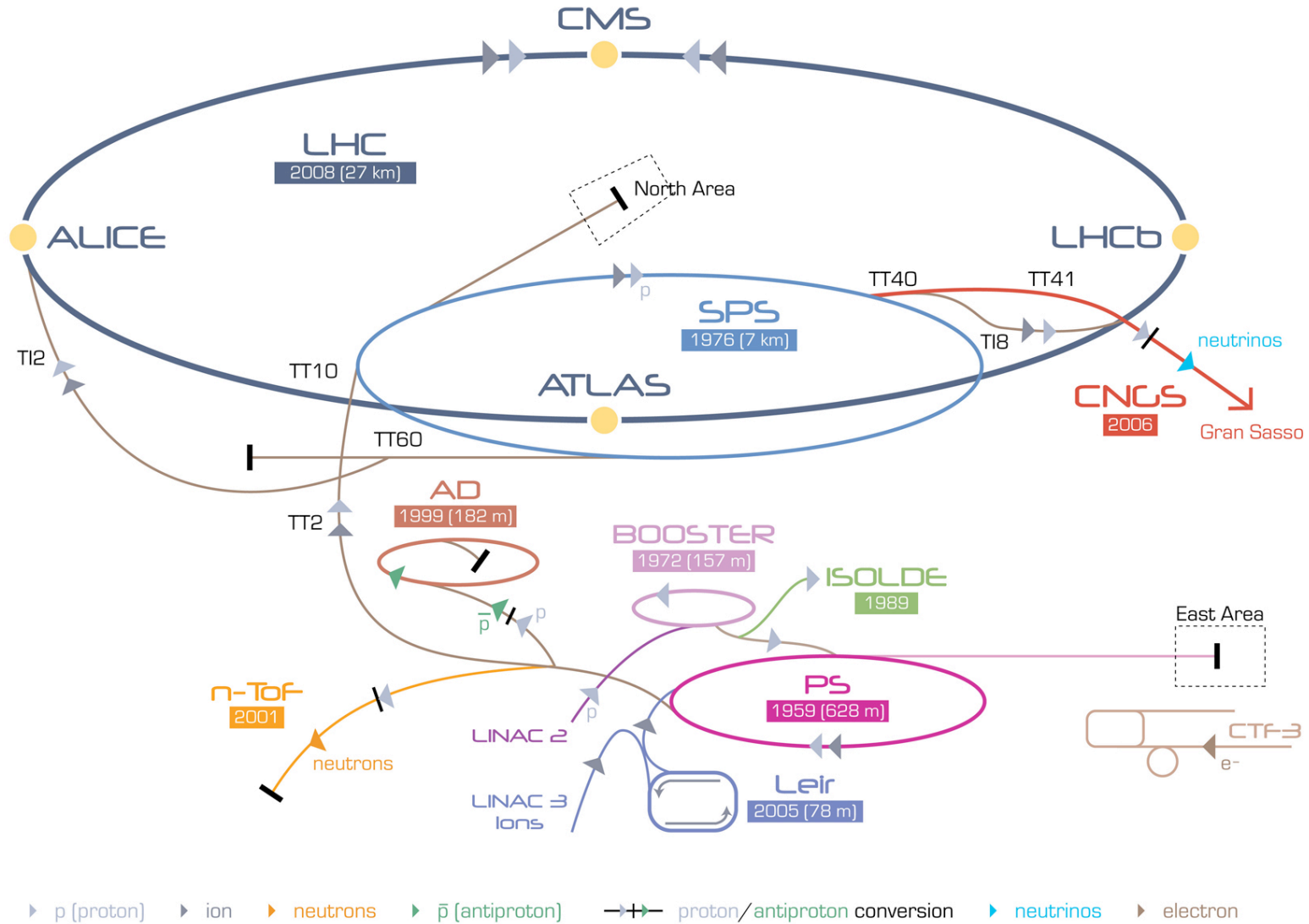
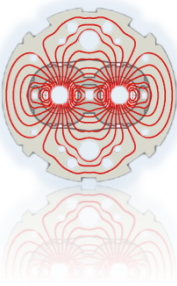
Perdita di energia partonica

Composizione chimica

Dove si produce il QGP ?



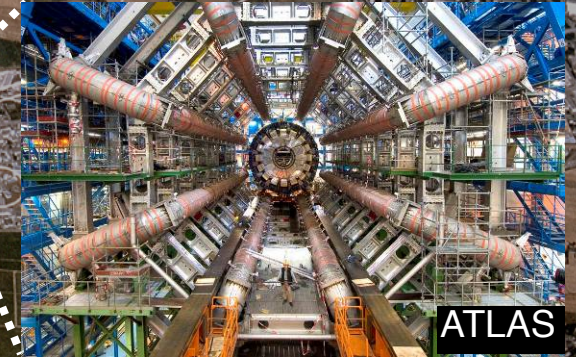
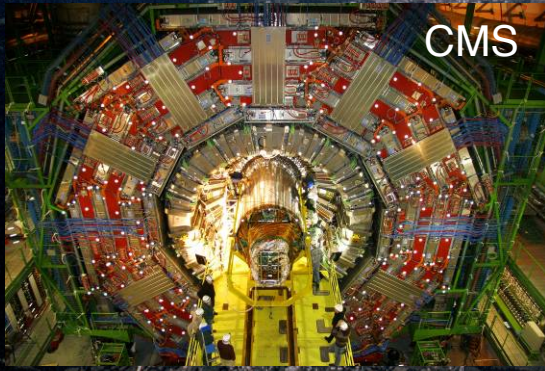
Complesso degli acceleratori del CERN



LHC, il più potente acceleratore del mondo



Anello di LHC:
27 km di circonferenza



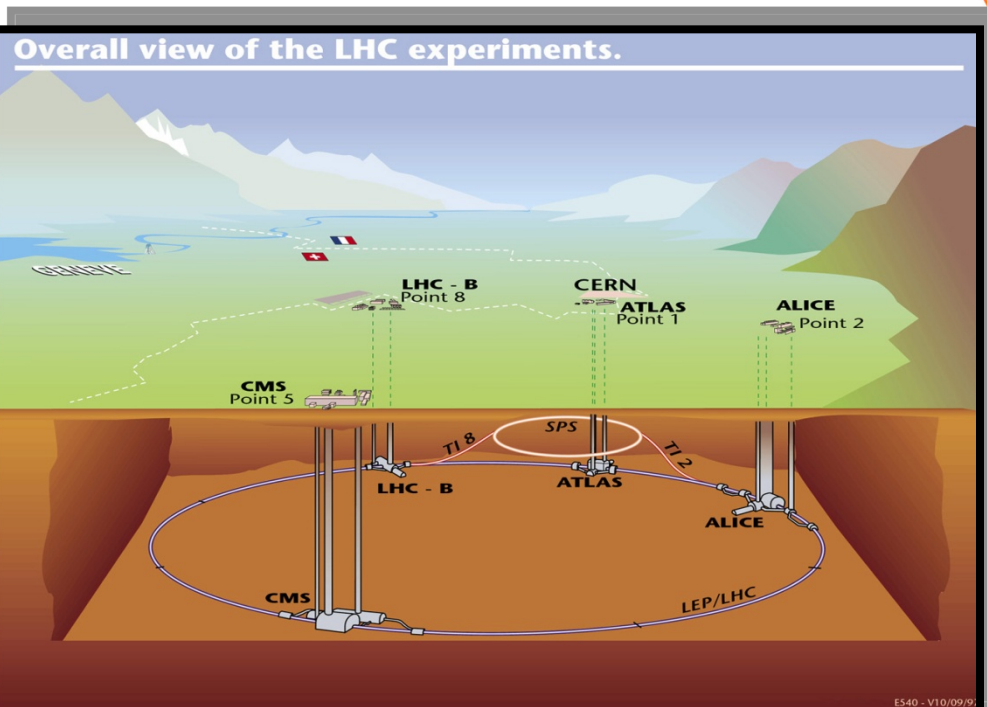
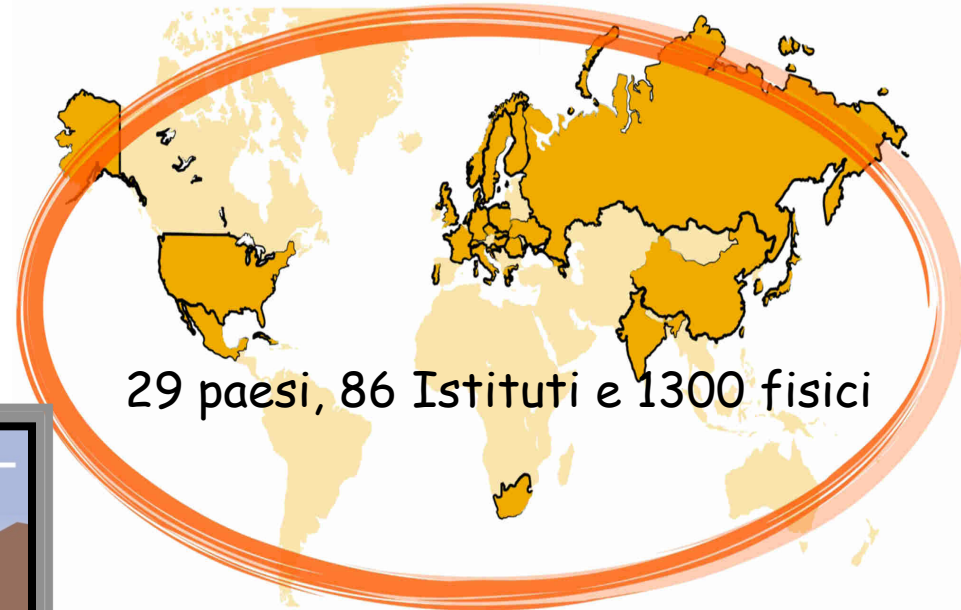
ALICE: A Large Ion Collider Experiment



ALICE

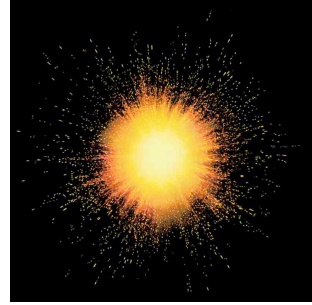
A JOURNEY OF DISCOVERY

Alice è l'unico esperimento a LHC dedicato alla fisica con fasci di ioni (5.5 TeV PbPb)



200 fisici Italiani: BA, BO, CA, CT, LNF, LNL, PD, RM1, SA, TO, TS

Un Mini-Bang in laboratorio



- Abbiamo bisogno di un “sistema piccolo” tale da poterlo accelerare a velocità ultrarelativistiche (99.9% c)
- Tale sistema (p.es. una quantità microscopica di materia e non una sola particella) deve poter seguire semplici regole termodinamiche e poter formare nuovi stati di materia sotto particolari condizioni
- Possiamo usare “ioni pesanti” (p.es. Pb); sono piccoli abbastanza ($\sim 10^{-14}$ m) ma hanno un volume finito tali da poterli sottoporre a misure/variazione di pressione e temperatura

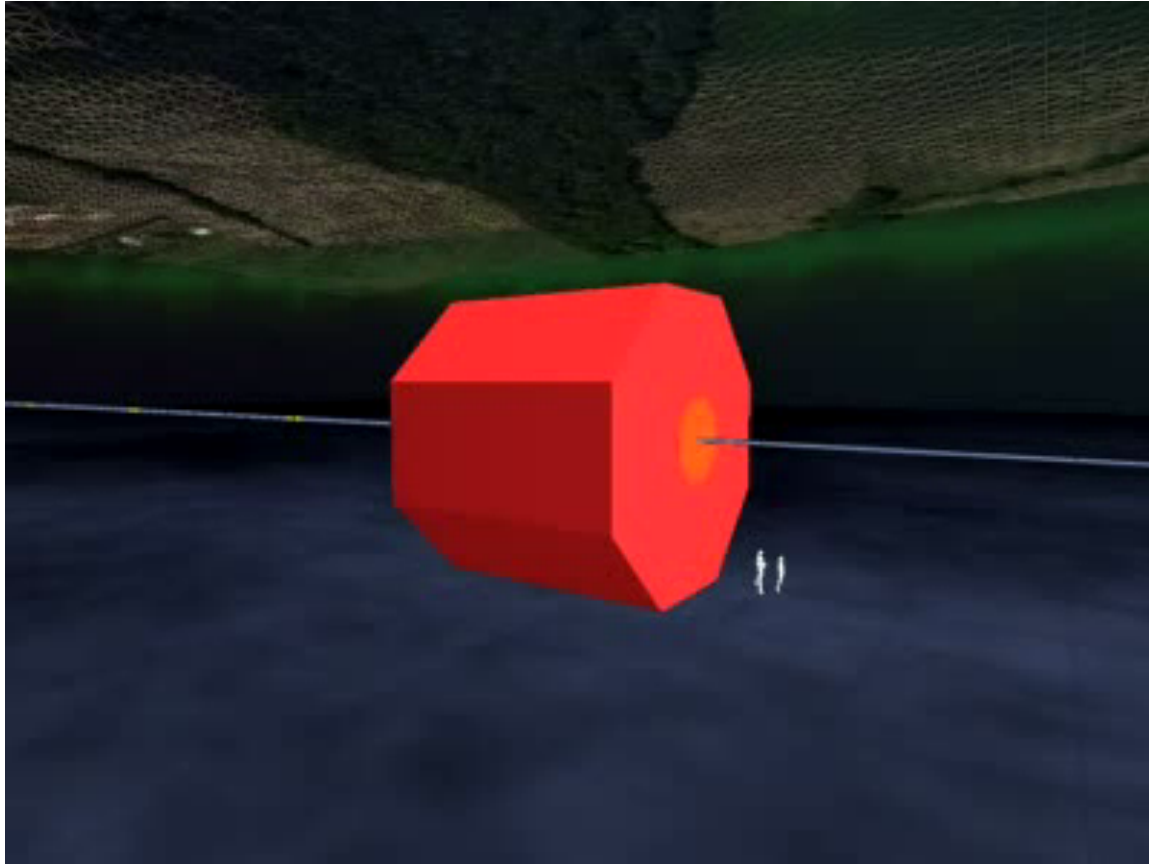
Proveremo a forzare la materia, attraverso una transizione di fase, a passare in un nuovo stato: il “Quark Gluon Plasma”

QGP attraverso gli Heavy Ions

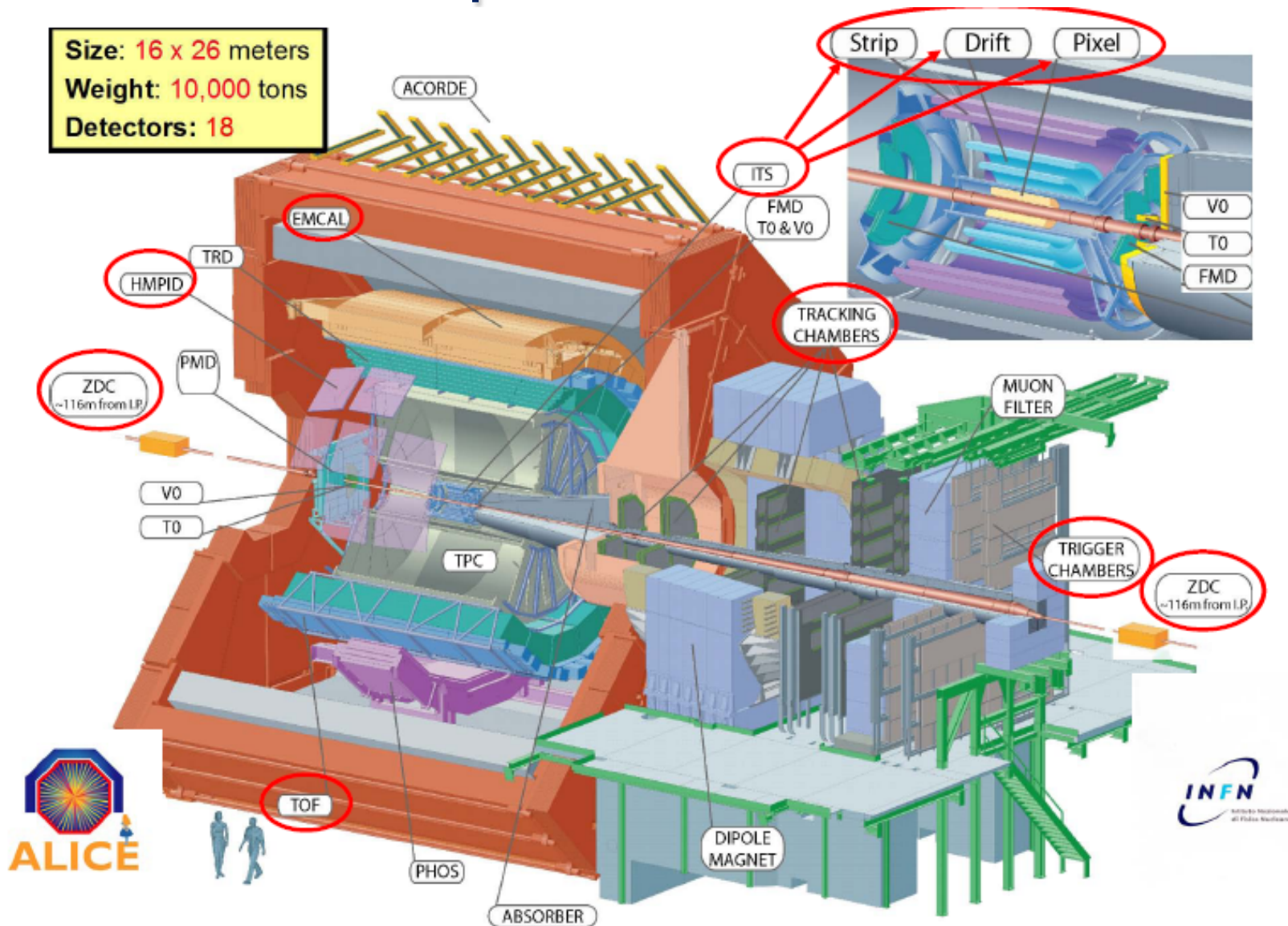
2 nuclei di Piombo, completamente ionizzati, collidono ad altissima energia creando un sistema ad altissima densità



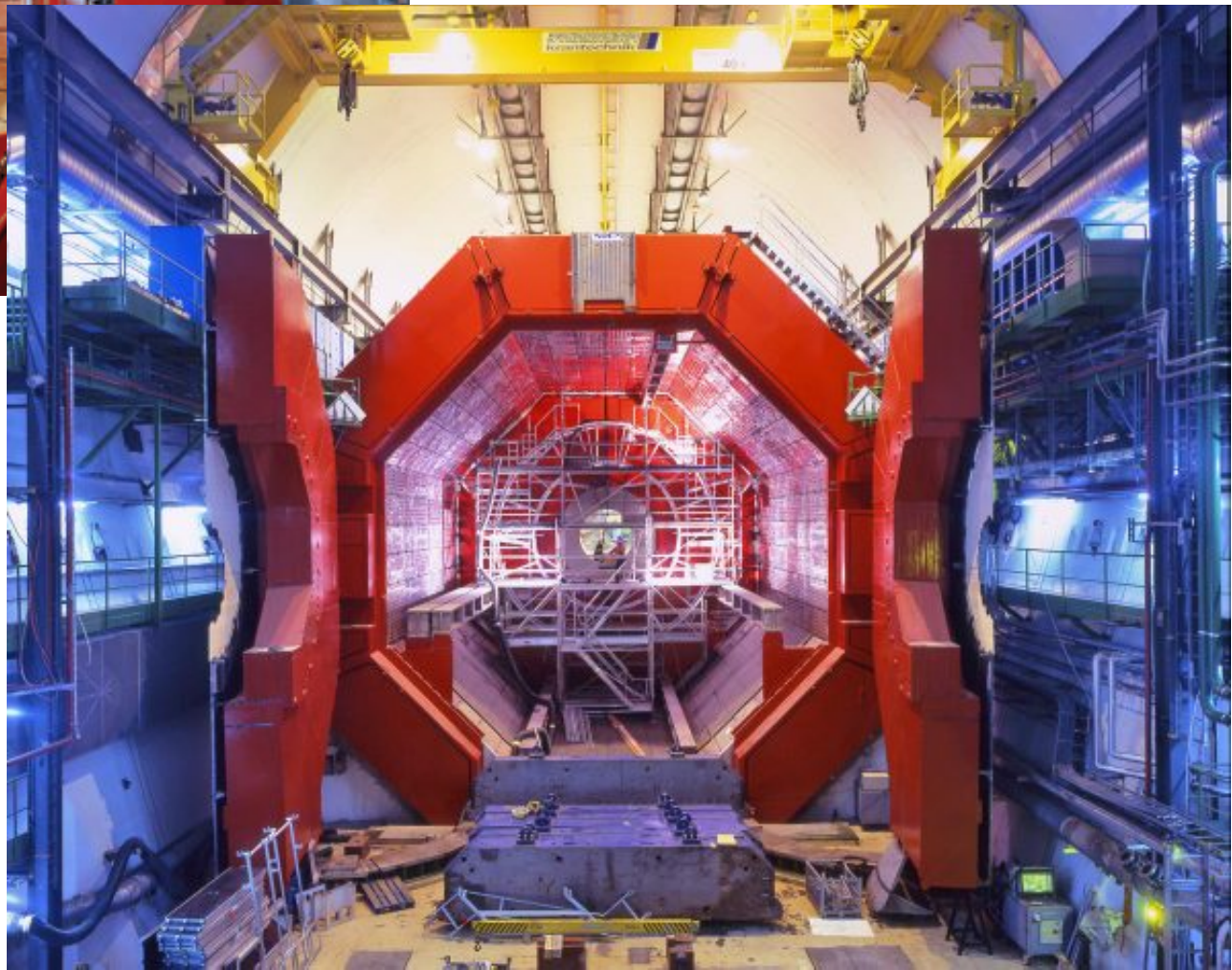
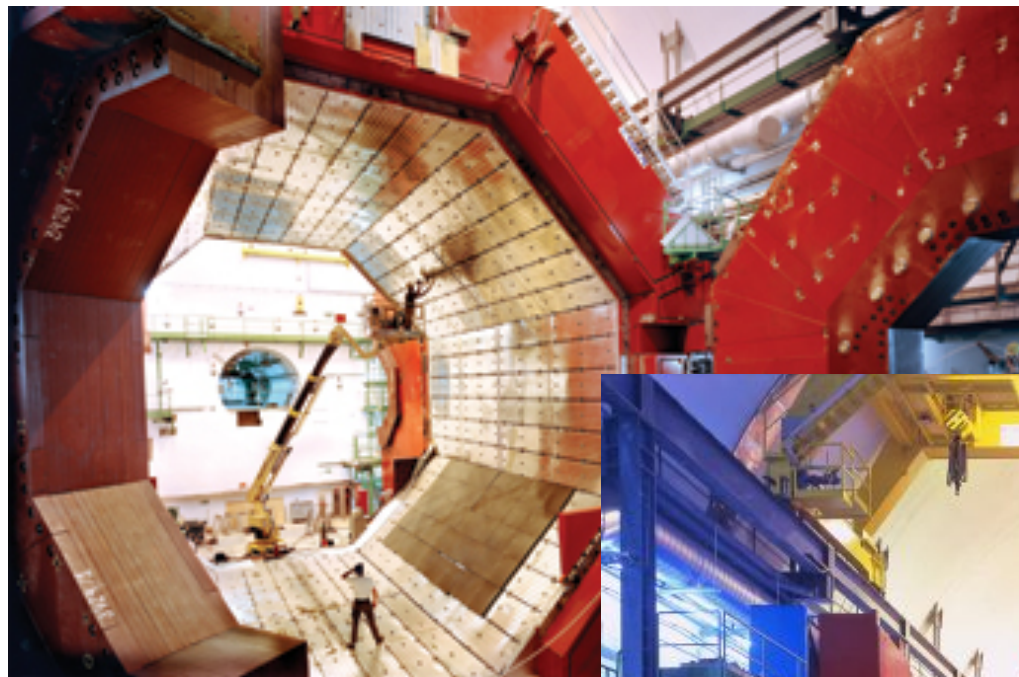
La collisione in Alice



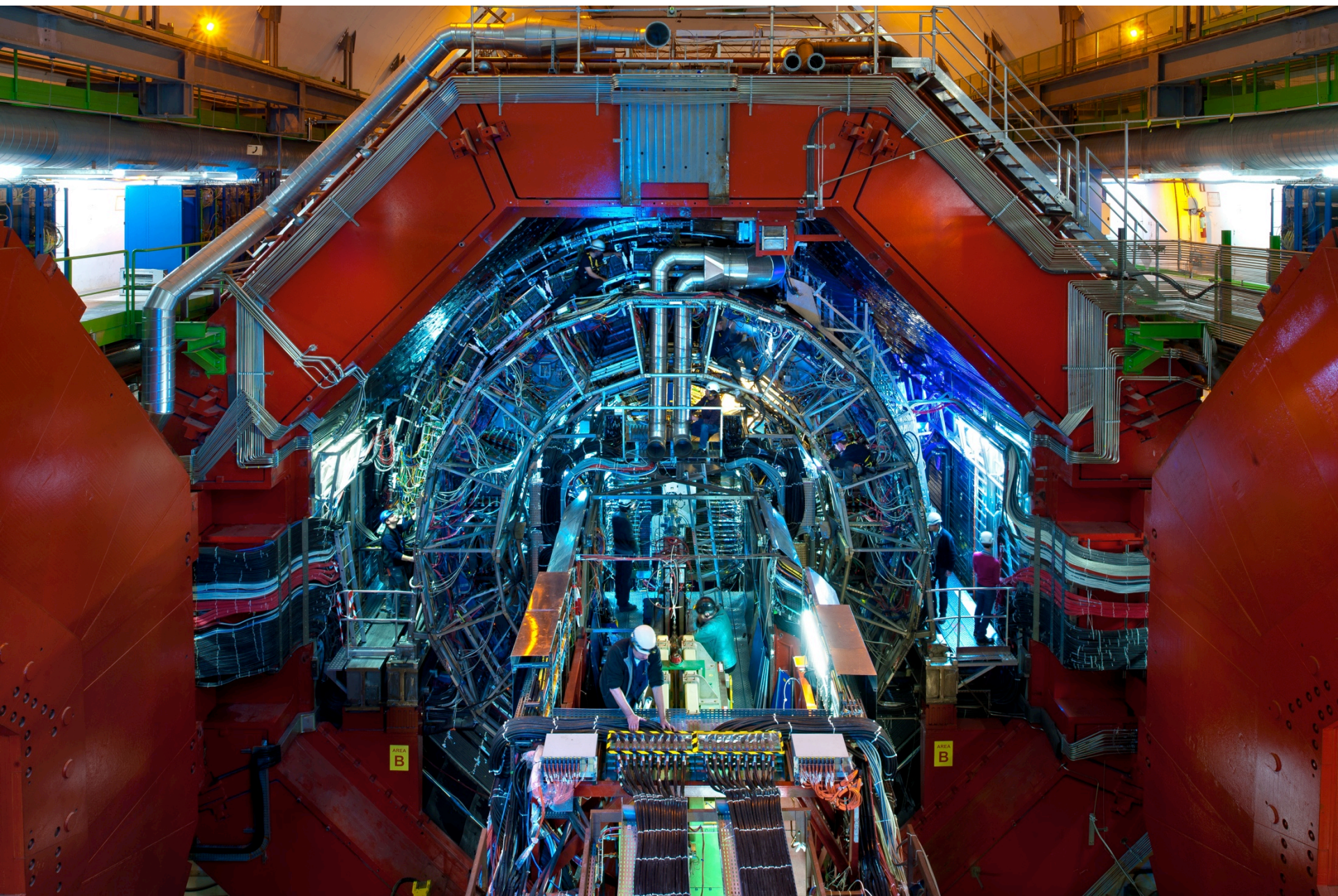
Lo spettrometro



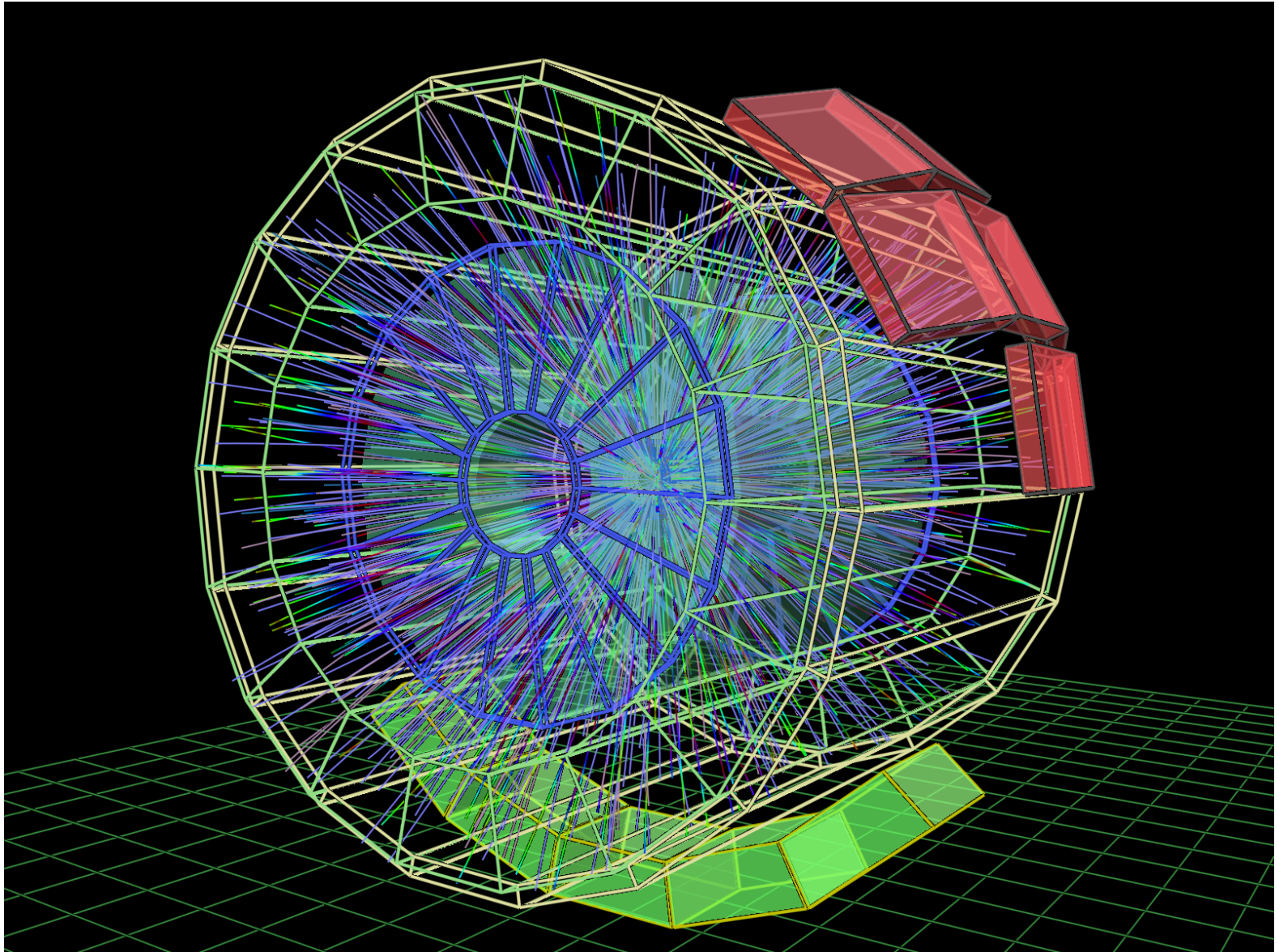
○ : Rivelatori sotto la completa o parziale responsabilità INFN



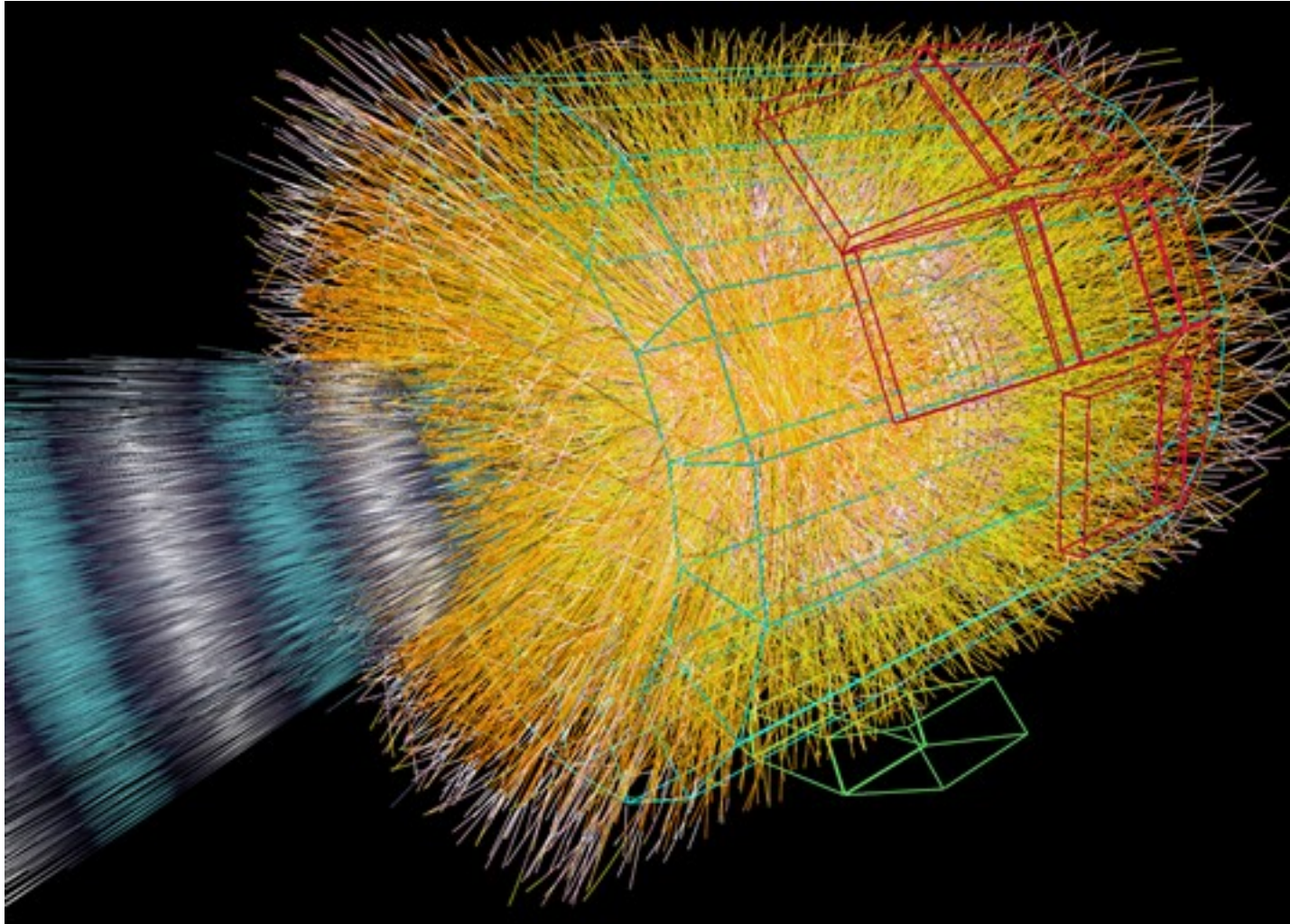




Eventi pp in Alice



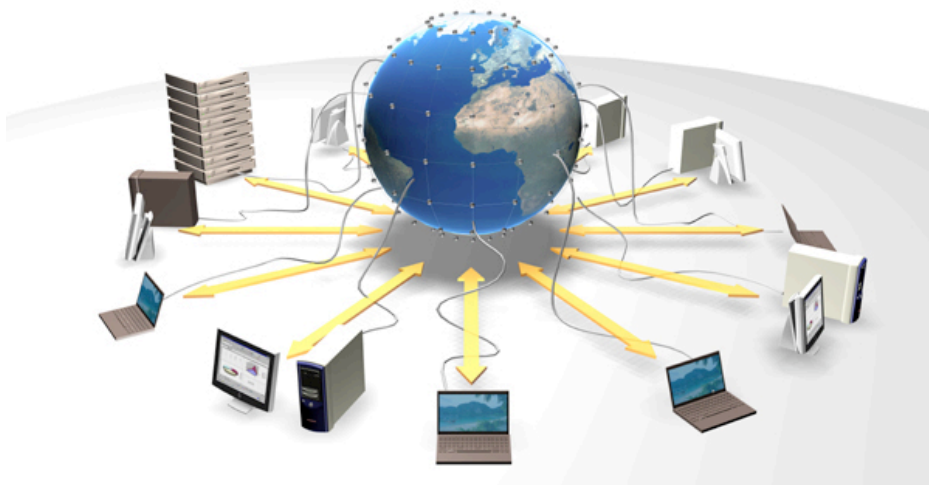
Eventi PbPb in Alice



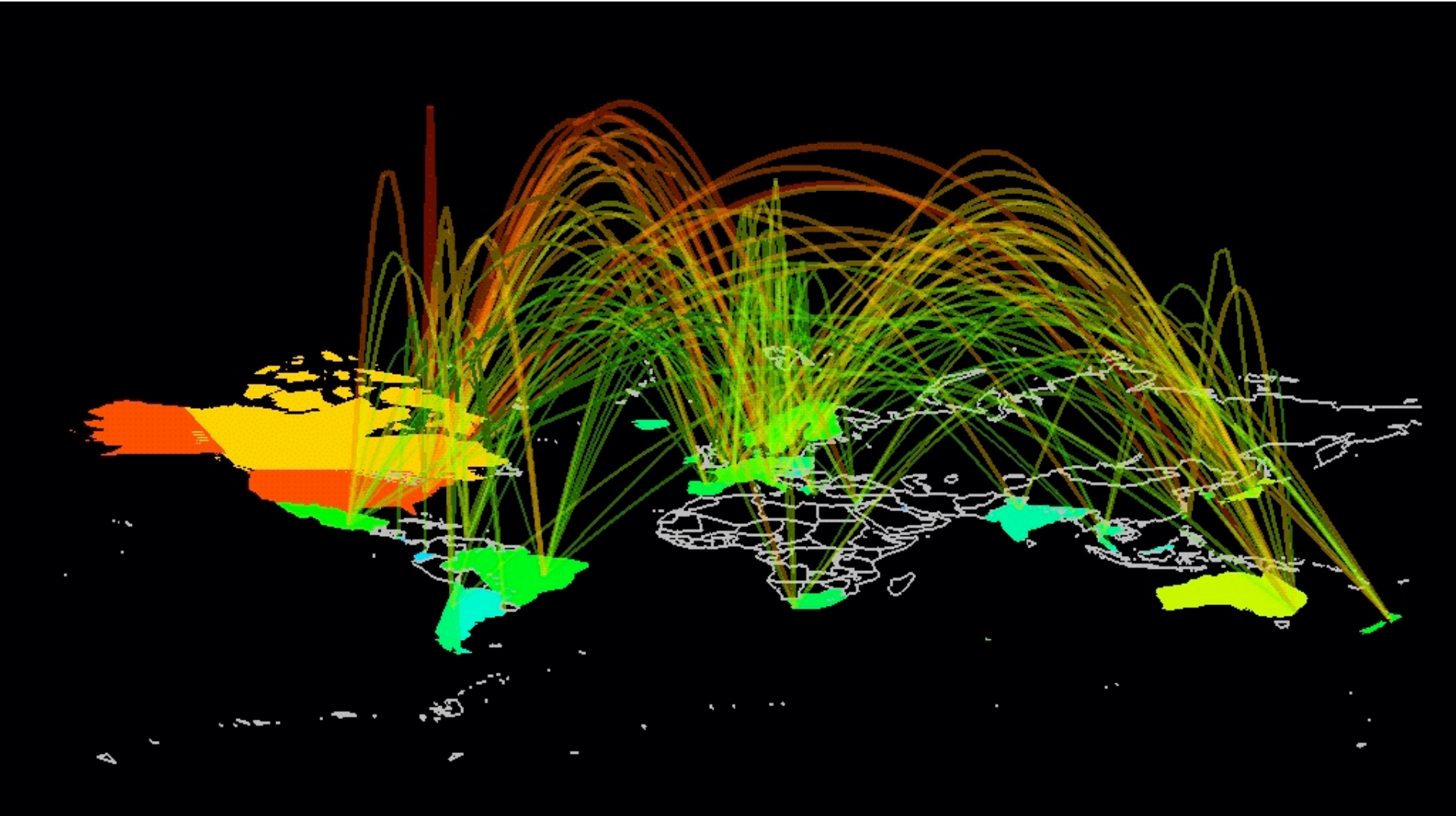
Migliaia di tracce prodotte ad ogni interazione (25 ns)

Dati sperimentali all'LHC

- La quantità dei dati prodotta è enorme! ~ 1.3 GB/s
- Se dovessimo salvare i dati su CD produrremmo una colonna di 20 km di dischi ogni l'anno
- Nuova soluzione sviluppata: GRID



GRID architecture



A black and white photograph of Albert Einstein, looking towards the camera with a questioning expression. He is pointing his right index finger at a chalkboard. A yellow speech bubble with a tail pointing to his finger contains the text "Tutto chiaro fin qui?". A blue rectangular shape is in the top-left corner of the slide. A small "Caption City" logo is in the bottom-left corner of the photo.

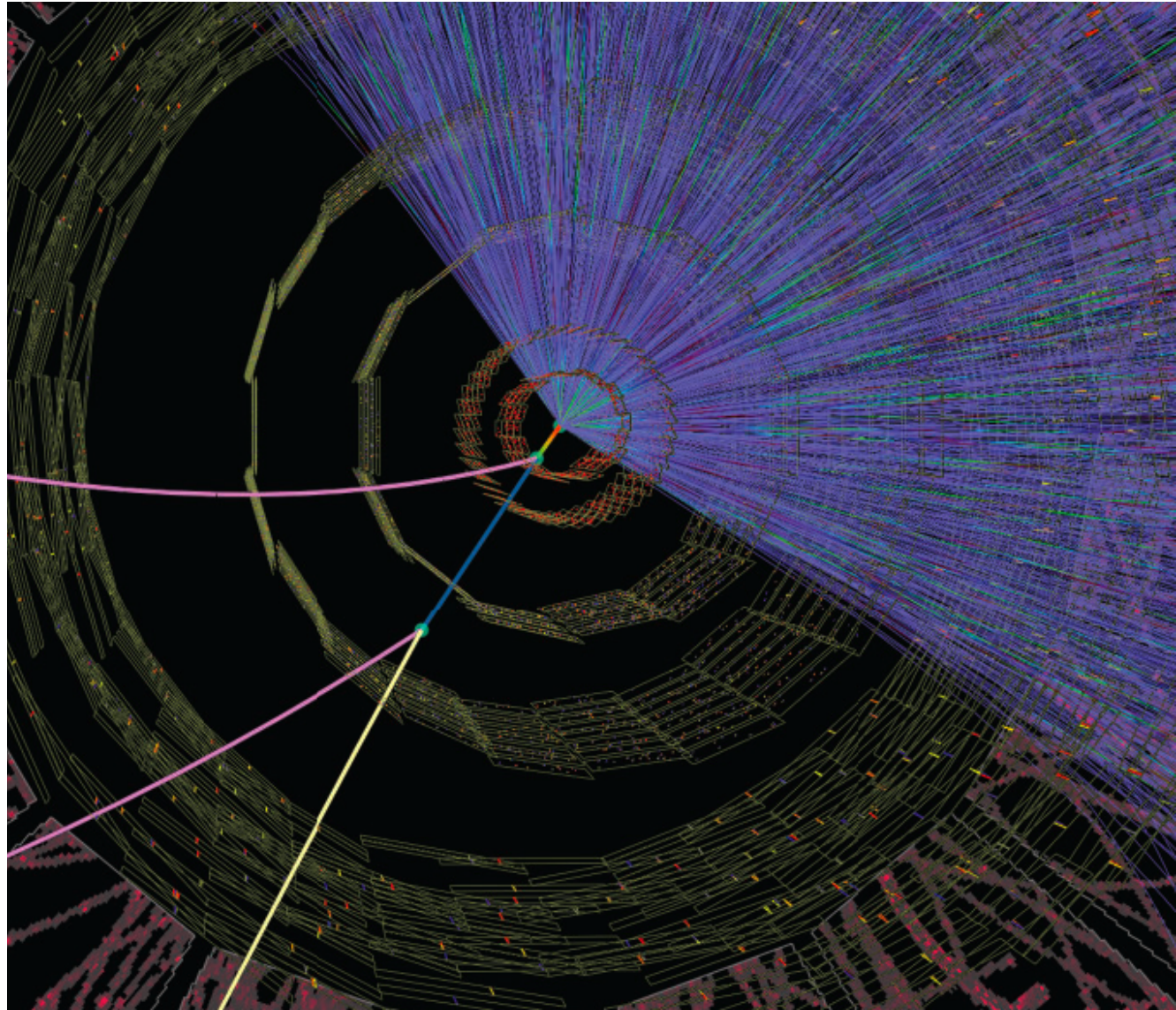
Tutto chiaro fin qui?

Caption
City

Selezione di tracce “buone”

Eccellente
tracking +
vertice +
Identificazione
di particelle
(PID)

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





$$\pi(u\bar{u})$$

$$Ks(d\bar{s})$$

$$p(uud)$$

$$n(udd)$$

$$\Lambda(uds)$$

$$K_s^0 \rightarrow \pi^+ \pi^-$$

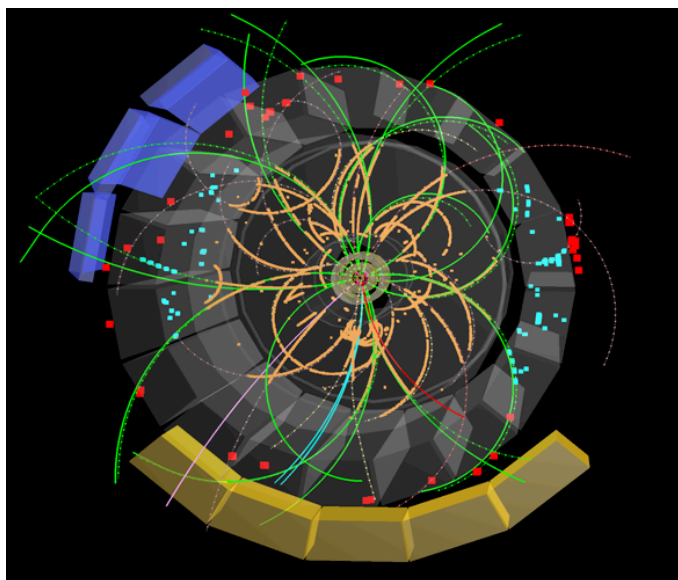
$$\tau = 0.89 \times 10^{-10} \text{ s}$$

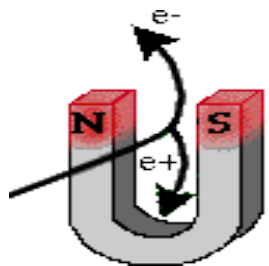
$$c\tau = 3 \times 10^{10} \text{ cm s}^{-1} \times 0.89 \times 10^{-10} \text{ s} = 2.67 \text{ cm dal punto d'interazione}$$

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

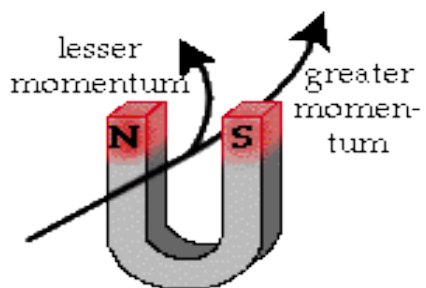
$$\tau = 2.6 \times 10^{-10} \text{ s}$$

$$c\tau = 3 \times 10^{10} \text{ cm s}^{-1} \times 10^{-9} \text{ s} = 7.2 \text{ cm dal punto d'interazione}$$



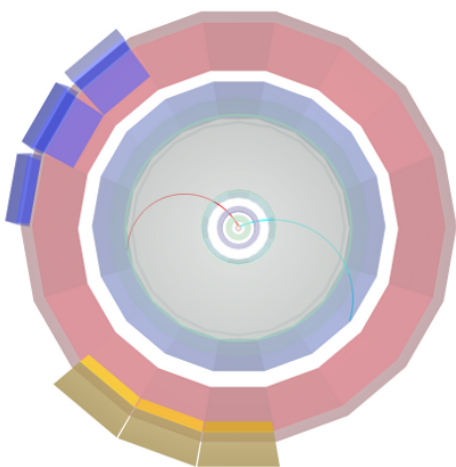


Identifica
la carica



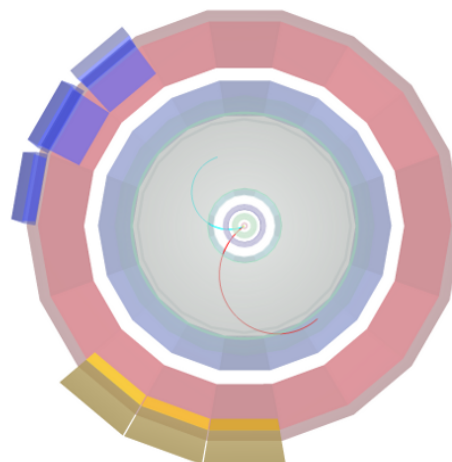
Misura
l'impulso

Simmetrico



$$K_s^0 \rightarrow \pi^+ \pi^-$$

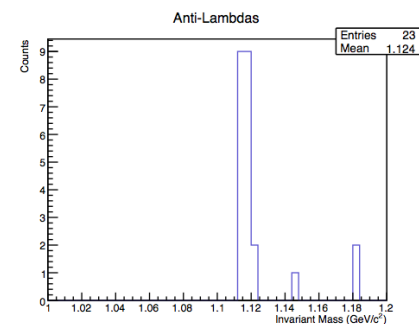
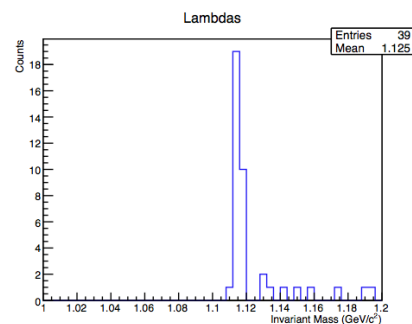
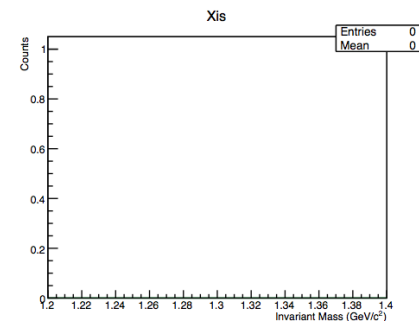
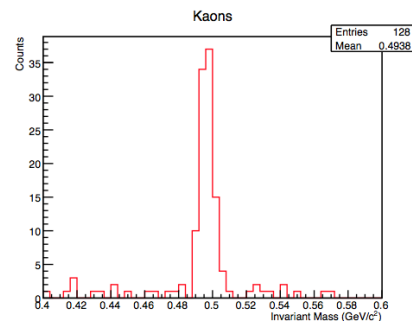
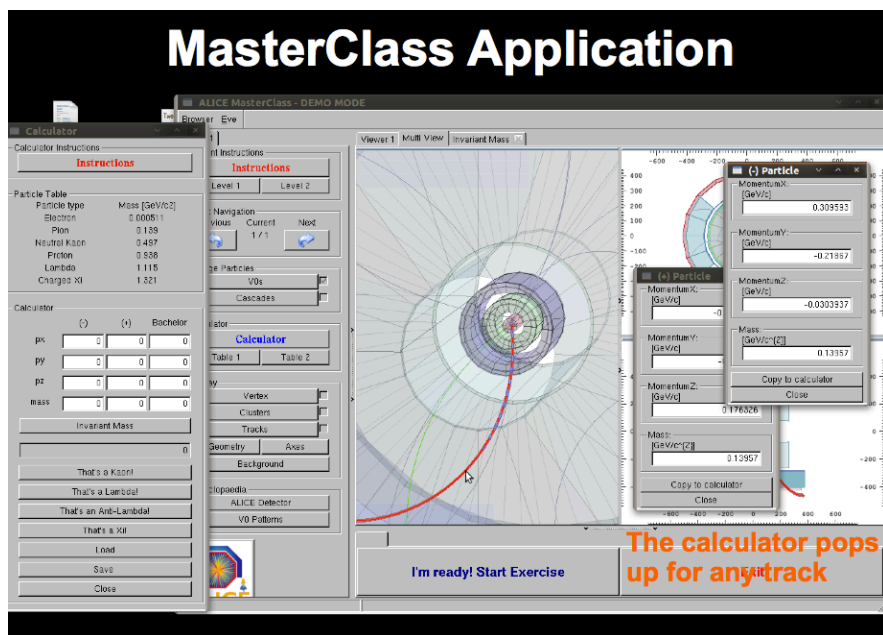
Asimmetrico



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

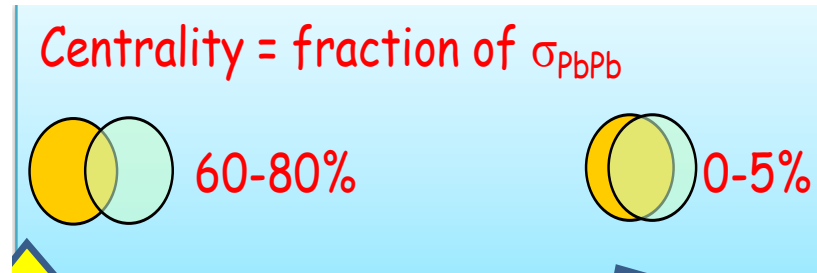
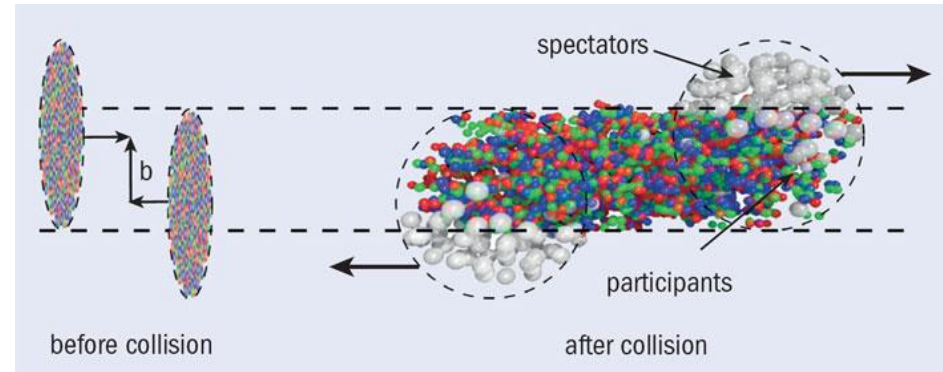
Prima parte

- Identificare i V0 (K^0 , Λ , anti- Λ) dai decadimenti
(V0 : due tracce con carica opposta
provenienti da uno stesso vertice secondario)
- Calcolo della massa invariante
- Classificare le particelle secondo la loro massa invariante ed il tipo di particelle di decadimento

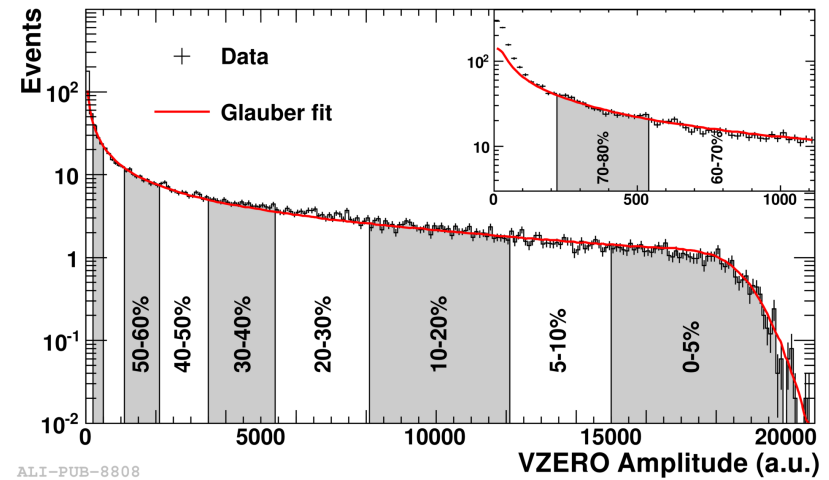


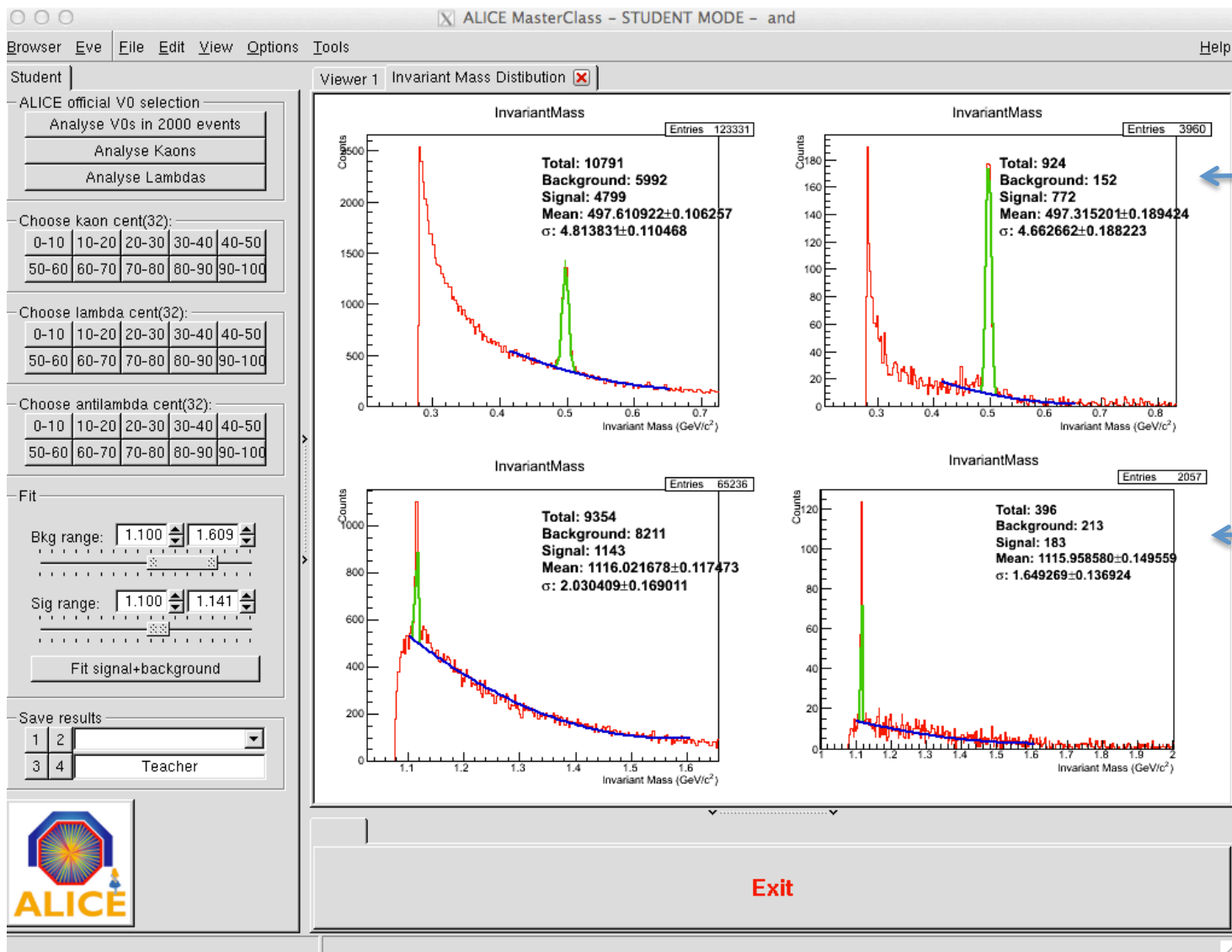
Seconda parte (Centralità)

- Analisi di un campione di migliaia di eventi
- Riempire gli istogrammi di massa invariante per K_s , Λ anti- Λ
- Fit del fondo (background) con polinomio di secondo e segnale (gaussiana)
- Trovare il numero di K_s , Λ , anti- Λ dopo la sottrazione del fondo in differenti bin di centralità nelle collisioni Pb-Pb





| Centrality | $dN_{\text{ch}}/d\eta$ | $\langle N_{\text{part}} \rangle$ | $(dN_{\text{ch}}/d\eta)/(\langle N_{\text{part}} \rangle/2)$ |
|------------|------------------------|-----------------------------------|--|
| 0%–5% | 1601 ± 60 | 382.8 ± 3.1 | 8.4 ± 0.3 |
| 5%–10% | 1294 ± 49 | 329.7 ± 4.6 | 7.9 ± 0.3 |
| 10%–20% | 966 ± 37 | 260.5 ± 4.4 | 7.4 ± 0.3 |
| 20%–30% | 649 ± 23 | 186.4 ± 3.9 | 7.0 ± 0.3 |
| 30%–40% | 426 ± 15 | 128.9 ± 3.3 | 6.6 ± 0.3 |
| 40%–50% | 261 ± 9 | 85.0 ± 2.6 | 6.1 ± 0.3 |
| 50%–60% | 149 ± 6 | 52.8 ± 2.0 | 5.7 ± 0.3 |
| 60%–70% | 76 ± 4 | 30.0 ± 1.3 | 5.1 ± 0.3 |
| 70%–80% | 35 ± 2 | 15.8 ± 0.6 | 4.4 ± 0.4 |








| centrality | <Npart> | Nevents | NKs | efficiency Ks | yield Ks | Ks enhancem |
|------------|---------|---------|------|---------------|----------|-------------|
| 0-10 | 360 | 213 | 4816 | 0.26 | 86.963 | 1.933 |
| 10-20 | 260 | 290 | 4638 | 0.26 | 61.512 | 1.893 |
| 20-30 | 186 | 302 | 3750 | 0.29 | 42.818 | 1.842 |
| 30-40 | 129 | 310 | 2610 | 0.29 | 29.032 | 1.800 |
| 40-50 | 85 | 302 | 1493 | 0.29 | 17.047 | 1.604 |
| 50-60 | 52 | 300 | 777 | 0.29 | 8.931 | 1.374 |
| 60-70 | 30 | 315 | 409 | 0.35 | 3.710 | 0.989 |
| 70-80 | 16 | 350 | 149 | 0.26 | 1.637 | 0.819 |



conosciuto


dato


misurato


dato


calcolato



Efficienza = $N_{\text{particelle(misurate)}} / N_{\text{particelle(prodotte)}}$

Yield : numero di particelle prodotte per interazione

Yield = $N_{\text{particelle(prodotte)}} / N_{\text{eventi}} = N_{\text{particelle(misurate)}} / (\text{efficienza} \times N_{\text{eventi}})$

Strangeness enhancement: yield per particella normalizzato al numero di nucleoni partecipanti nella collisione e diviso per lo yield delle collisioni protone-protone

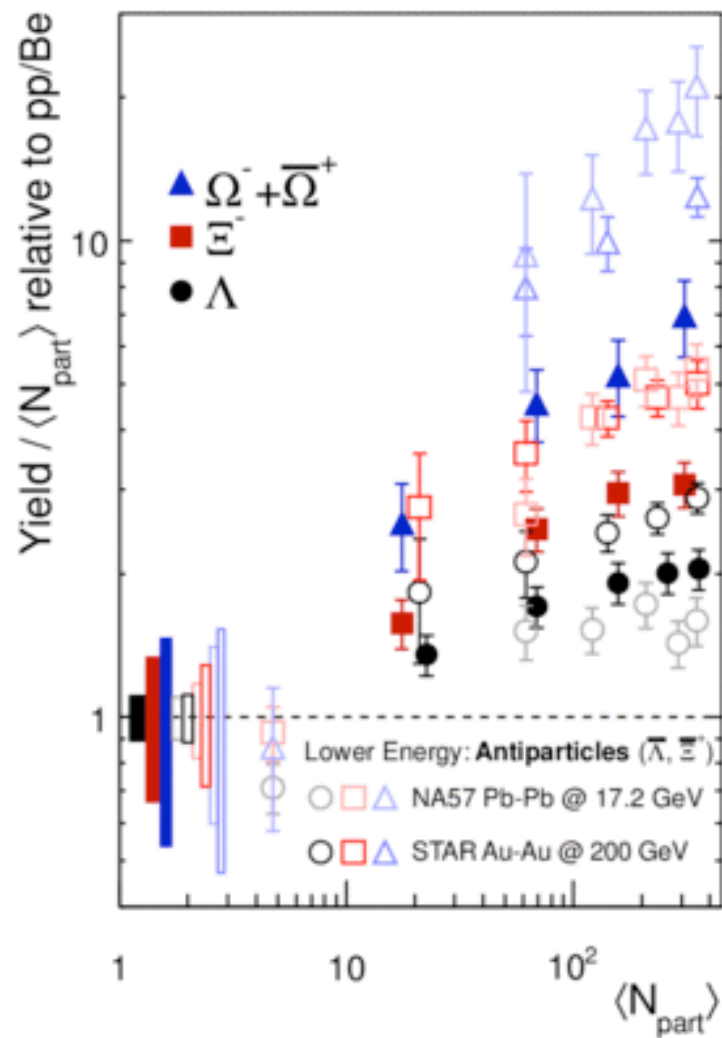
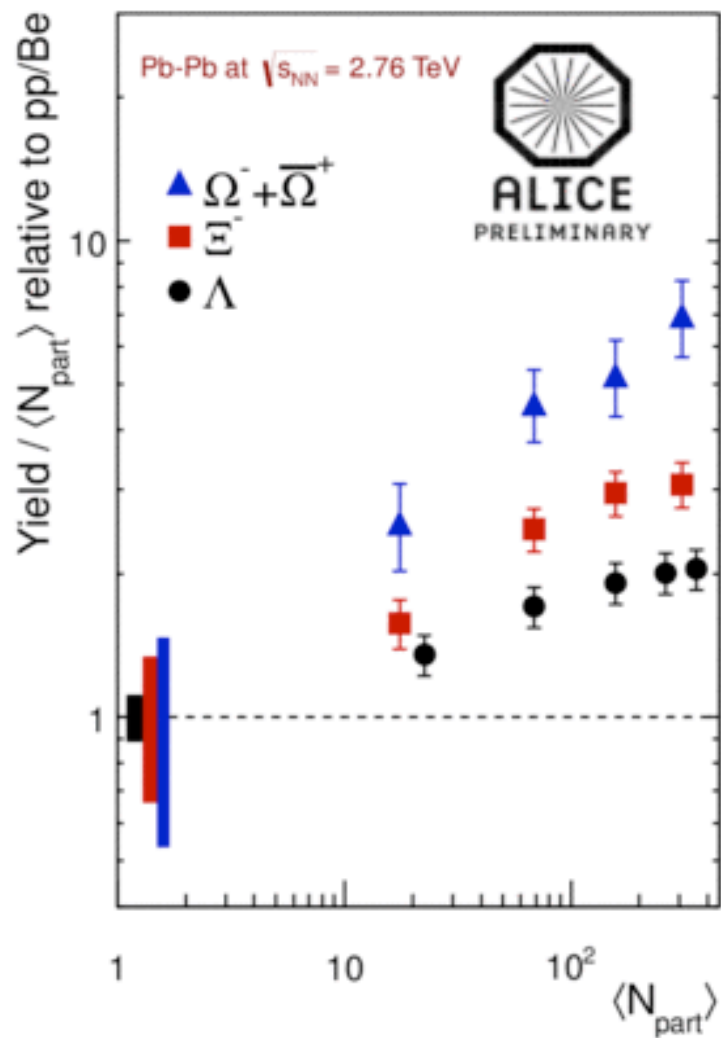
K_s -Yield (pp) = 0.25 /interazione ; Λ -Yield(pp) = 0.0617 /interazione ; $\langle N_{\text{part}} \rangle = 2$ per pp

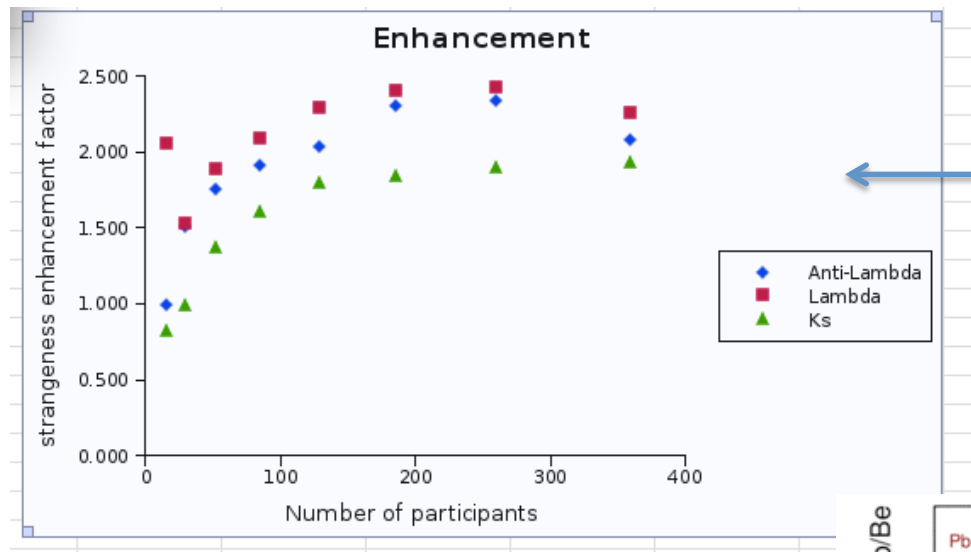
Dove scaricare il materiale

<http://alice.physicsmasterclasses.org/MasterClassWebpage.html>

Video: All'interno dell'esperimento ALICE

<https://www.youtube.com/watch?v=NFRSX00qeIU>





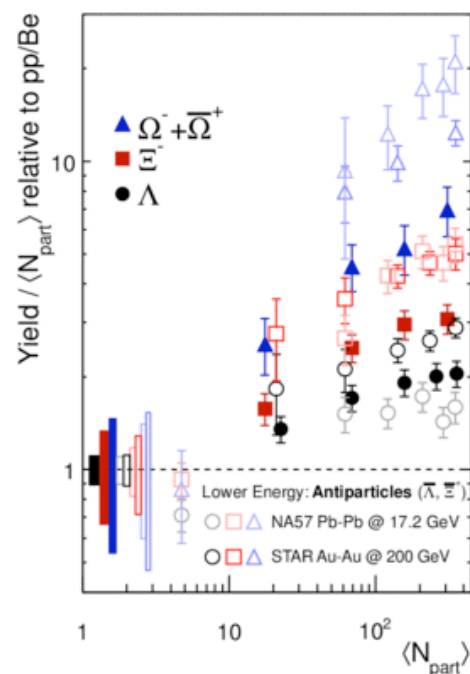
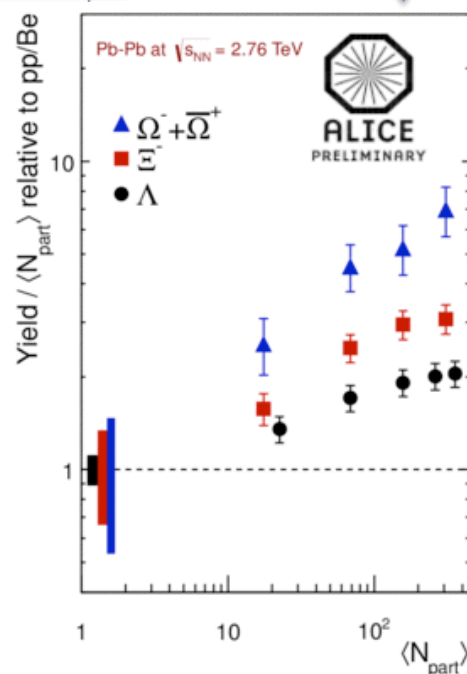
Example of presentation of results

Preliminary ALICE results
+ lower energy (STAR, NA57) results

Possible comments

Enhancement increases with number of strange quarks in the hadron (Λ has 1 strange quark, Ξ has 2, Ω has 3)

Enhancement decreases with collision energy (going from SPS to RHIC to LHC)



ALI-PREL-43394