Alice
l'esperimento e la fisica

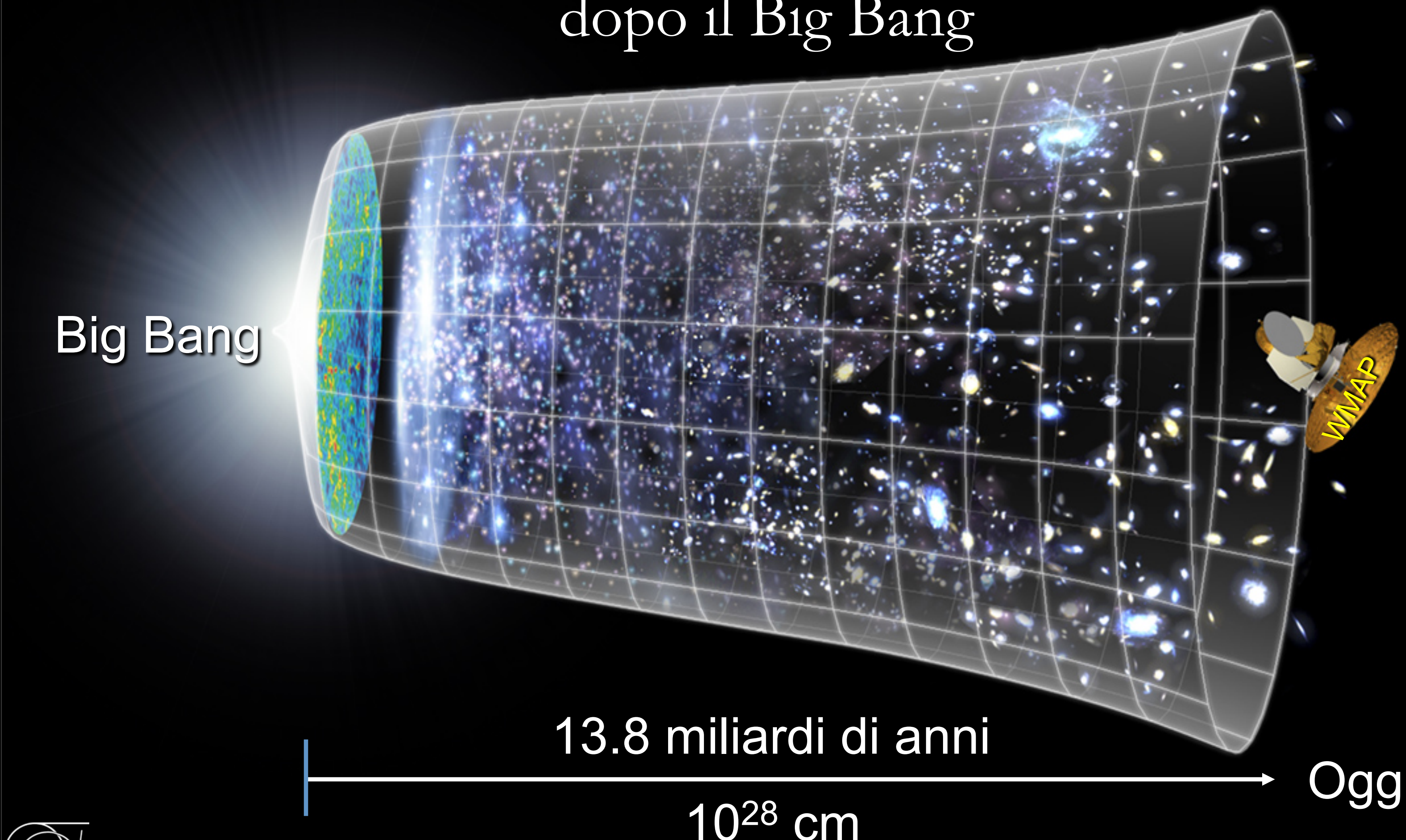
INFN Frascati

Pasquale Di Nezza

Masterclass 2013

La prossima sfida della scienza

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

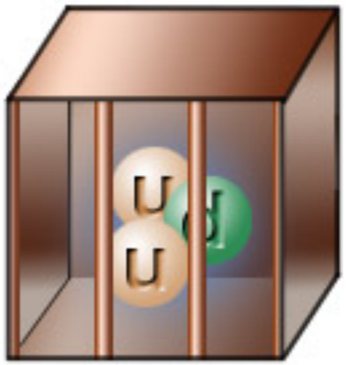


Alice … in viaggio nel tempo

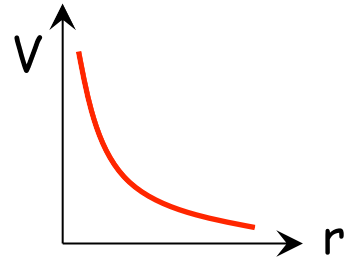
Fino a circa un centomillesimo di secondo dal Big Bang (10^{-37} - 10^{-5} s) l'Universo era formato da una "zuppa" di quark e gluoni … il Quark Gluon Plasma (QGP)

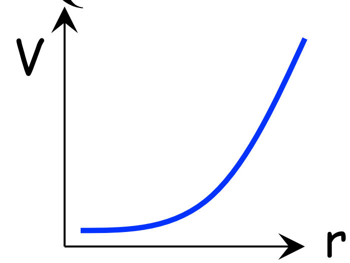
- Perchè studiare il QGP?
- Quali sono le caratteristiche del QGP?
- E' possibile riprodurlo in laboratorio?

Liberta' Asintotica → Confinamento



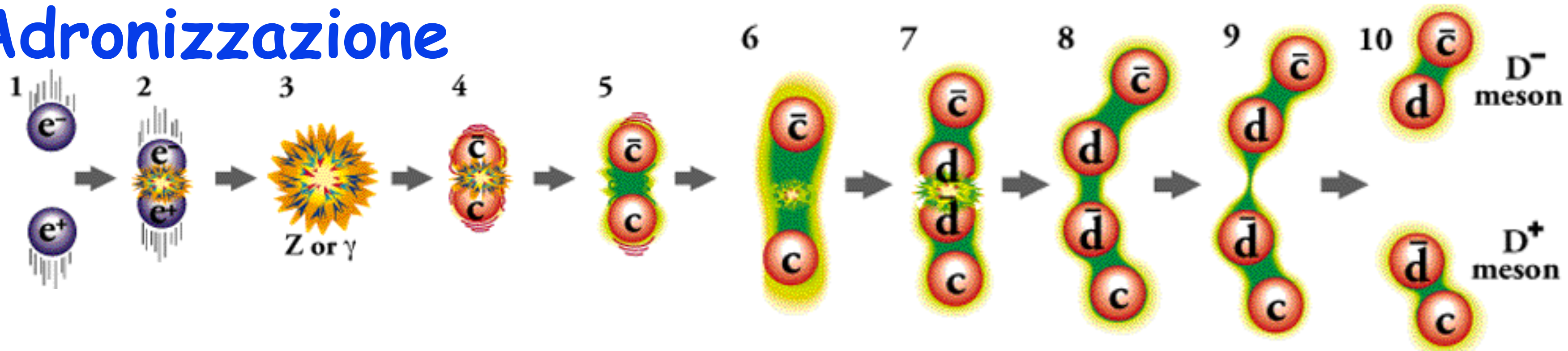
$$V_{Coulomb} \propto \frac{q_1 q_2}{r} \Rightarrow V_{QCD} \propto e^{k \cdot r}$$



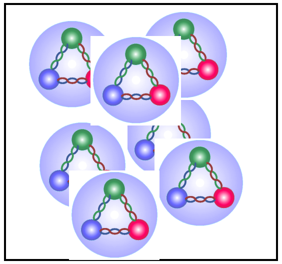


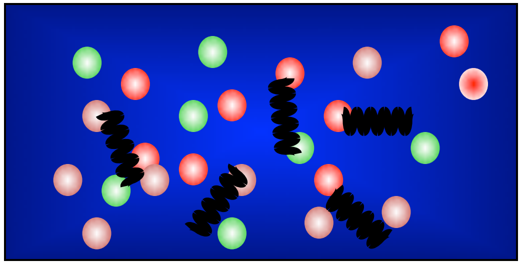
Allontanando i quark, si crea una tensione con energia sufficiente a creare altre particelle (1000 MeV / fm)

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

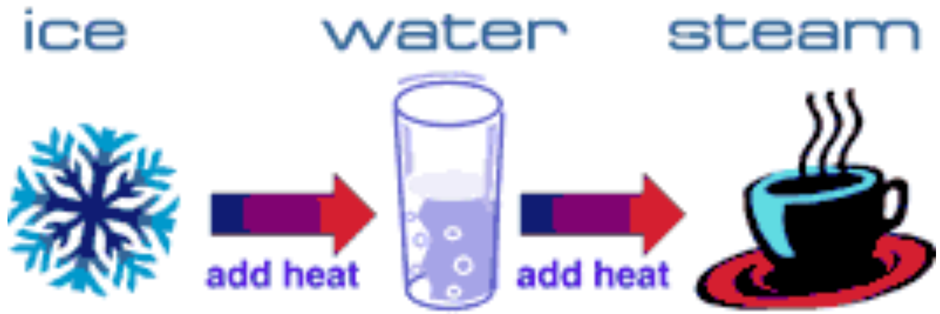
Nobel Prize 2005

D. Gross
H.D. Politzer
F. Wilczek

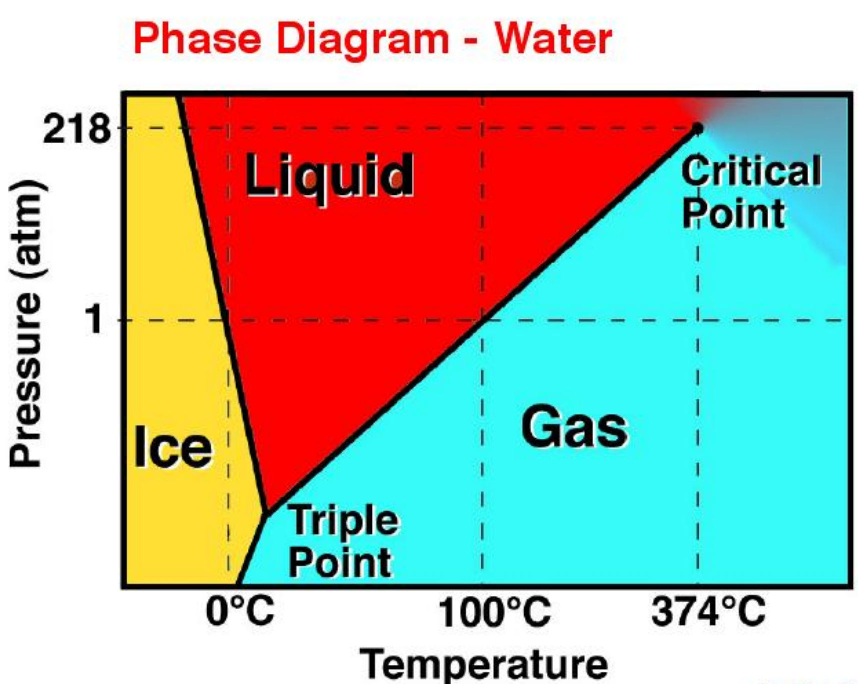
QCD Asymptotic Freedom (1973)

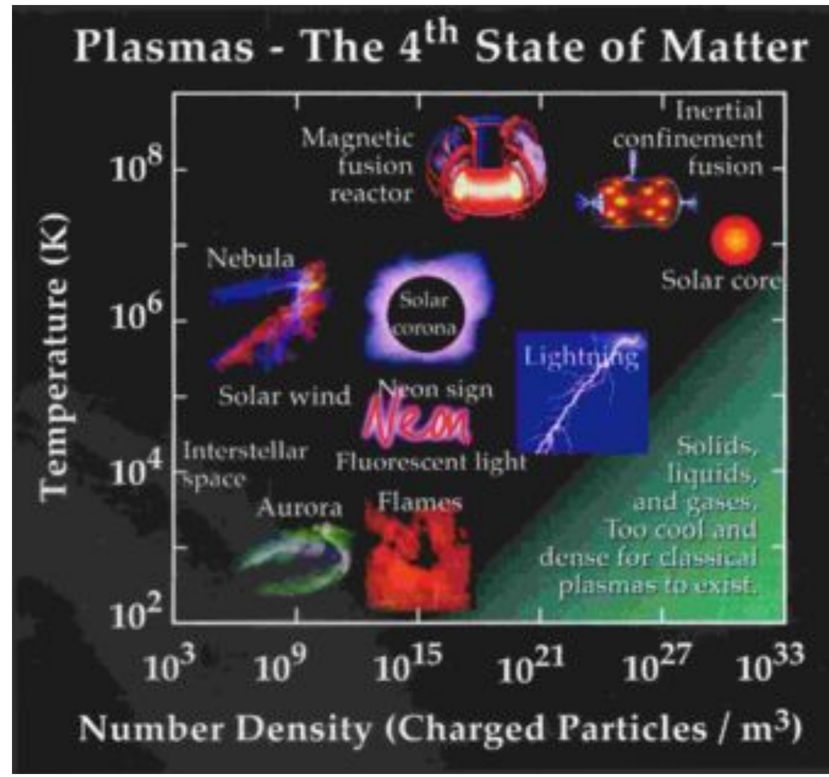
"Before [QCD] we could not go back further than 200,000 years after the Big Bang. Today…since QCD simplifies at high energy, we can extrapolate to very early times when nucleons melted…to form a quark-gluon plasma."
David Gross, Nobel Lecture (RMP 05)

Fasi della materia "normale"



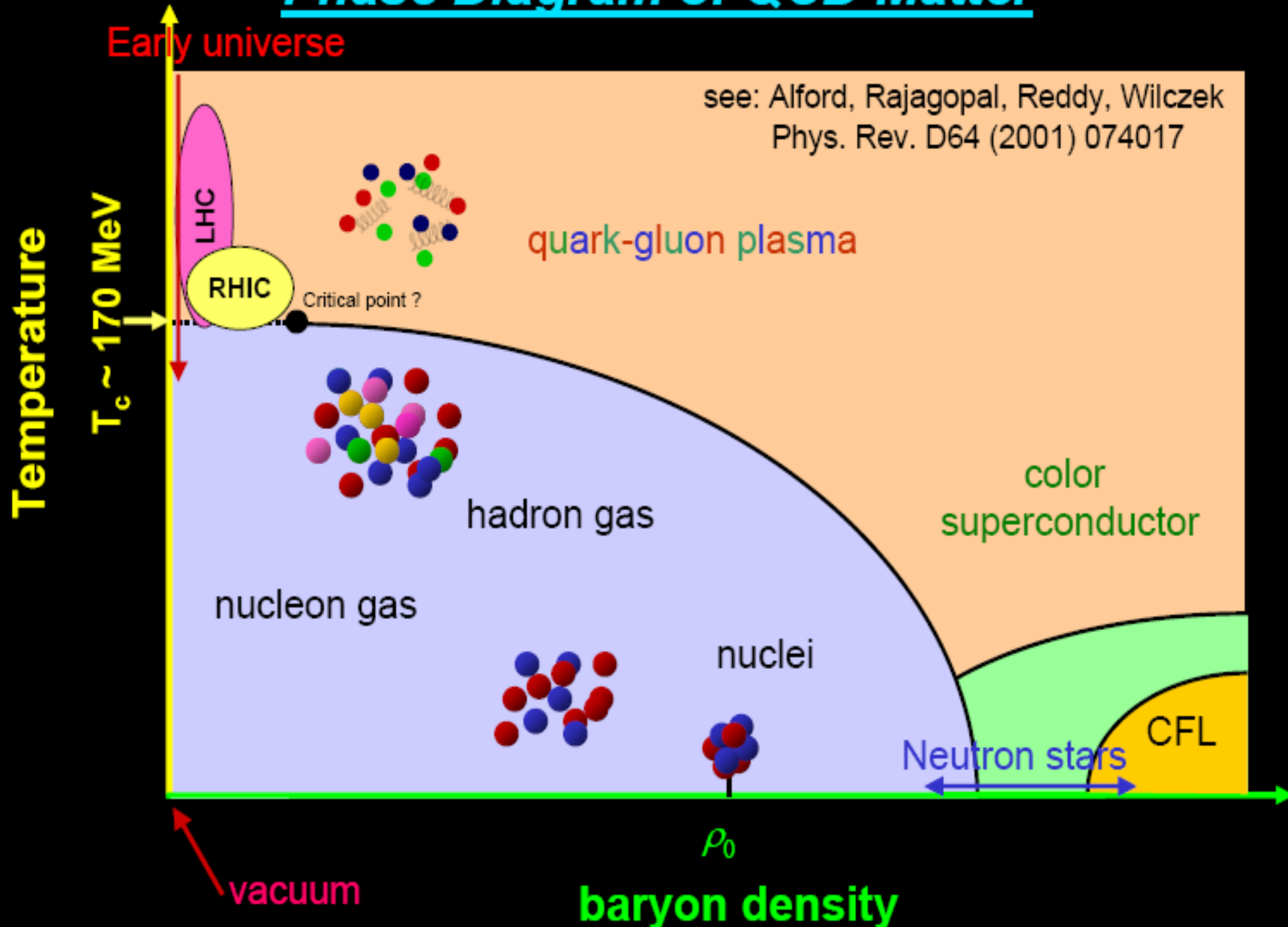
solido liquido gassoso





Plasma Classico

Phase Diagram of QCD Matter



Una “zuppa“ ricca di informazioni

Evoluzione spazio-temporale della nascita di un adrone

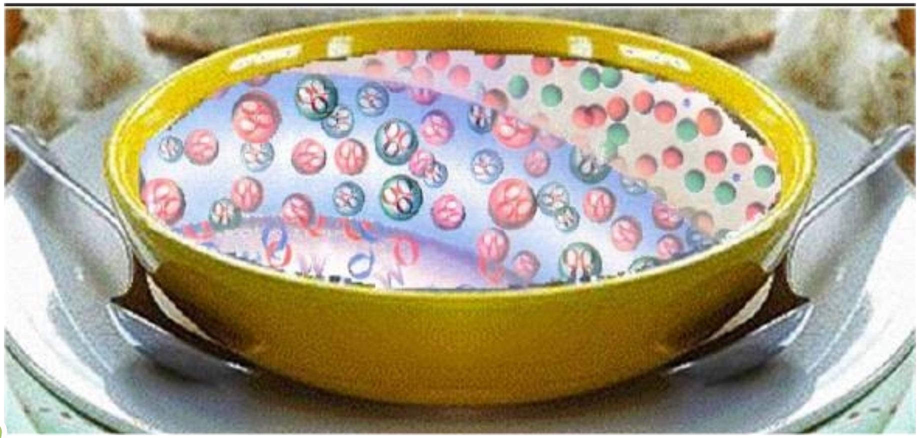
Proprietà della QCD ad alte temperature: gradi di libertà, viscosità, conduttività, …

Flusso ellittico

Restaurazione della simmetria chirale

Freezout

Puzzle barionico



Instabilità di plasma, caos di colore

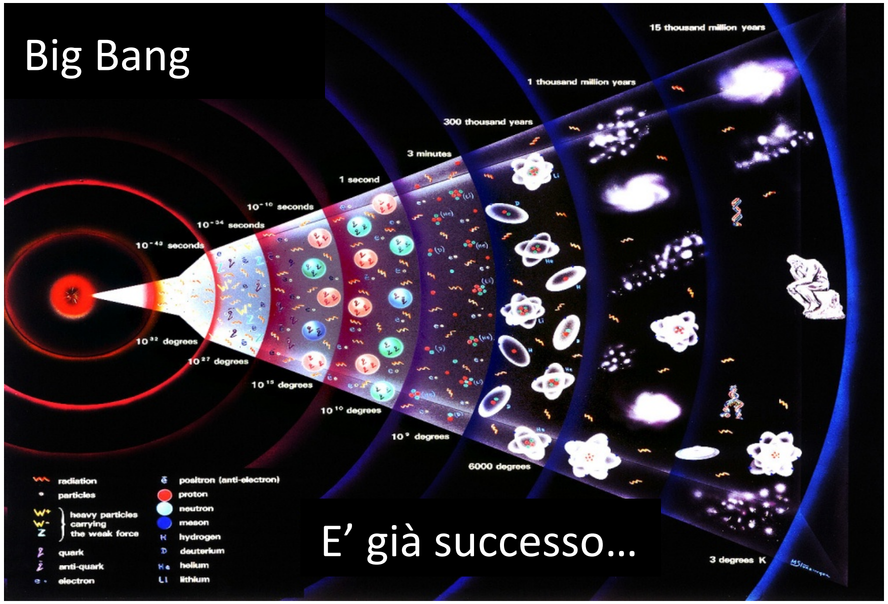
Transizione di fase q-g nelle teorie cosmologiche dell’Universo primordiale

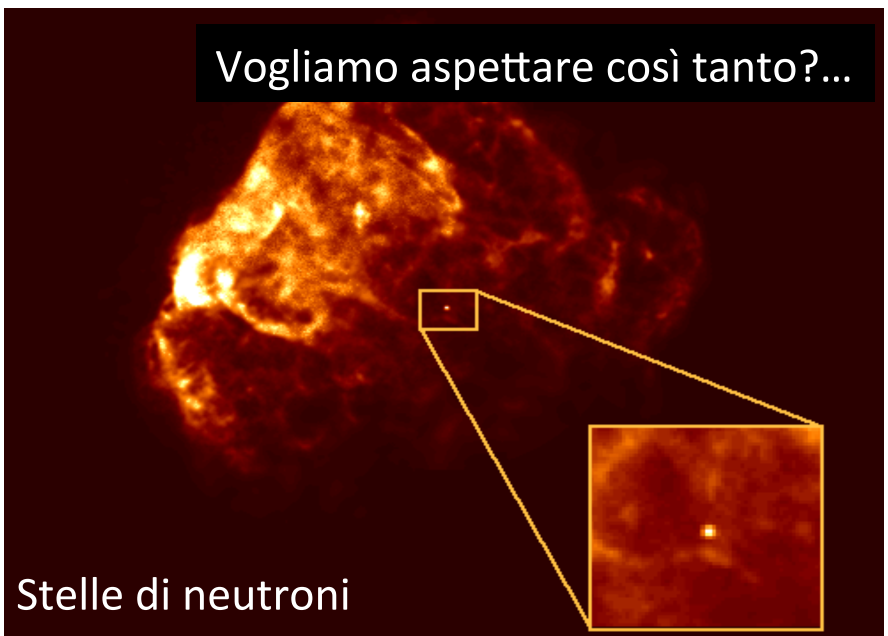
Equazione di stato della QCD

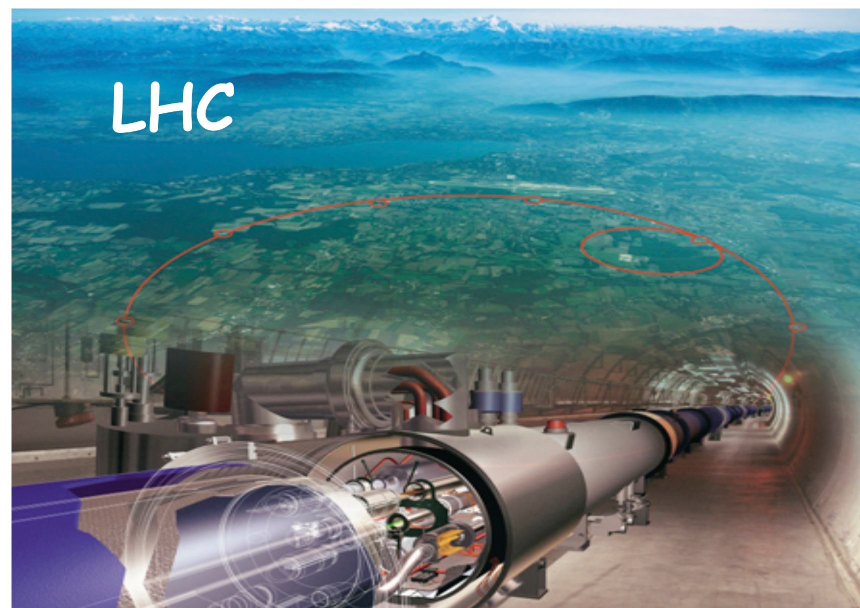
Perdita di energia partonica

Composizione chimica

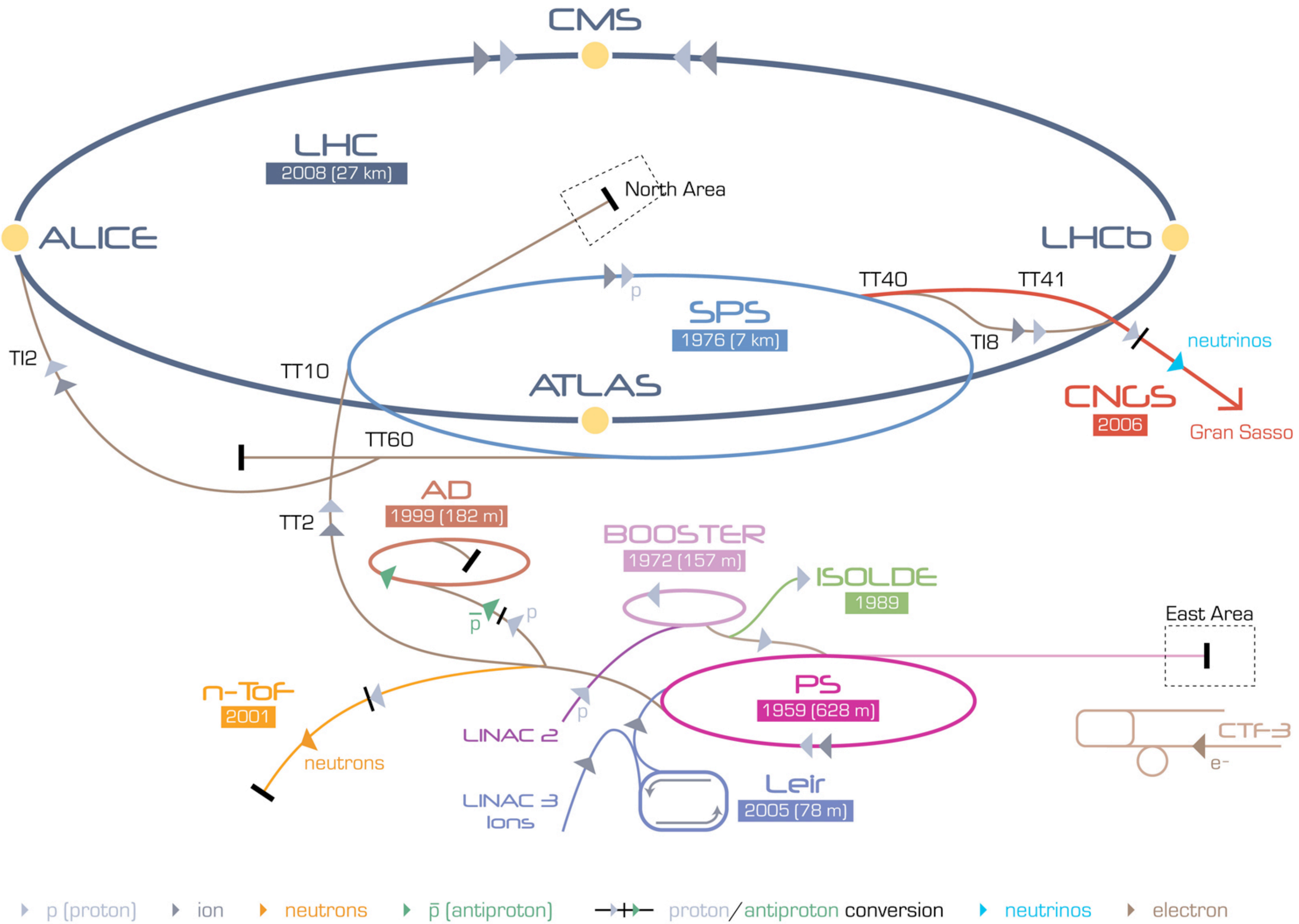
Dove si produce il QGP ?







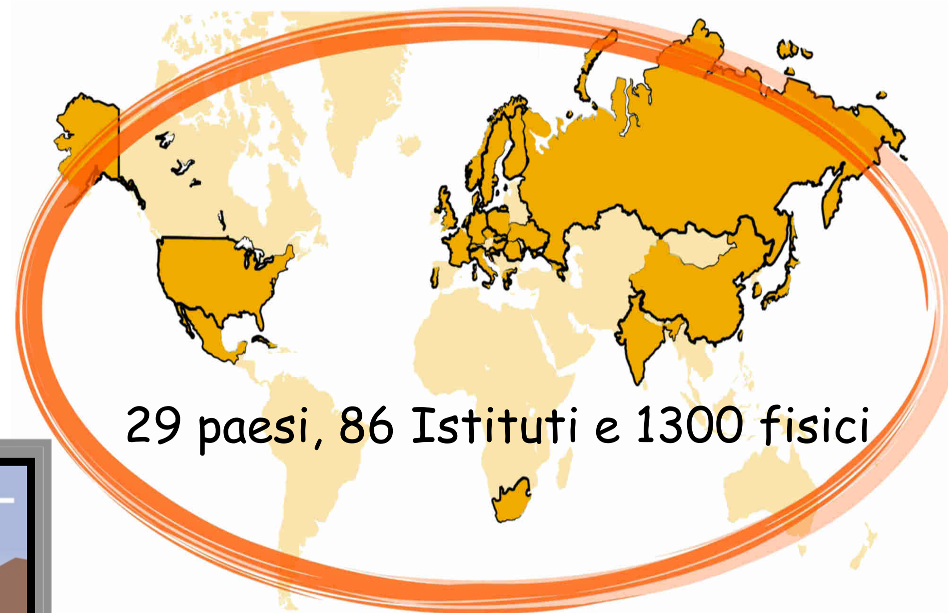
Complesso degli acceleratori del CERN

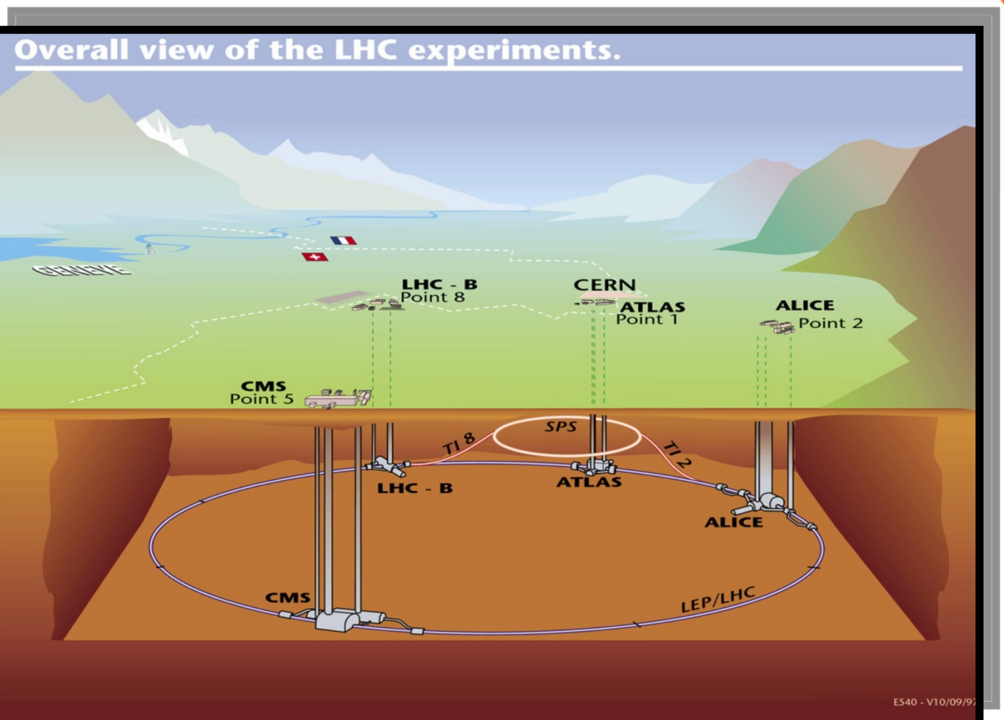


LHC, il più potente acceleratore del mondo

ALICE: A Large Ion Collider Experiment

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





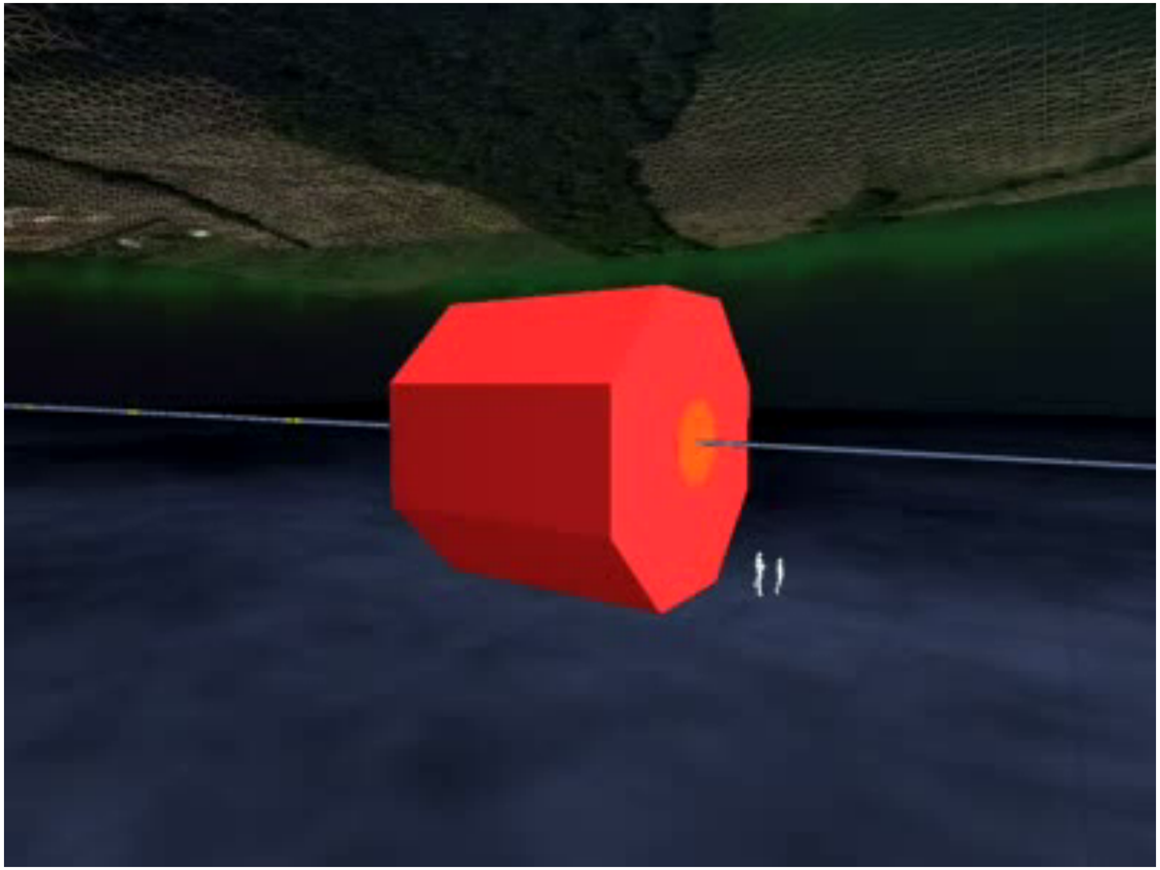
200 fisici Italiani: BA, BO, CA, CT, LNF, LNL, PD, RM1, SA, TO, TS

QGP attraverso gli Heavy Ions

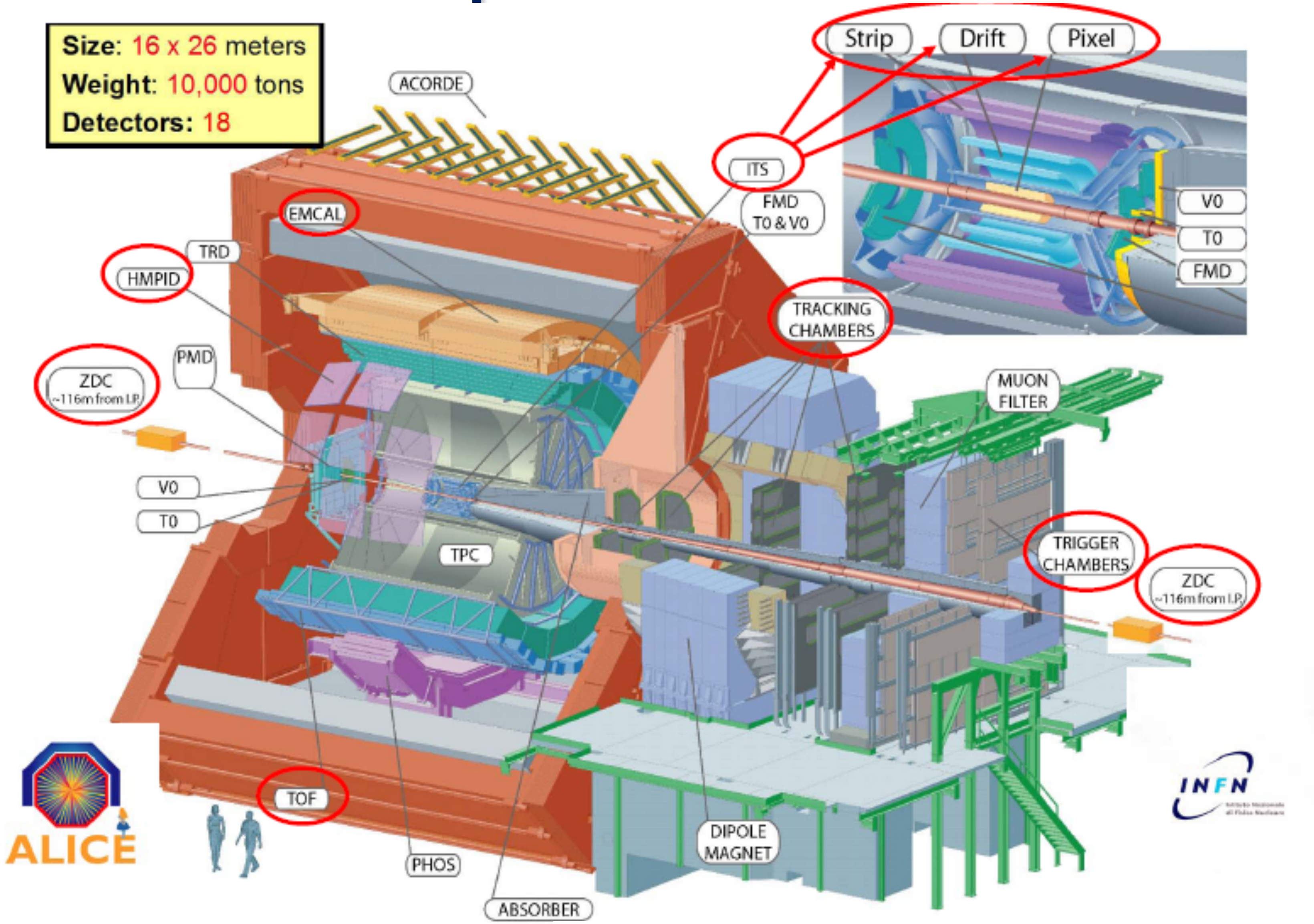
Energia: $E_{beam} = 7\frac{Z}{A}\text{TeV} \Rightarrow \sqrt{s} = 5.5\ \text{TeV/A per Pb - Pb}$

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

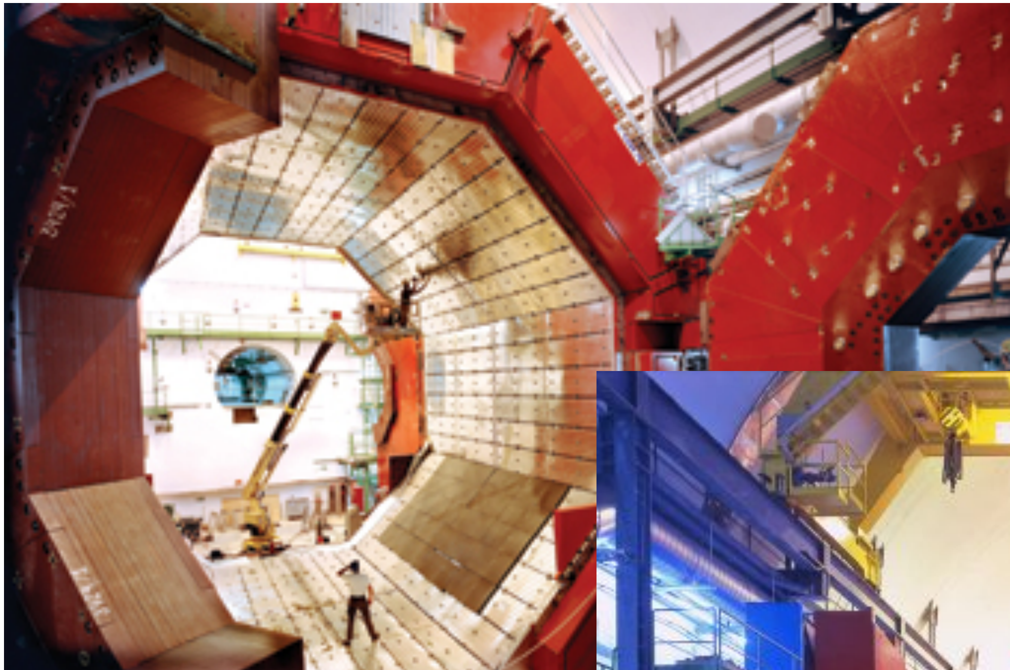
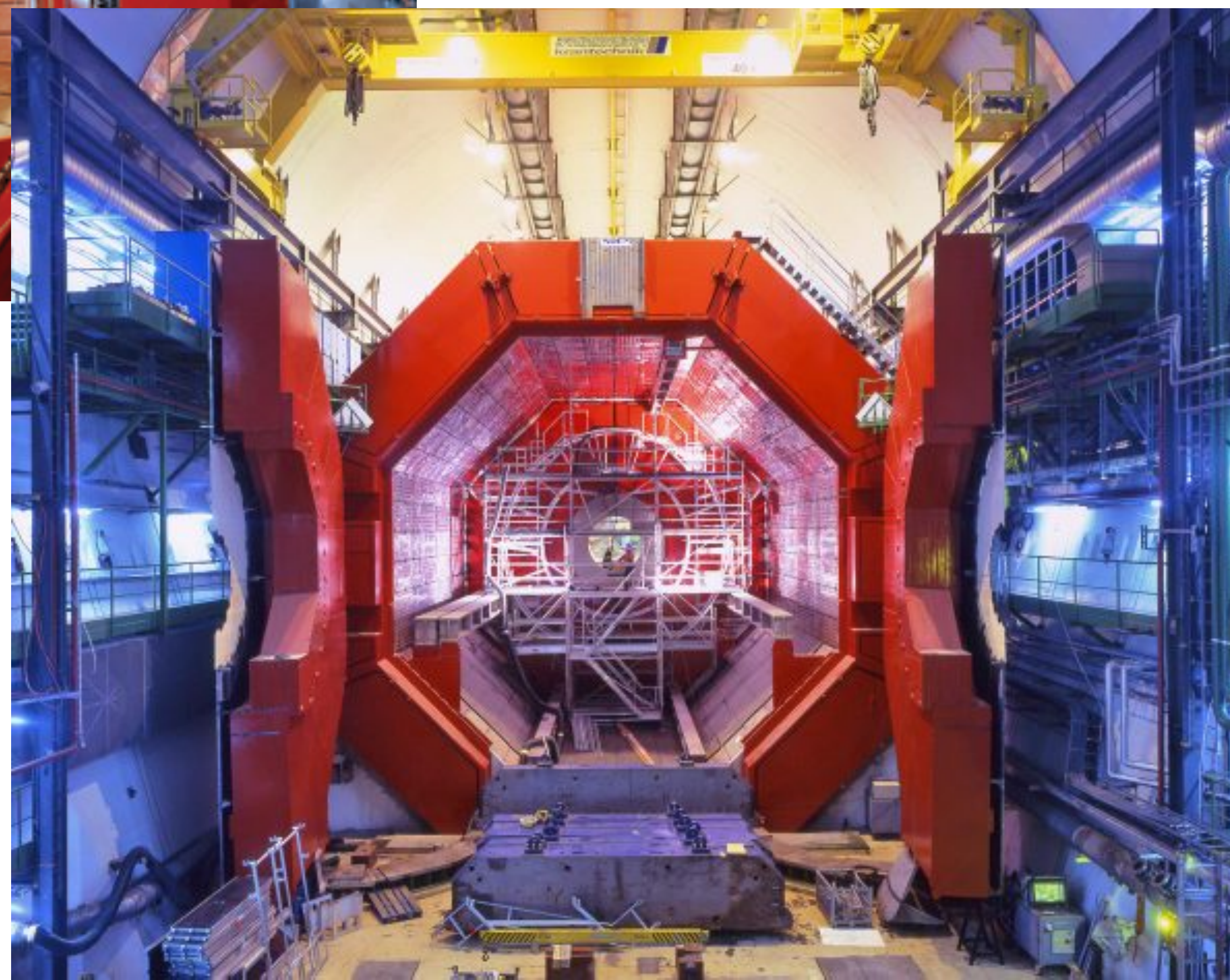
La collisione in Alice

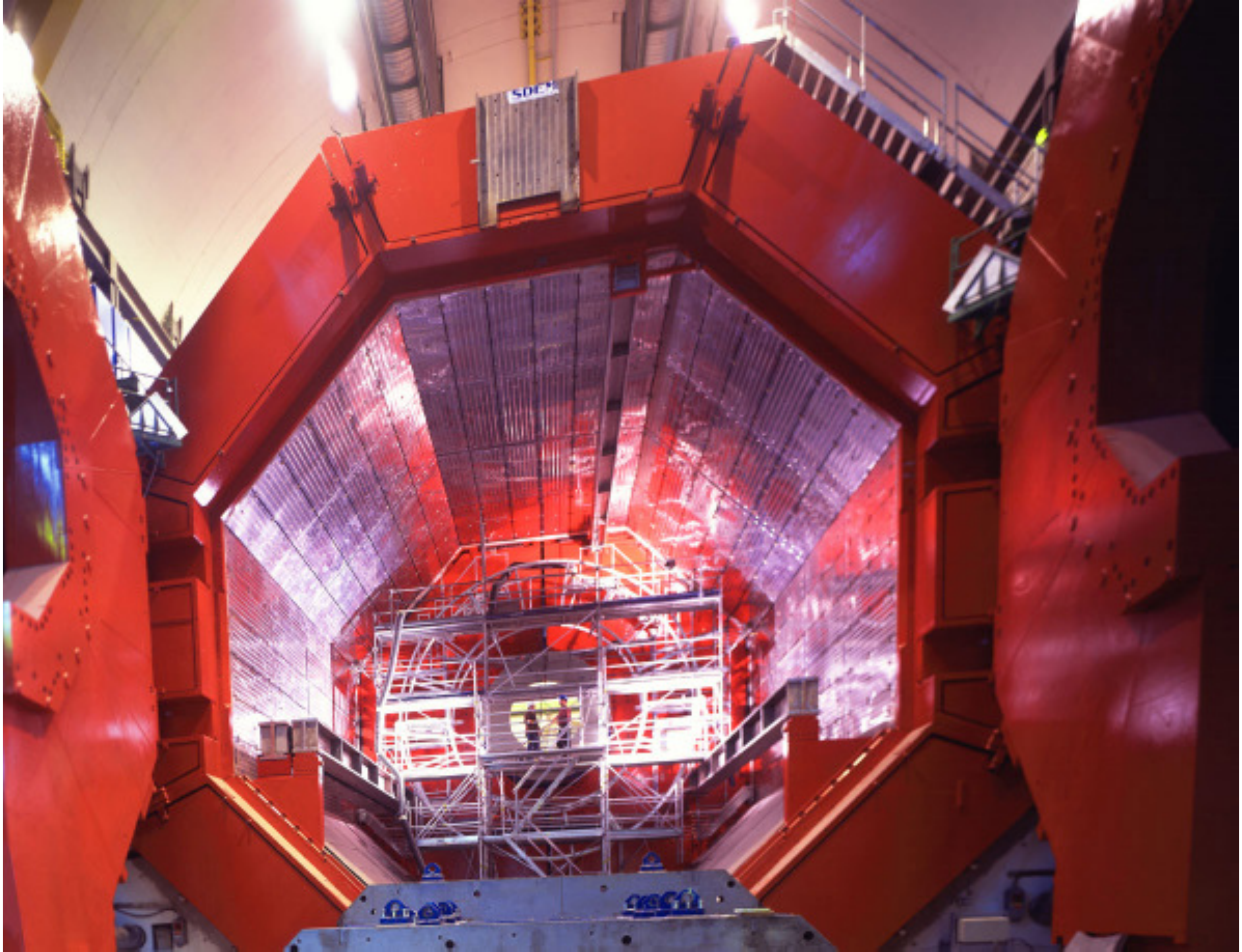


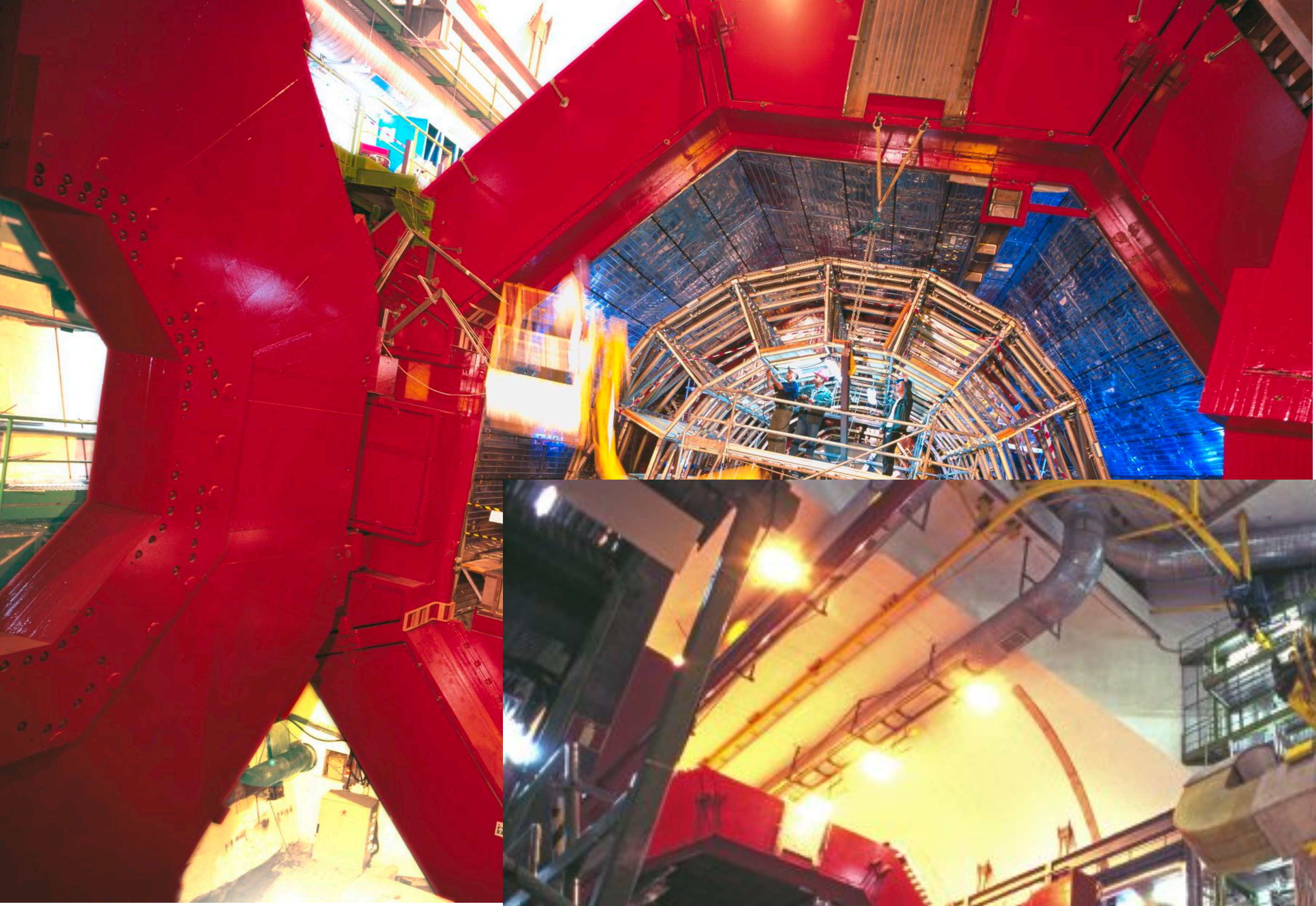
Lo spettrometro

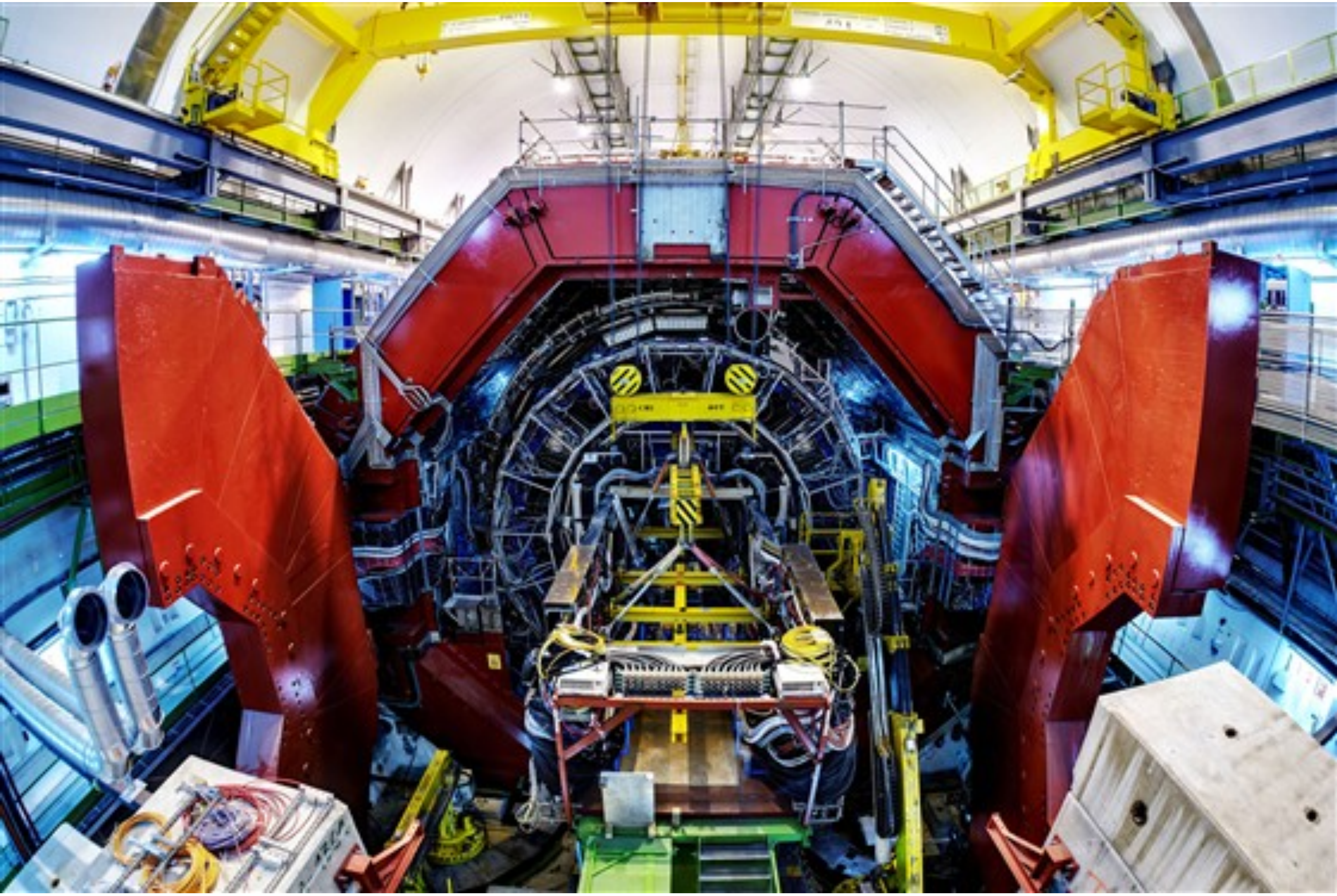


: Rivelatori sotto la completa o parziale responsabilità INFN

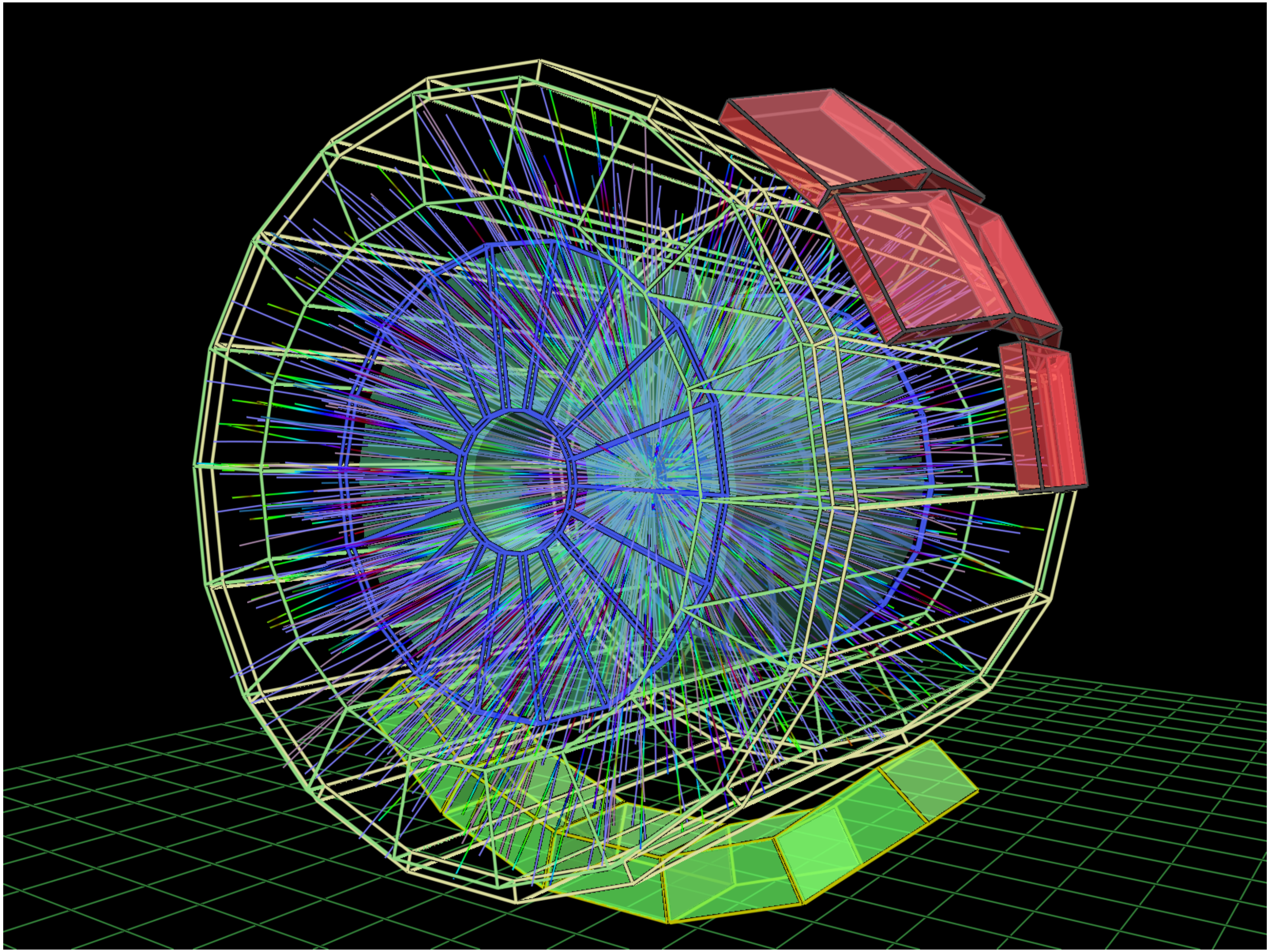





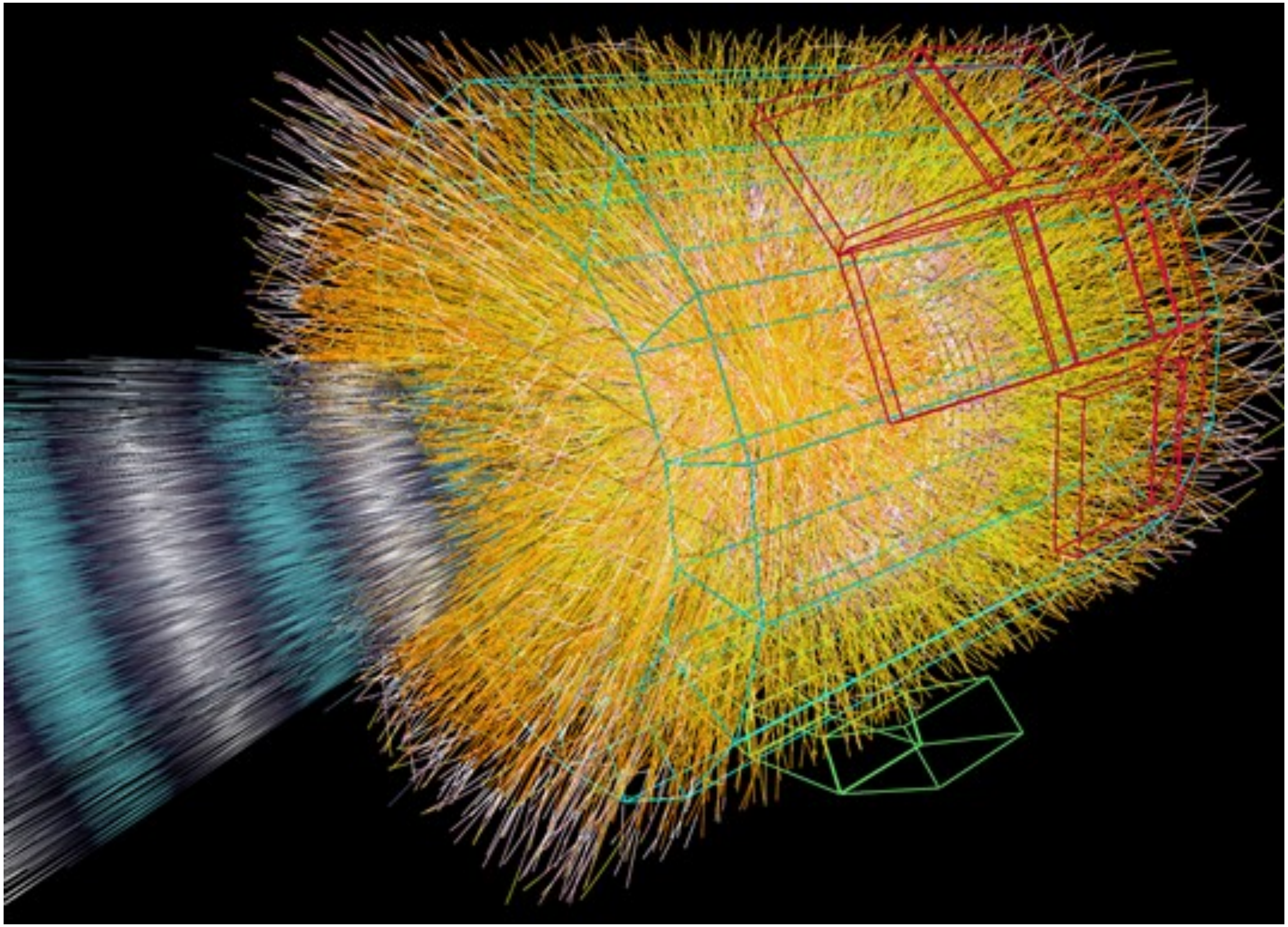




Eventi pp in Alice



Eventi PbPb in Alice

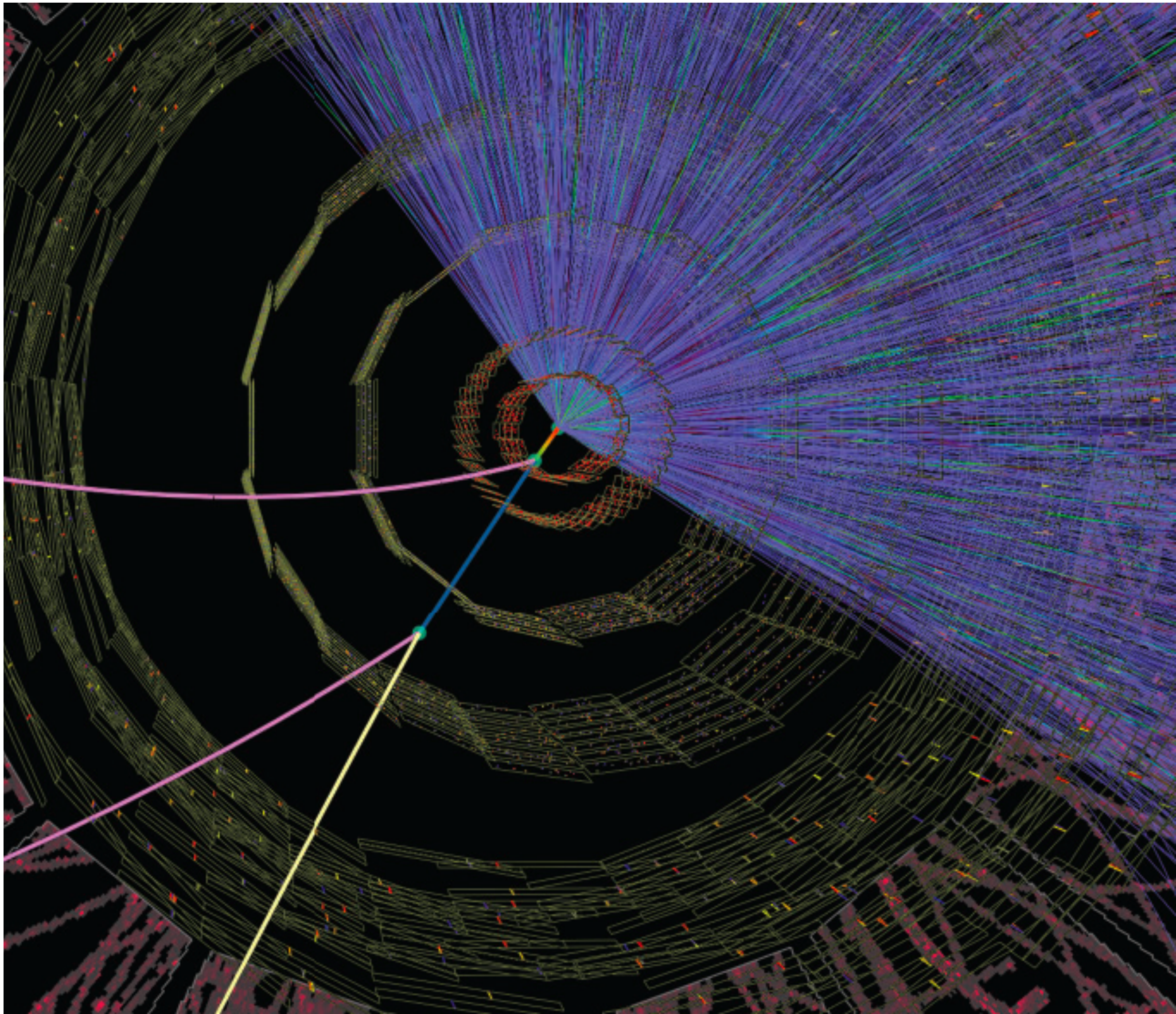


Migliaia di tracce prodotte ad ogni interazione (25 ns)

Selezione di tracce "buone"

Eccellente tracking + vertice + Identificazione di particelle (PID)

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



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

$Ks(d\overline{s})$

$p(uud)$

$n(udd)$

$\Lambda(uds)$

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

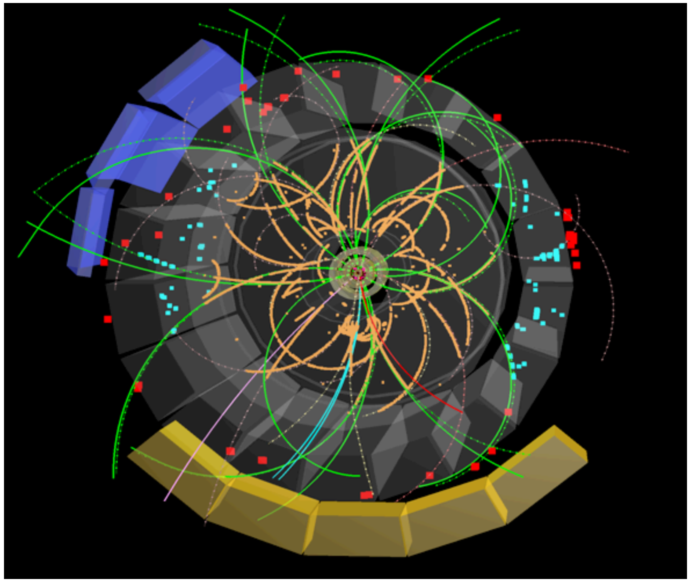
$\tau = 0.89 \times 10^{-10}$ s

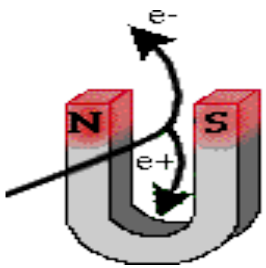
$c\tau = 3\times10^{10}$ cm $s^{-1} \times 0.89 \times10^{-10}$ s = 2.67 cm dal punto d'interazione

$\Lambda \rightarrow \pi^- p$

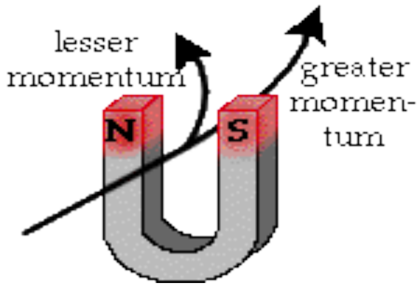
$\tau = 2.6 \times 10^{-10}$ s

$c\tau = 3\times10^{10}$ cm $s^{-1} \times 10^{-9}$ s = 7.2 cm dal punto d'interazione



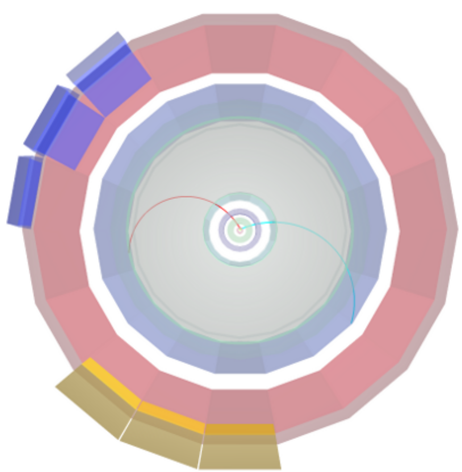


Identifica
la carica



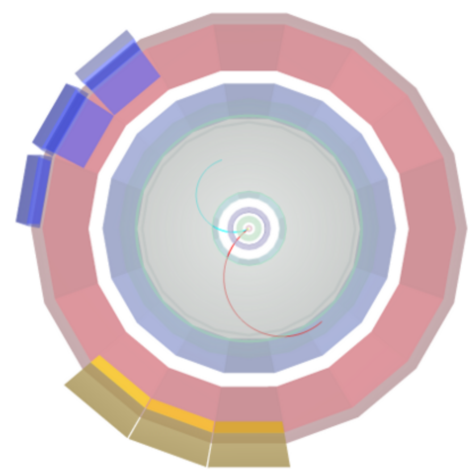
Misura
l'impulso

Simmetrico



$\boxed{K^0_s \rightarrow \pi^+\pi^-}$

Asimmetrico



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

Prima parte

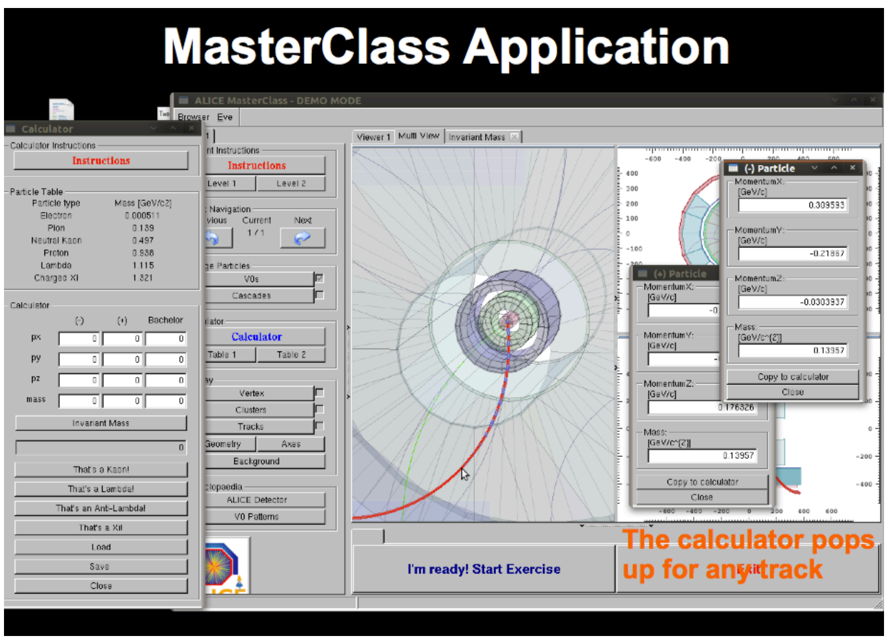
- Identificare i V0 (K^0_s, Λ, anti-Λ) dai decadimenti

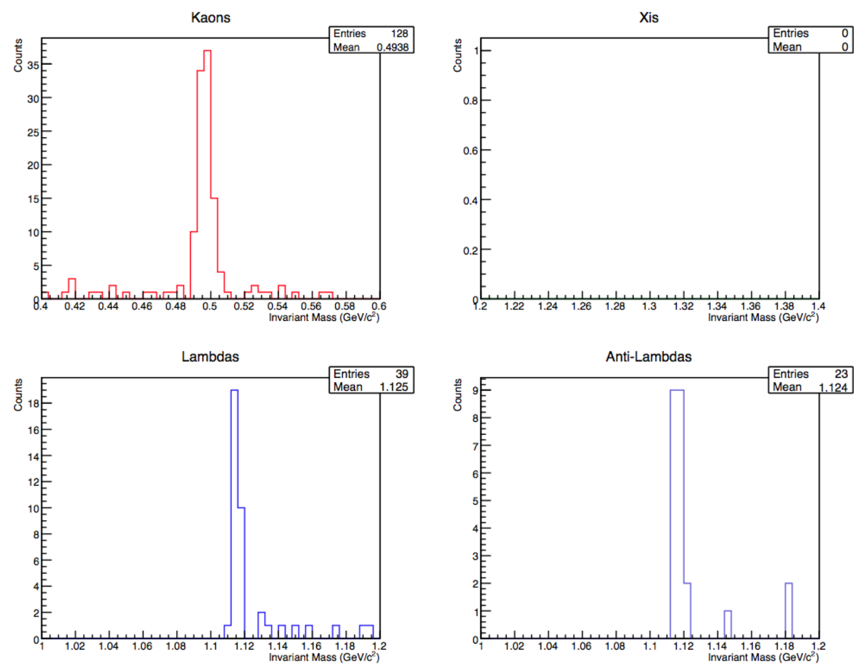
  (V0 : due tracce con carica opposta

  provenienti da uno stesso vertice secondario)

- Calcolo della massa invariante

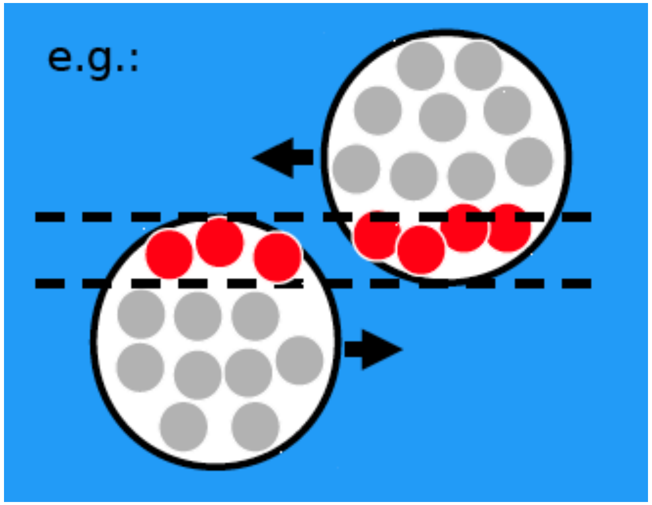
- Classificare le particelle secondo la loro massa invariante ed il tipo di particelle di decadimento



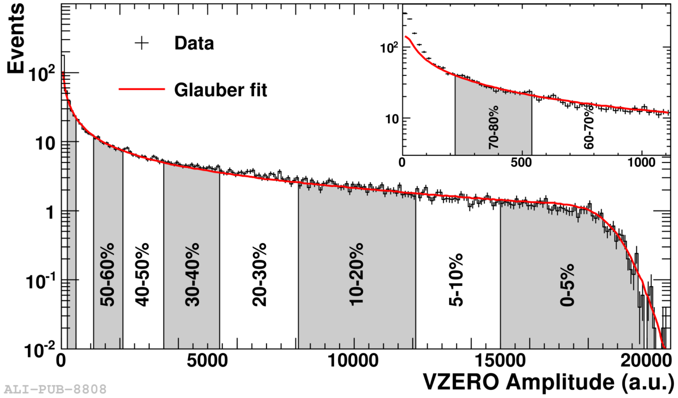


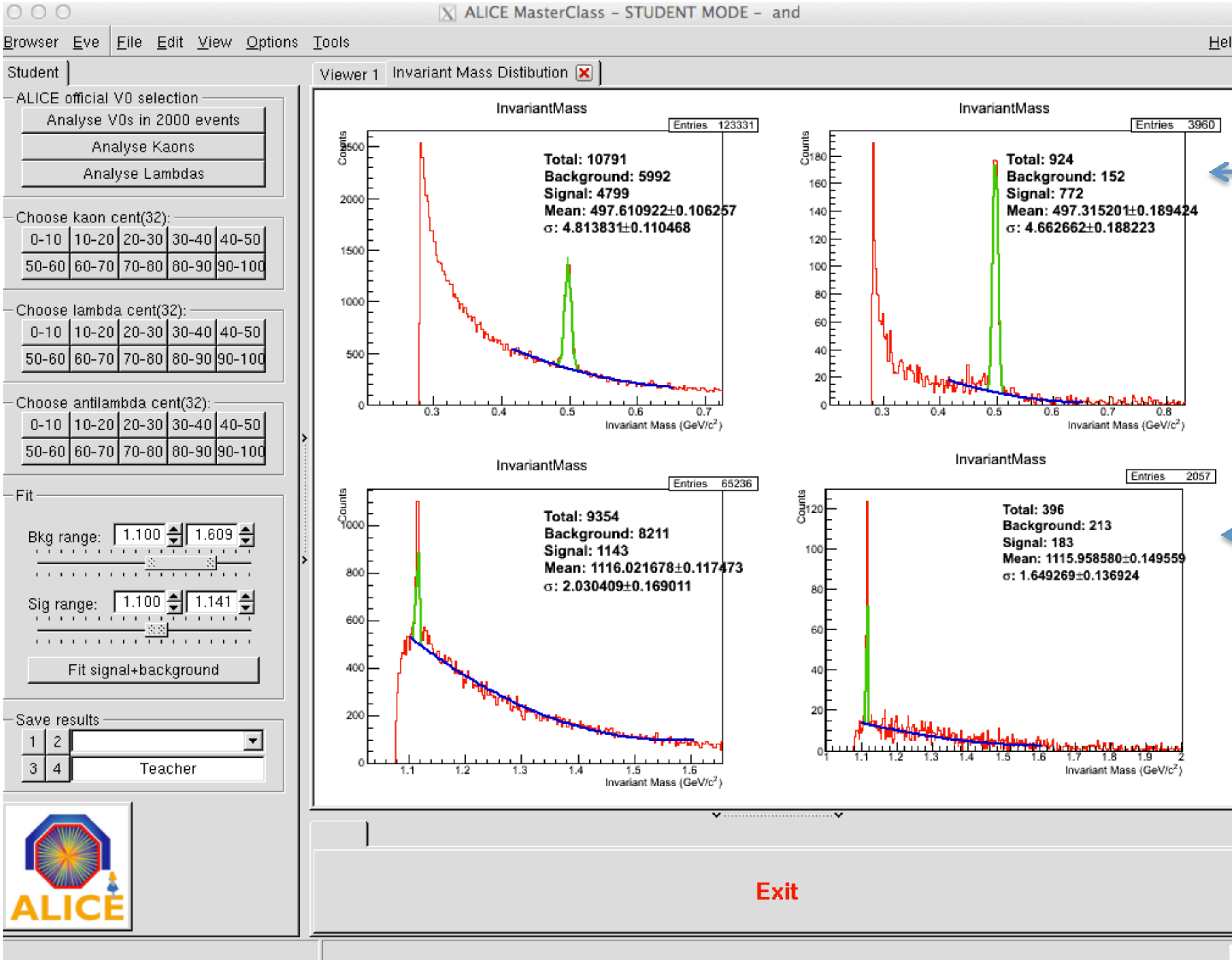
Seconda parte

- 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	$dN_{ch}/d\eta$	$\langle N_{part} \rangle$	$(dN_{ch}/d\eta)/(\langle N_{part} \rangle/2)$
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





K_s

Sinistra: 0-10% centralità

Destra : 50-60% centralità

Λ

Sinistra: 0-10% centralità

Destra: 50-60% centralità

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 = Nparticelle(misurate)/Nparticelle(prodotte)

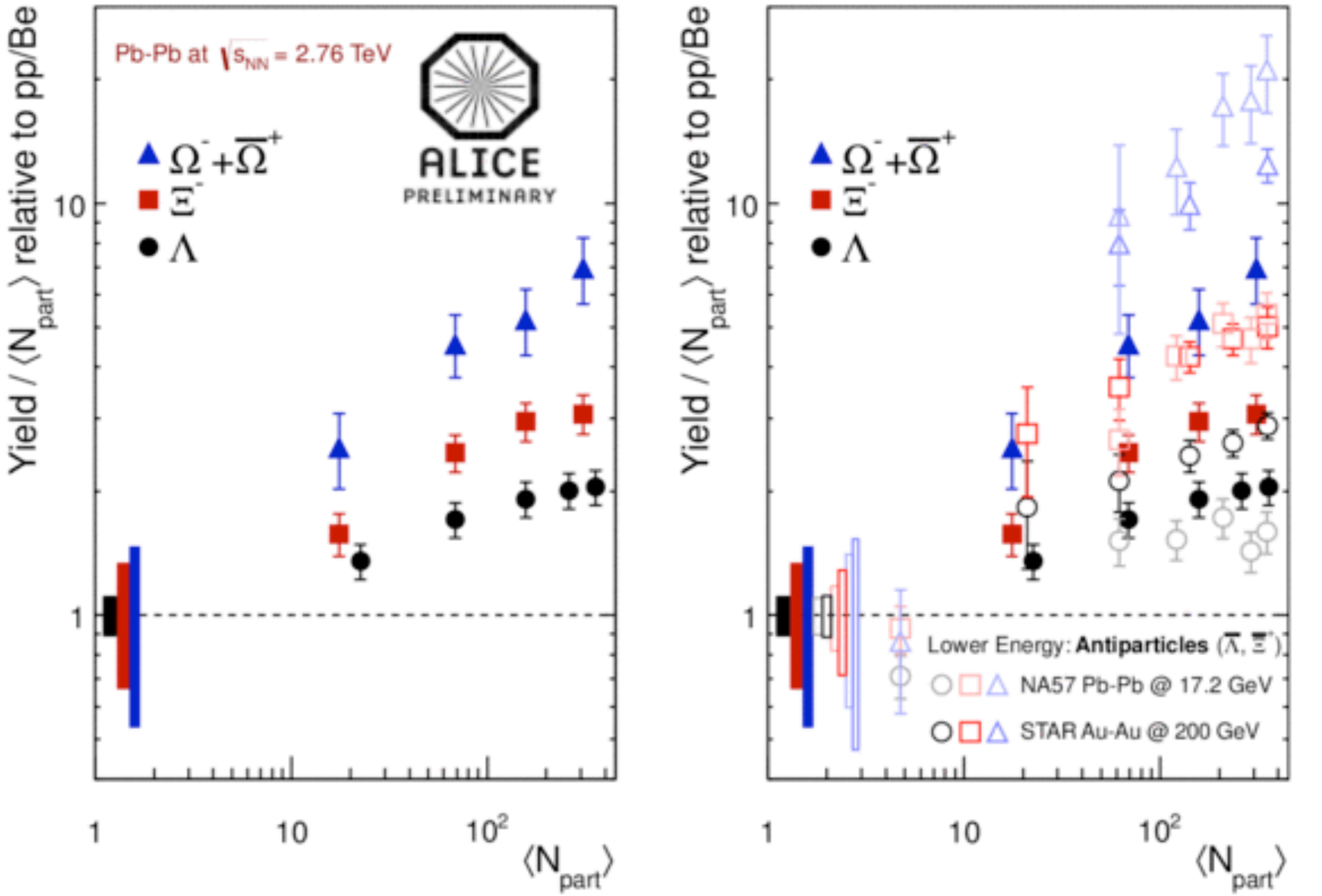
Yield : numero di particelle prodotte per interazione
Yield = Nparticelle(prodotte)/Neventi = Nparticelle(misurate)/(efficienza x Neventi)

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 ; $\langle N_{part} \rangle$ = 2 per pp

Dove scaricare il materiale

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



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Outline of measurement

First Part

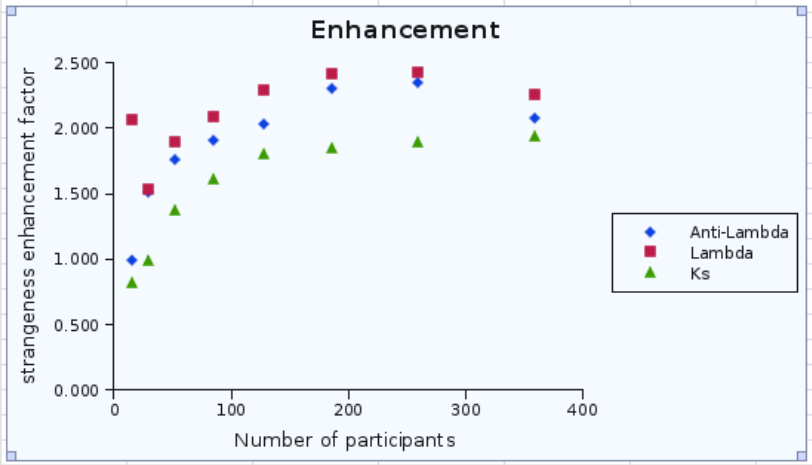
- Students (each group): Visual analysis of 15 events → fill tables + invariant mass histograms
- Institute (all groups): Add up numbers / merge histograms / comments

Second Part

- Students (each group): Analyse events in a centrality bin → invariant mass histograms
- Students (each group): Fit curve/ subtract background → find number of Λ, anti-Λ and K^0_s
- Institute (all groups): Calculate yields of each particle type

  (give number of events in each centrality bin; give global efficiency)
- Calculate strangeness enhancement (ratio of yields normalised to N_{part})
- (give yield for proton-proton at 2.76 TeV)
- Produce strangeness enhancement plots -> To be presented by Institutes for the video-conference

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
centrality	<Npart>	Nevents	NKs	efficiency Ks	yield Ks	Ks enhancem	Nlambda	efficiency L	Yield Lambda	Lambda enh	Nantilambda	effic antiL	yield antiLam	antiL enha
0-10	360	213	4816	0.26	86.963	1.933	1066	0.2	25.023	2.253	980	0.2	23.005	2.071
10--20	260	290	4638	0.26	61.512	1.893	1185	0.21	19.458	2.426	1142	0.21	18.752	2.338
20-30	186	302	3750	0.29	42.818	1.842	917	0.22	13.802	2.405	875	0.22	13.170	2.295
30-40	129	310	2610	0.29	29.032	1.800	621	0.22	9.106	2.288	550	0.22	8.065	2.026
40-50	85	302	1493	0.29	17.047	1.604	363	0.22	5.464	2.084	332	0.22	4.997	1.906
50-60	52	300	777	0.29	8.931	1.374	182	0.2	3.033	1.891	169	0.2	2.817	1.756
60-70	30	315	409	0.35	3.710	0.989	89	0.2	1.413	1.526	88	0.2	1.397	1.509
70-80	16	350	149	0.26	1.637	0.819	71	0.2	1.014	2.055	34	0.2	0.486	0.984



http://www.editgrid.com/user/alice-masterclass/centr-results-example+plot.csv example spreadsheet
http://www.editgrid.com/user/alice-masterclass/centr-results-institute1.csv spreadsheet filled by each institute

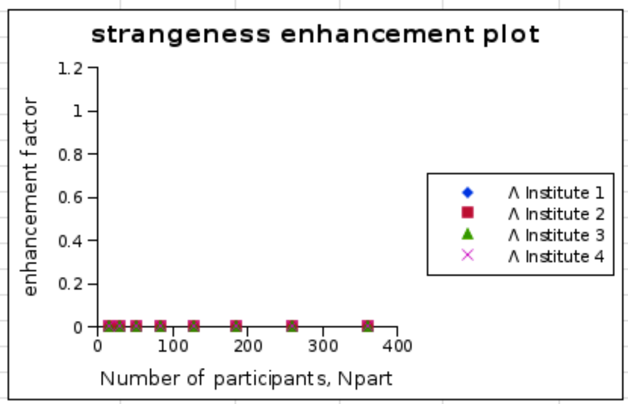
Username alice-masterclass
Password alice

login at www.editgrid.com

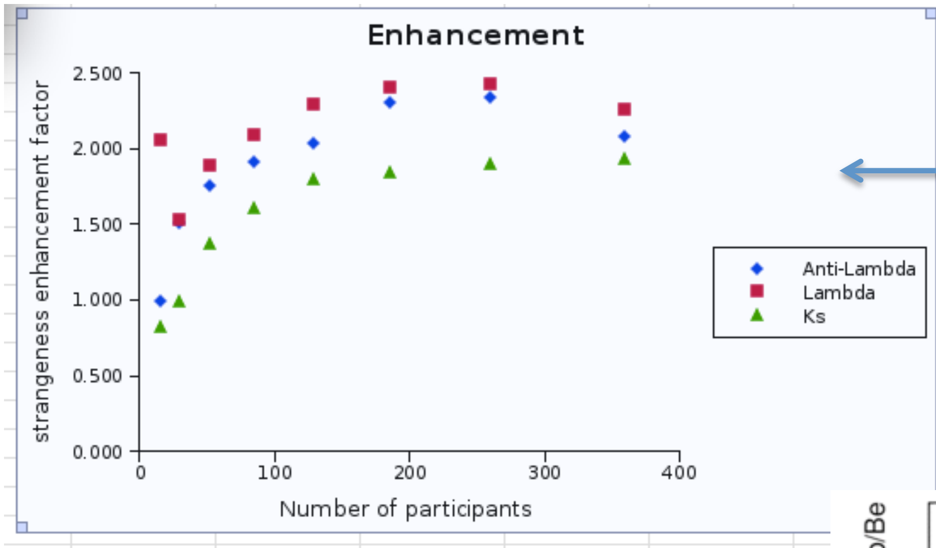
Compare all institutes results, for example for Lambdas

EditGrid — Spreadsheet /alice-masterclass/centr-results-lambda-all.csv

centrality	<Npart>	Nevents	Λ Inst.1	Λ Inst2	Λ Inst.3	Λ Inst. 4	eff. Λ	yield Inst1	yield Inst 2	yield inst3	yield inst4	Λ enh. inst1	Λ enh. iinst.2	Λ enh. inst3	Λ enh. inst.4
0-10	360	213	0	0	0	0	0.2	0.00	0.00	0.00	0.00	0.000	0.000	0.00	0.00
10--20	260	290	0	0	0	0	0.21	0.00	0.00	0.00	0.00	0.000	0.000	0.00	0.00
20-30	186	302	0	0	0	0	0.22	0.00	0.00	0.00	0.00	0.000	0.000	0.00	0.00
30-40	129	310	0	0	0	0	0.22	0.00	0.00	0.00	0.00	0.000	0.000	0.00	0.00
40-50	85	302	0	0	0	0	0.22	0.00	0.00	0.00	0.00	0.000	0.000	0.00	0.00
50-60	52	300	0	0	0	0	0.2	0.00	0.00	0.00	0.00	0.000	0.000	0.00	0.00
60-70	30	315	0	0	0	0	0.2	0.00	0.00	0.00	0.00	0.000	0.000	0.00	0.00
70-80	16	350	0	0	0	0	0.2	0.00	0.00	0.00	0.00	0.000	0.000	0.00	0.00

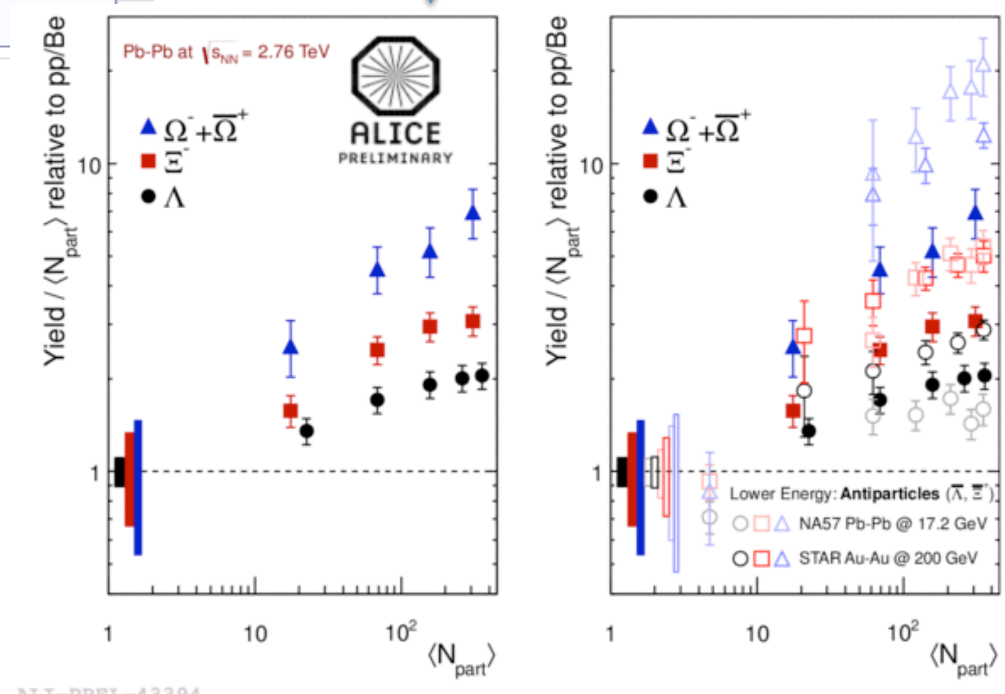


To combine results of all institutes in one plot, use
http://www.editgrid.com/user/alice-masterclass/centr-results-lambda-all.csv to be filled by moderator



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)