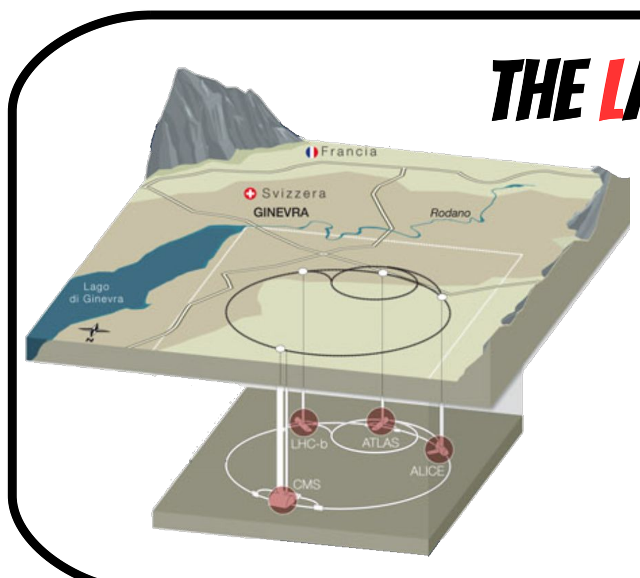
ALICE ACTIVITIES IN TRIESTE

https://www.ts.infn.it/com/ricerca/gr3/alice/

THE LARGE HADRON COLLIDER



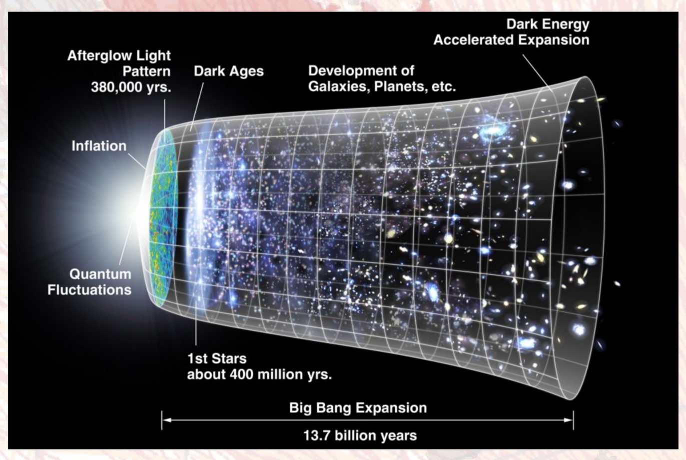
The Large Hadron Collider (LHC) is a synchrotron built 100 meters underground at the border of Switzerland and France able to accelerate pp, p–Pb and AA.

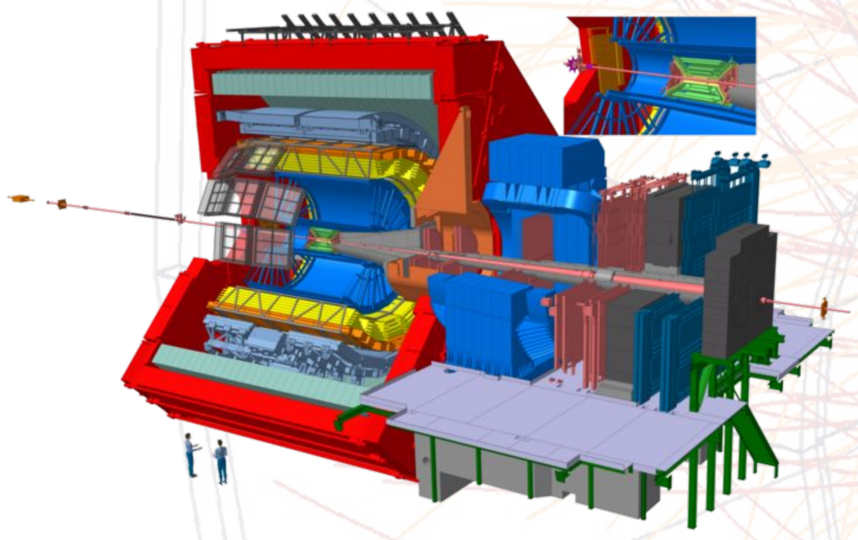
It has a circumference of 27 km and is instrumented with 8 Tesla superconducting magnets, providing the bending power to orbit 13 TeV protons in opposite directions.

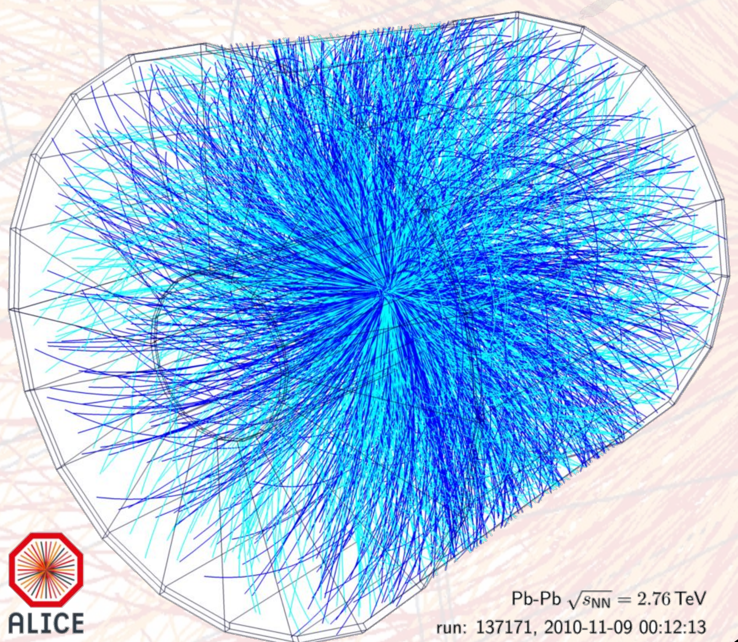
A LARGE ION COLLIDER EXPERIMENT

The ALICE Collaboration has built a dedicated detector to exploit the unique physics potential of nucleus–nucleus collisions at LHC energies. Its aim is to study the physics of strongly interacting matter at the highest energy densities reached so far in the laboratory. In such condition, an extreme phase of matter – called the Quark–Gluon Plasma (QGP) – is formed.

Our universe is thought to have been in such a primordial state for the first few millionths of a second after the Big Bang. The properties of such a phase are key issues for Quantum Chromodynamics, the understanding of confinement deconfinement and chiral phase transitions.
For this purpose, we are carrying out a comprehensive study of the hadrons, electrons, muons and photons produced in the collisions of heavy nuclei.
ALICE is also studying proton–proton and proton–nucleus collisions both as a comparison with nucleus–nucleus collisions and in their own right.



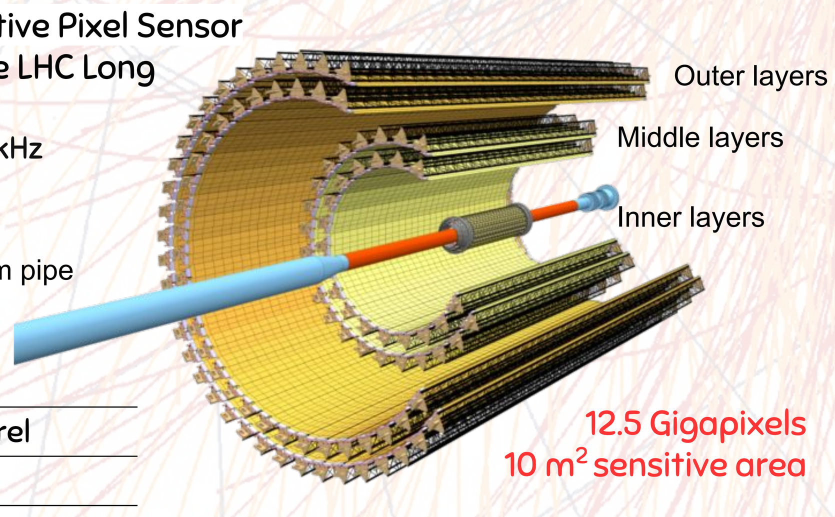




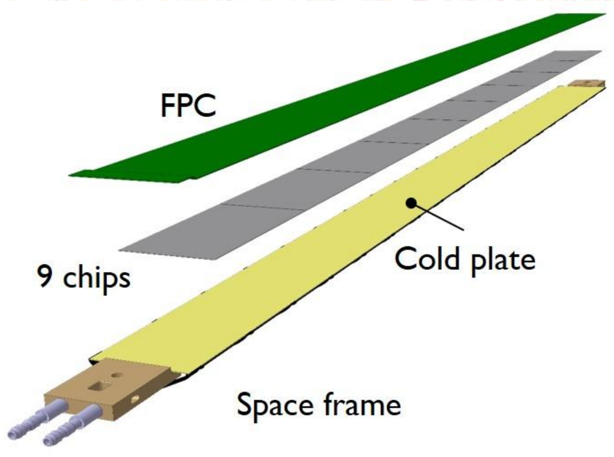
INNER TRACKING SYSTEM UPGRADE

First large-area vertex detector based on Monolithic Active Pixel Sensor (MAPS) technology aimed to replace ALICE ITS during the LHC Long Shutdown 2 in 2019/20

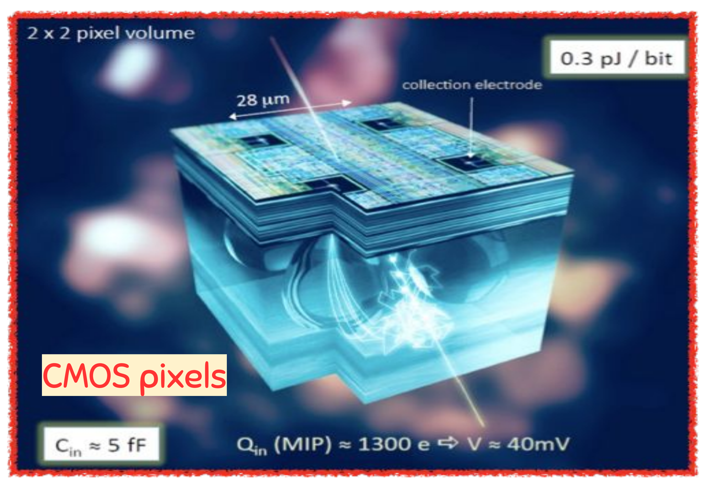
- Increase readout speed → Readout Pb–Pb collisions at 100 kHz
- Improve impact parameter resolution
  - Reduce pixel size: O(50 x 425 μm²) → O(30 x 30 μm²)
  - Reduce distance from the IP: 39 mm → 23 mm
- Reduce inner layers X_0: ~1.14% → ~0.3%
- Improve tracking efficiency at low p_T
- All 7 layers with binary pixels



ITS requirements	Inner Barrel	Outer Barrel
Spatial resolution	5 μm	10 μm
Detection efficiency	> 99 %	
Fake hit rate	< 10^{-6} pixel^{-1} event^{-1}	
Power density	<300 mW cm^{-2}	<100 mW cm^{-2}
TID radiation hardness	2700 krad	100 krad
NIEL radiation hardness	1.7×10^{13} 1 MeV n_{eq} cm^{-2}	10^{12} 1 MeV n_{eq} cm^{-2}

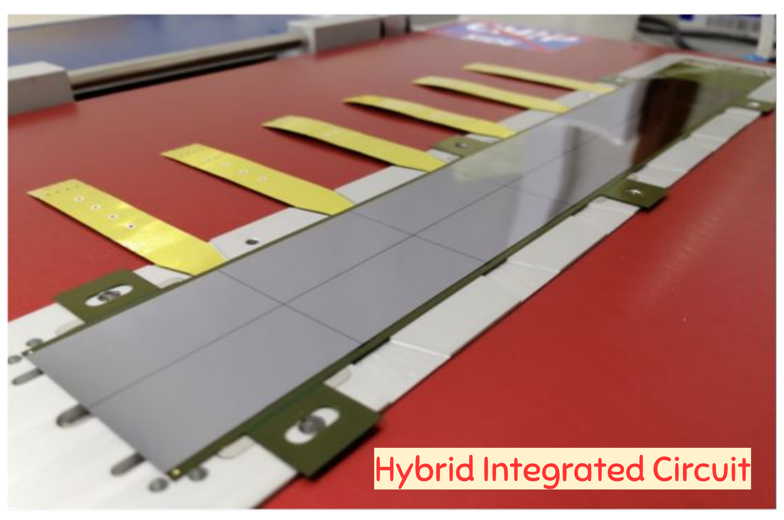


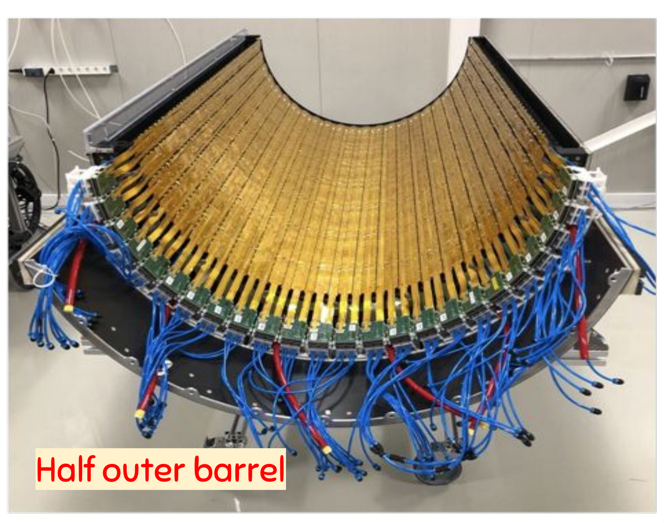
TECHNOLOGY



Tower Jazz 180 nm CMOS imaging sensor process

- Deep p-well shielding n-well allowing in-pixel PMOS
- High-resistivity (> 1 kΩ cm) p-type epitaxial layer (18 to 30 μm) on p-type substrate
- Substrate bias → Increase of depletion volume
- Larger charge collected by seed pixel
- Lower input capacitance → better S/N ratio
- Short collection time
- Better non-ionising radiation tolerance

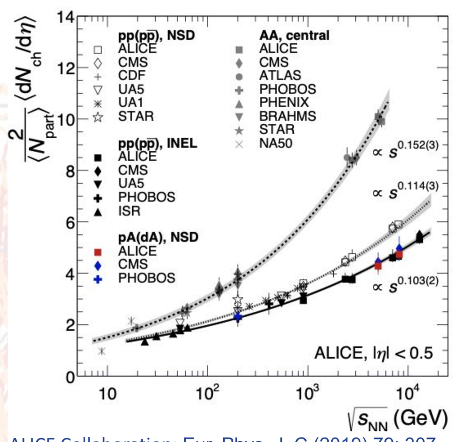




DATA ANALYSIS

MINIMUM BIAS AND UNDERLYING EVENT

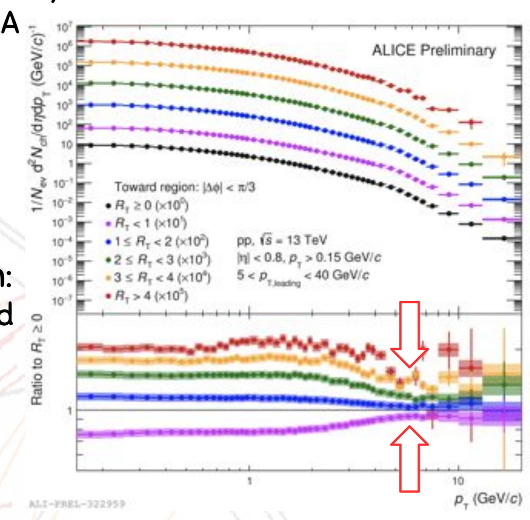
Heavy-ion collisions produce in proportion more particles than small system collisions:
➢ we can estimate energy density from multiplicity → ~ 20 GeV/m³ for AA



ALICE Collaboration: Eur. Phys. J. C (2019) 79: 307

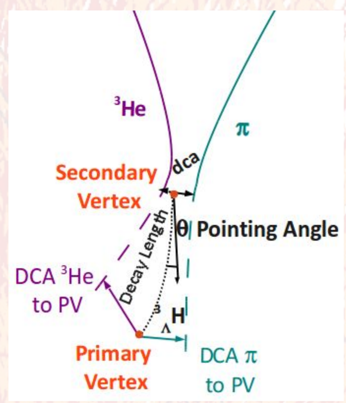
Underlying event (UE):
➢ Multiple Parton Interactions
➢ semi-hard + soft interactions (ISR/FSR and beam remnants)

Selecting multiplicity in the UE region:
➢ complete separation among soft and hard part of the event at high transverse momentum (p_T)
➢ unique opportunity to test jet universality!

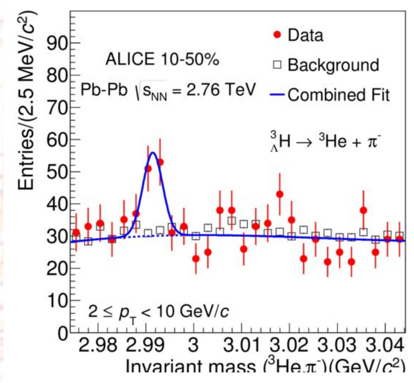


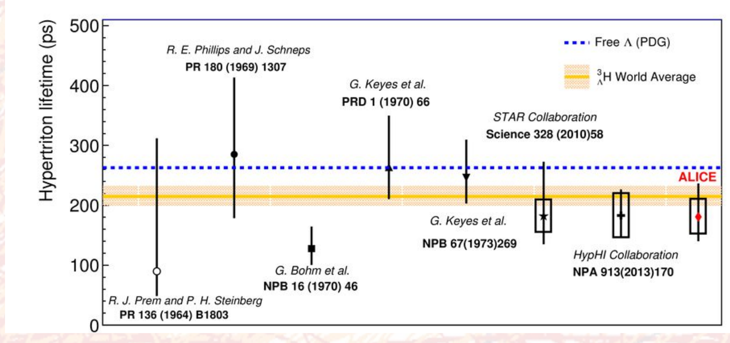
HYPERNUCLEI PRODUCTION

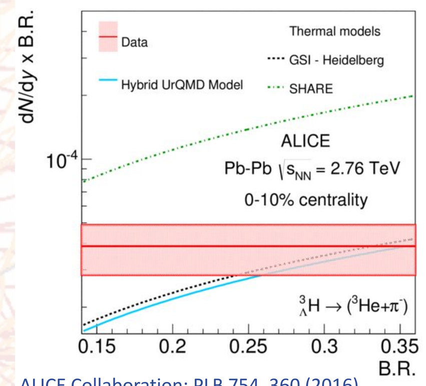
$^3_\Lambda$H is the lightest known hypernucleus and is formed by (p, n, Λ)
Mass = 2.991 GeV/c^2 B_Λ = 0.13 ± 0.05 MeV Lifetime ~ 263 ps



Signal extracted in 3 p_T bins for 2 centrality classes:
➢ the measured yield is in agreement with equilibrium thermal model expectations
➢ the measured lifetime is smaller w.r.t. the free Λ one

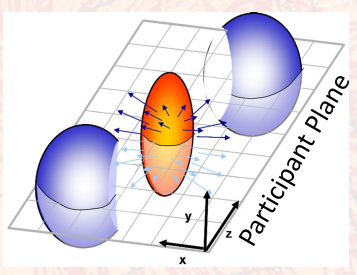




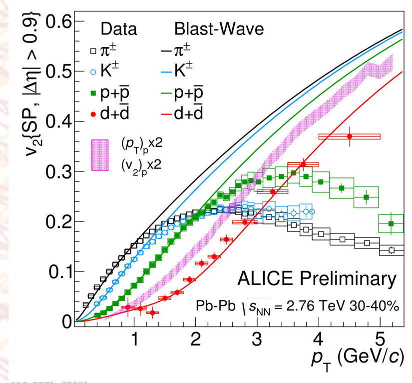


ALICE Collaboration: PLB 754, 360 (2016)

LIGHT NUCLEI ELLIPTIC FLOW

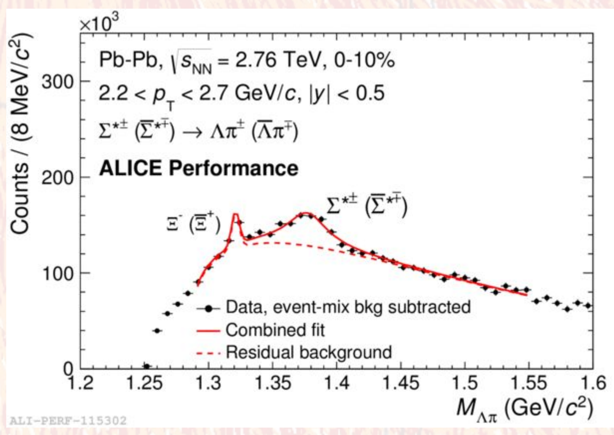


Angular distribution of reconstructed charged particles can be expanded into a Fourier series w.r.t. symmetry plane



- Blast–Wave vs. Coalescence:
  ➢ deuteron v_2 follows the mass ordering
  ➢ a Blast–Wave (red curve) parameterization obtained from lower mass species can describe the deuteron v_2 reasonably well
  ➢ a simple coalescence model (magenta band) is not able to reproduce the measured v_2

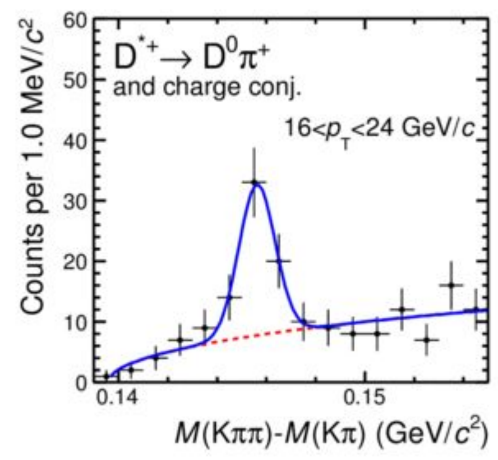
PRODUCTION OF RESONANCES



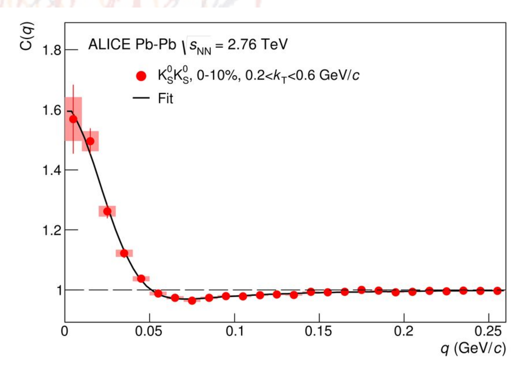
- Hadronic resonances decay under the strong interaction with lifetimes of the same order of magnitude as that of the fireball created in AA collisions
- After chemical freeze–out resonances decay and can undergo re–scattering and regeneration depending on:
  - lifetime of the hadronic phase and of resonances
  - scattering cross–section of the decay products
- Key measurements:
  - Resonance yields and ratios to long–lived particles vs. centrality
  - Resonances with different lifetimes

MEASUREMENT OF D-MESONS PRODUCTION

- Heavy flavours (i.e. charm and beauty quarks) can probe the QGP:
  - are produced in the initial stages of the collision:
    ➢ Heavy–flavours production time: t_{prod} < $h/m_{c(b)}$ ~ 0.1 (0.4) fm/c
    ➢ QGP formation time at LHC: t_{form} ~ 0.3 fm/c
- Heavy flavours experience the whole system evolution interacting with the medium constituents



FEMTOSCOPY

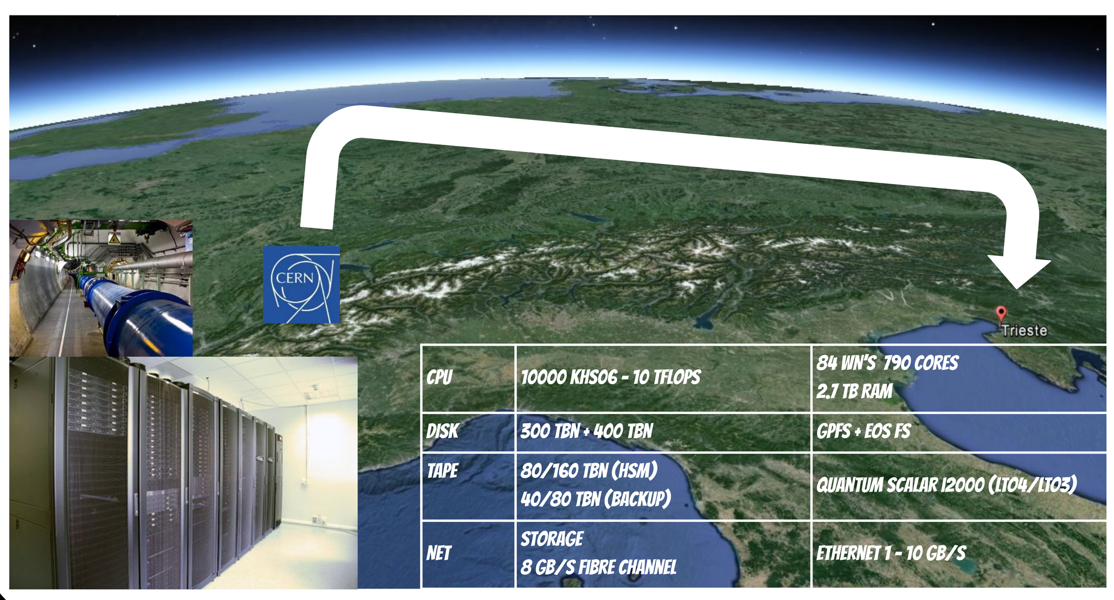


Femtoscopy is based on the measurement of the two–particle correlation function:

$$C(k^*) = \mathcal{N}\frac{N_{\rm same}(k^*)}{N_{\rm mixed}(k^*)} \quad k^* = \frac{1}{2}|\mathbf{p}_1^* - \mathbf{p}_2^*| \quad \mathbf{p}_1^* + \mathbf{p}_2^* = 0$$

Sensitive to the size of particle emission region and their final state interactions:
➢ Exploring interactions which are unknown with femtoscopy!

COMPUTING



- The ALICE experiment has originally been designed as a relatively low–rate experiment: this will not be the case anymore for the Run 3 that is scheduled to start in 2021: expected rate ~100 kHz → a part of ALICE upgrade includes major improvements in the computing side of the experiment
- Advanced data–analysis techniques, as Machine Learning and Artificial Intelligence, are applied on big data on a worldwide computing grid

FOR INFORMATION:

- Prof. Paolo Camerini (paolo.camerini@ts.infn.it)
- Dott. Giacomo Contin (giacomo.contin@ts.infn.it)
- Dott. Enrico Fragiacomo (enrico.fragiacomo@ts.infn.it)
- Dott.ssa Ramona Lea (ramona.lea@ts.infn.it)
- Dott.ssa Grazia Luparello (grazia.luparello@ts.infn.it)
- Prof. Giacomo–Vito Margagliotti (giacomo.margagliotti@ts.infn.it)
- Dott. Stefano Piano (stefano.piano@ts.infn.it)
- Prof. Rinaldo Rui (rinaldo.rui@ts.infn.it)
- Dott.ssa Valentina Zaccolo (valentina.zaccolo@ts.infn.it)