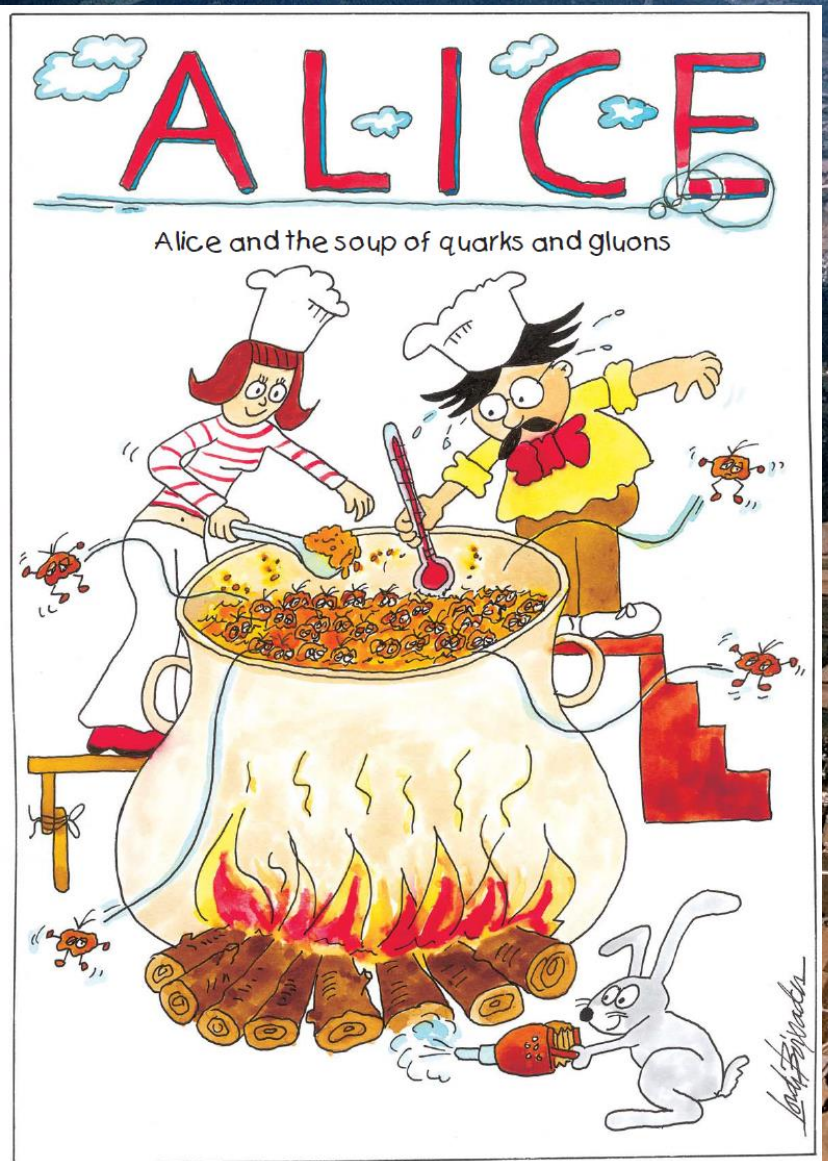
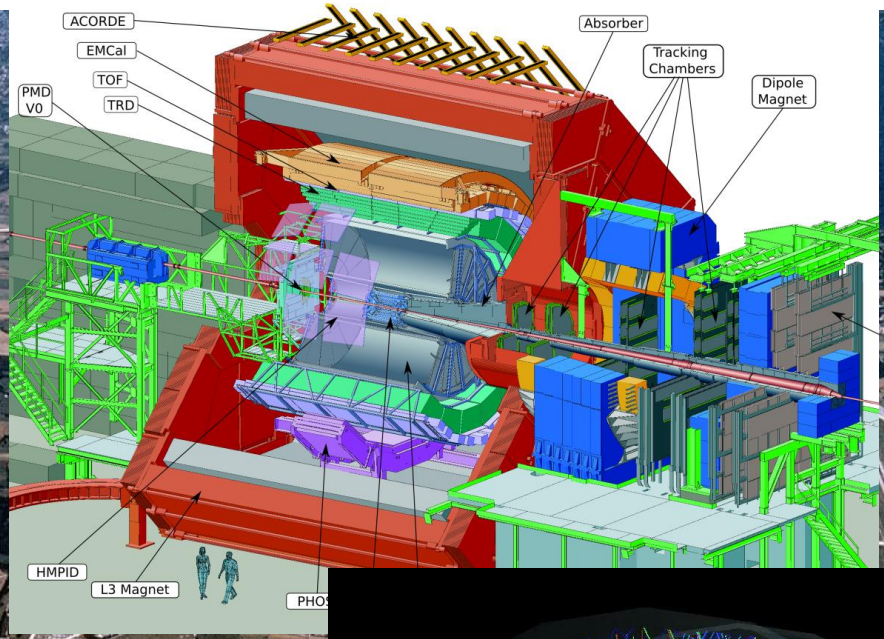
Kvark-gluon suppen og ALICE

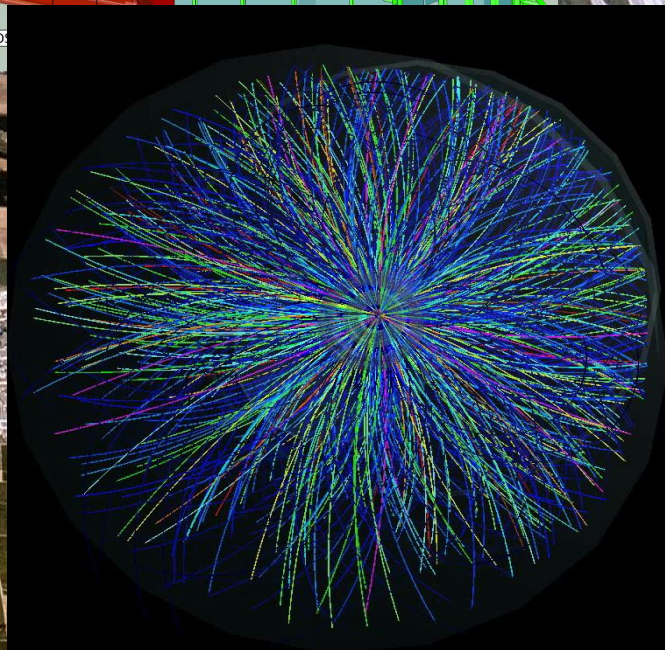
Teachers Training Programme, CERN, 6. februar 2025

Børge Svane Nielsen, Niels Bohr Institutet, København

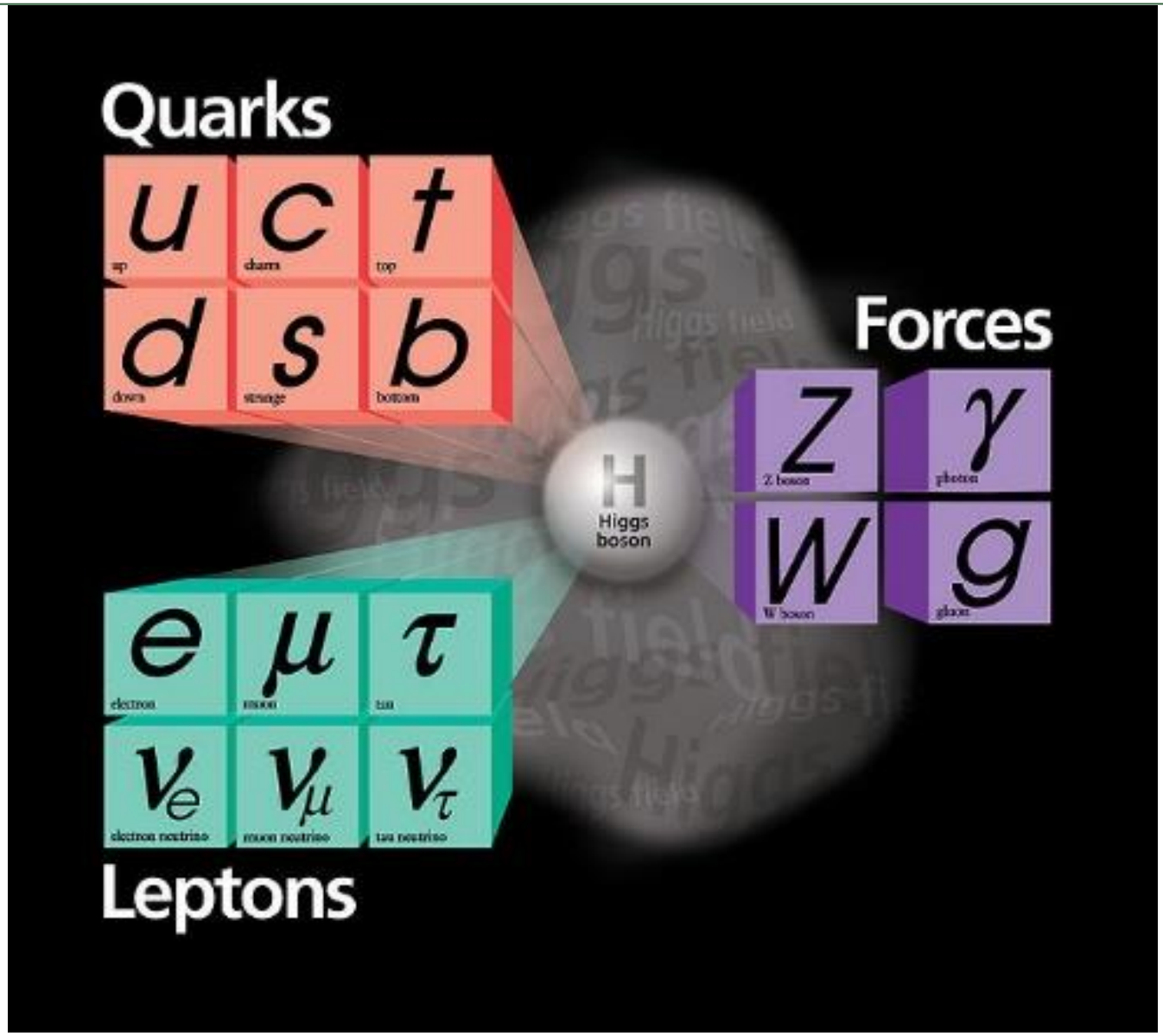
Kvark-suppen og ALICE

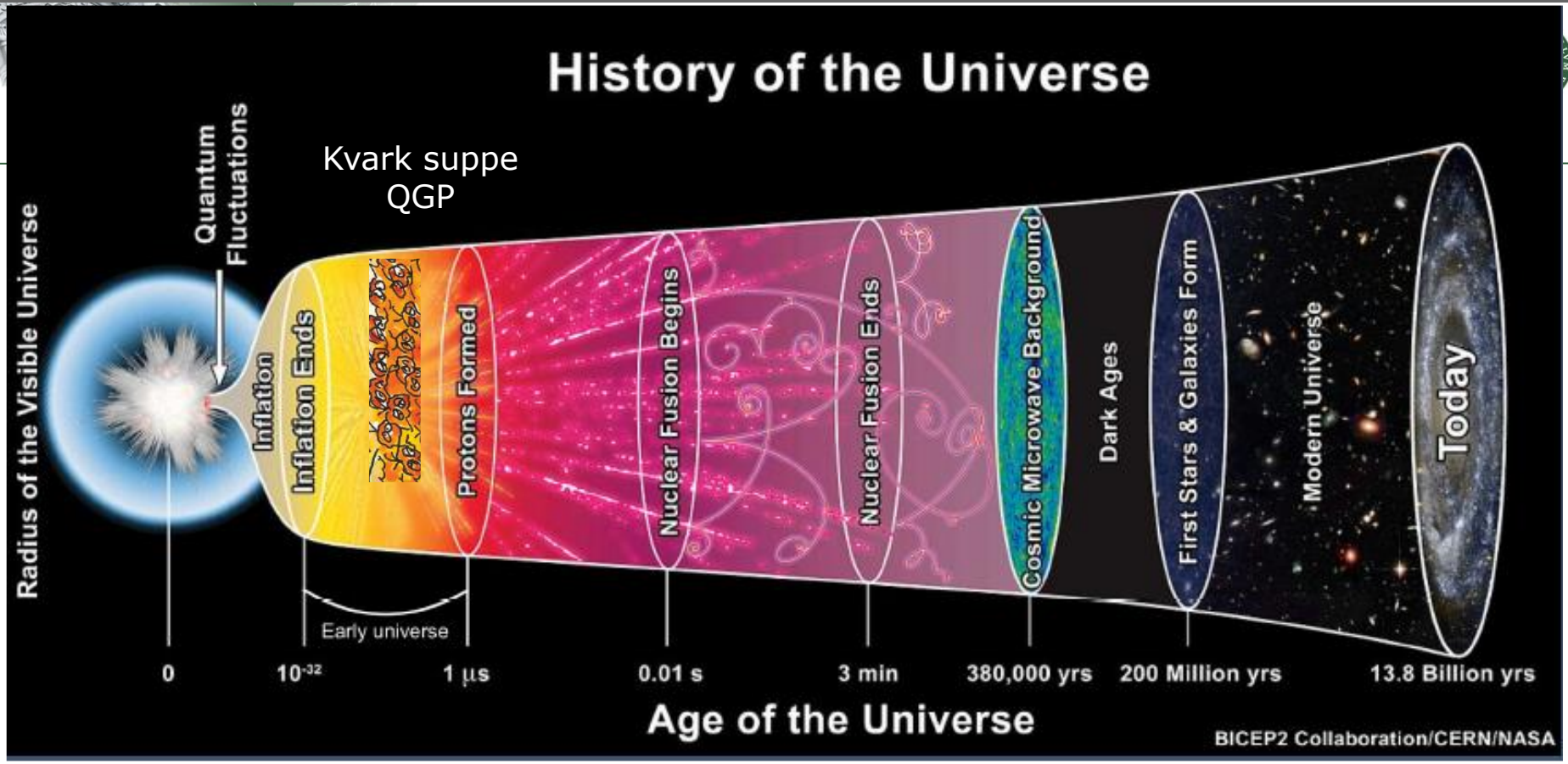


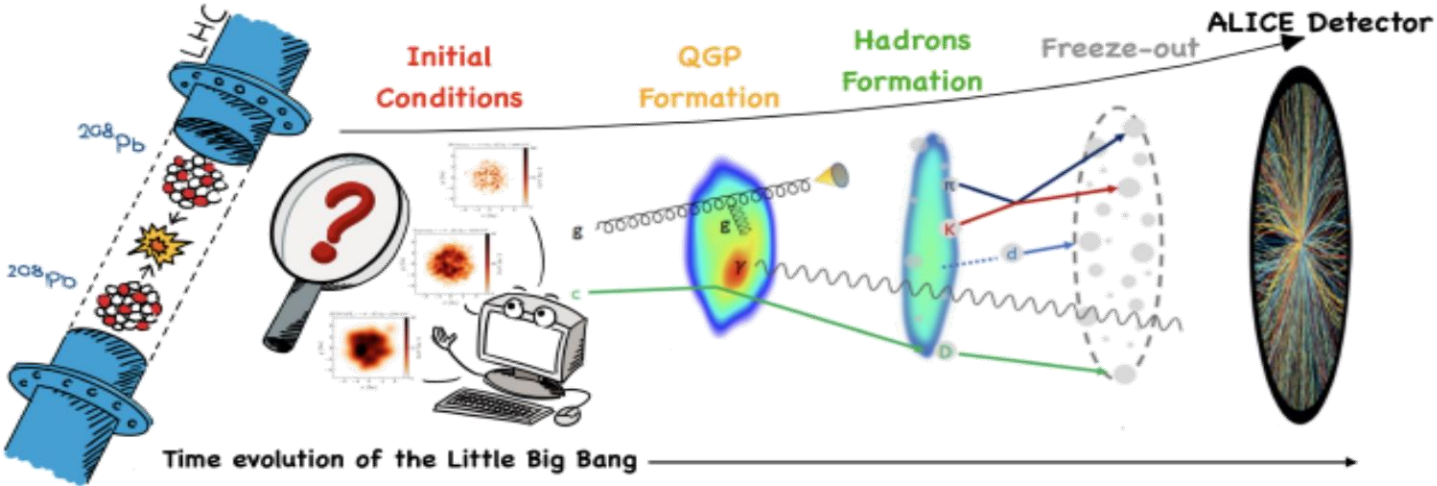




Standardmodellen

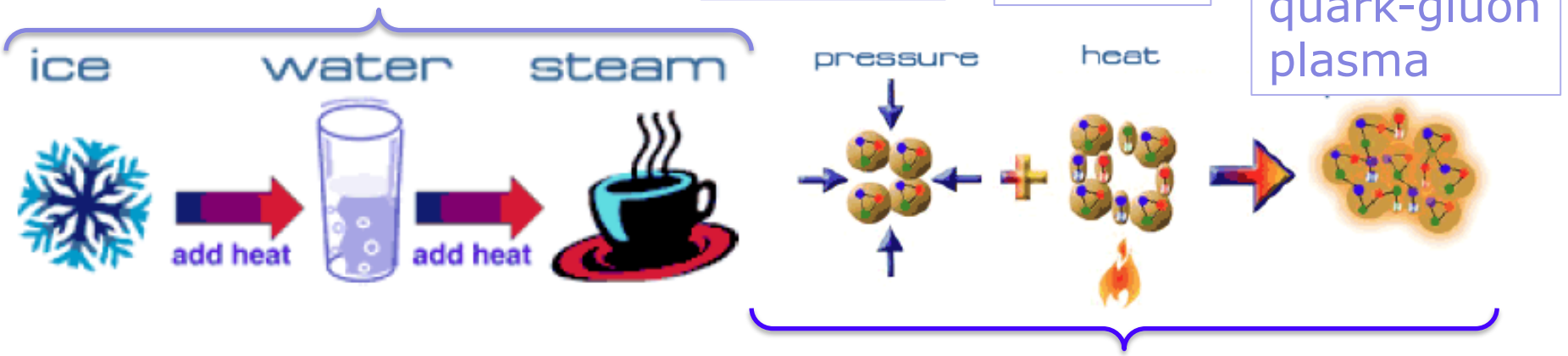



History of the Universe
Kvark suppe
QGP
Quantum Fluctuations
Radius of the Visible Universe
Inflation
Inflation Ends
Protons Formed
Nuclear Fusion Begins
Nuclear Fusion Ends
Cosmic Microwave Background
Dark Ages
First Stars & Galaxies Form
Modern Universe
Today
Early universe
0
10-32
1 µs
0.01 s
3 min
380,000 yrs
200 Million yrs
13.8 Billion yrs
Age of the Universe
BICEP2 Collaboration/CERN/NASA


LHC
208Pb
208Pb
Initial Conditions
QGP Formation
Hadrons Formation
Freeze-out
ALICE Detector
Time evolution of the Little Big Bang

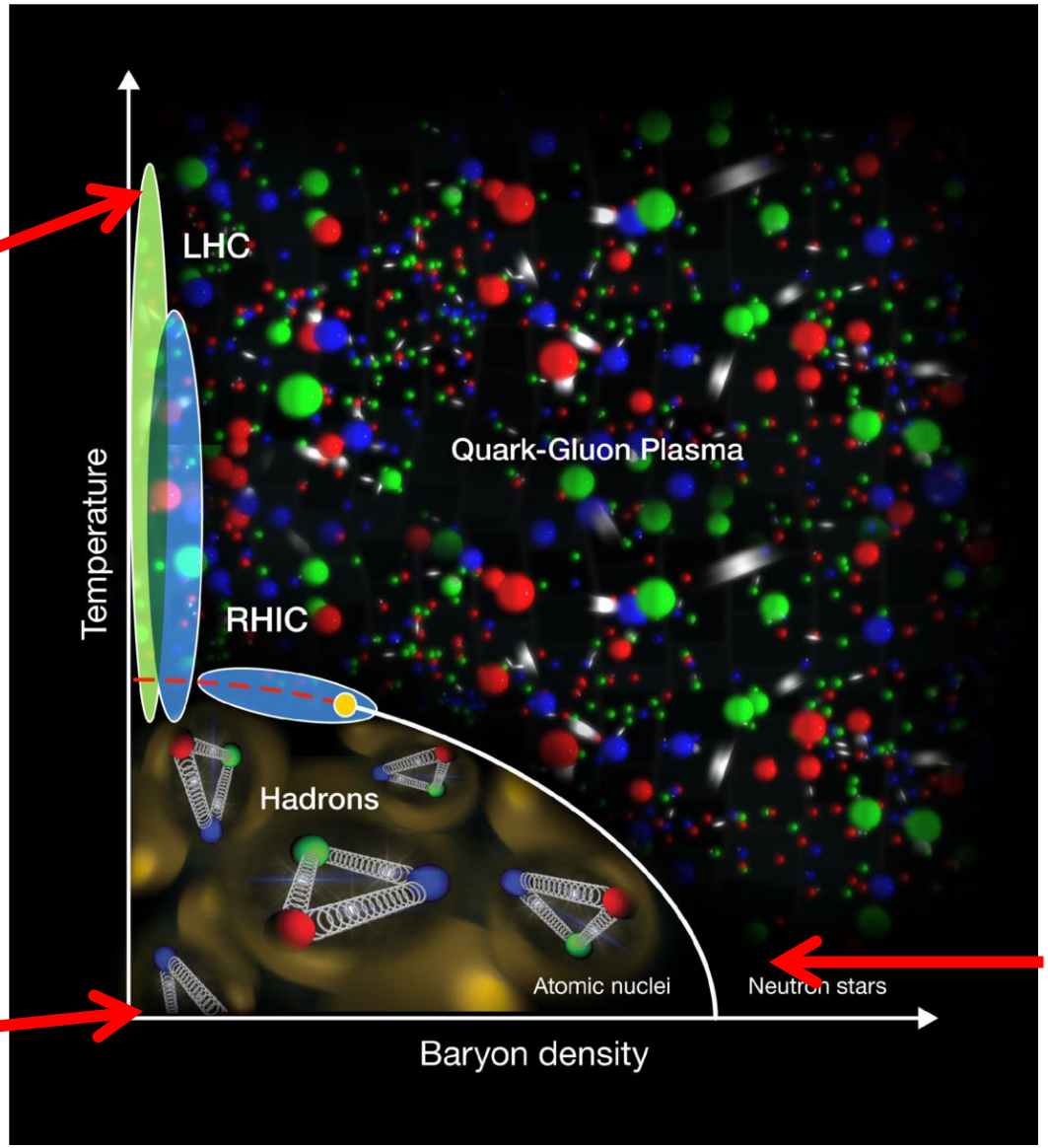
Hvordan laver man Universets "urstof"?

Stof findes i flere faser



- Er det muligt at smelte atomkerner?
- Hvis vi kan gøre det, kan vi forstå det meget tidlige Univers
- Varme + tryk: Blykerner i en accelerator!

Fasediagram for atomkernestof

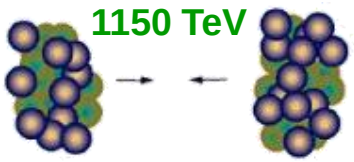


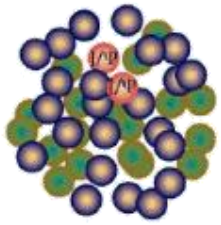
LHC

Normalt kernestof

Neutron stjerner

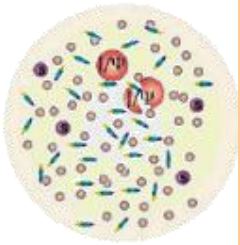
Tunge ioner i LHC

^{208}Pb  ^{208}Pb kollision



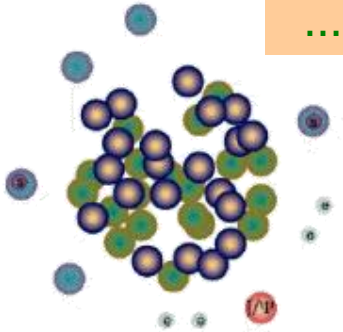
superkerne med
høj energi

?

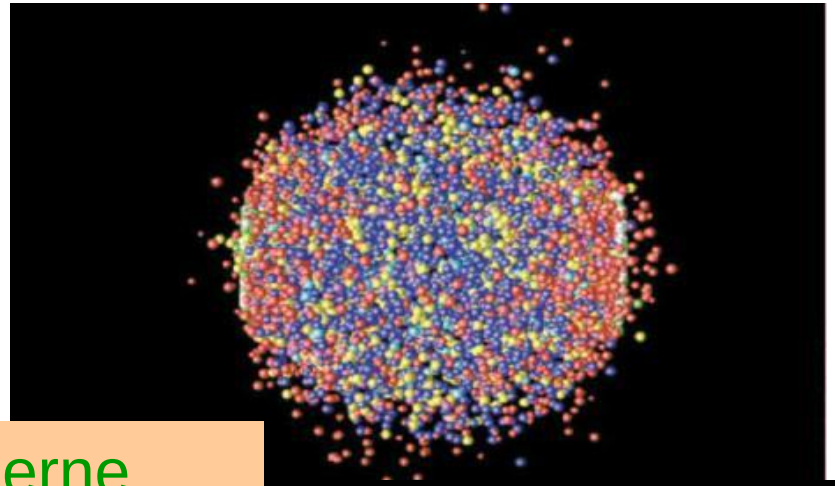


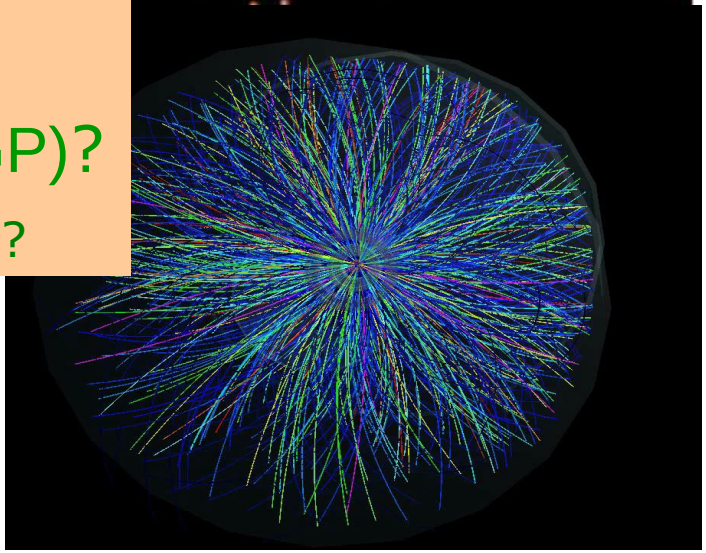
smelter kernepartiklerne
sammen til et
kvark-gluon plasma (QGP)?

…og hvordan ser suppen ud?

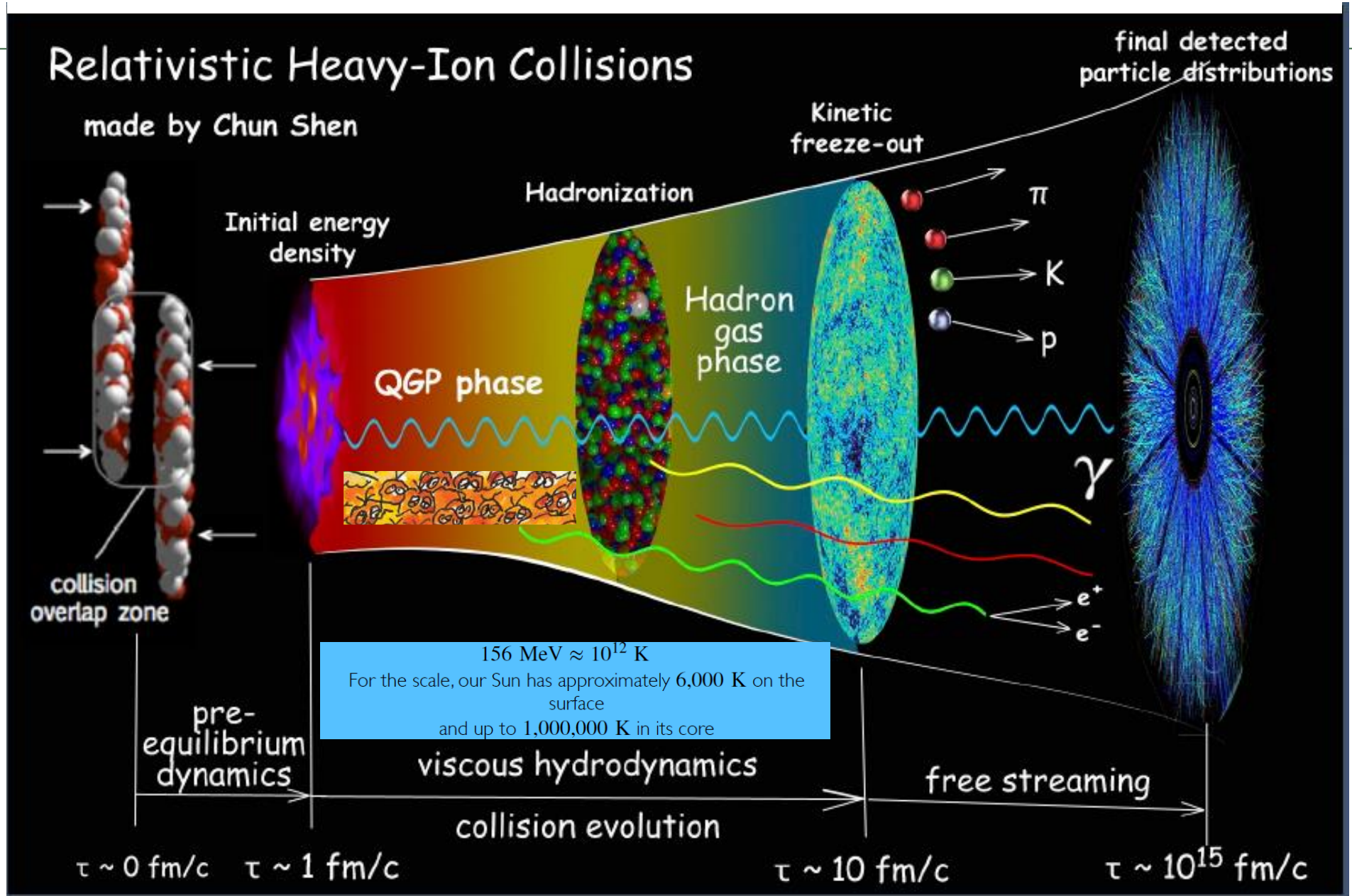


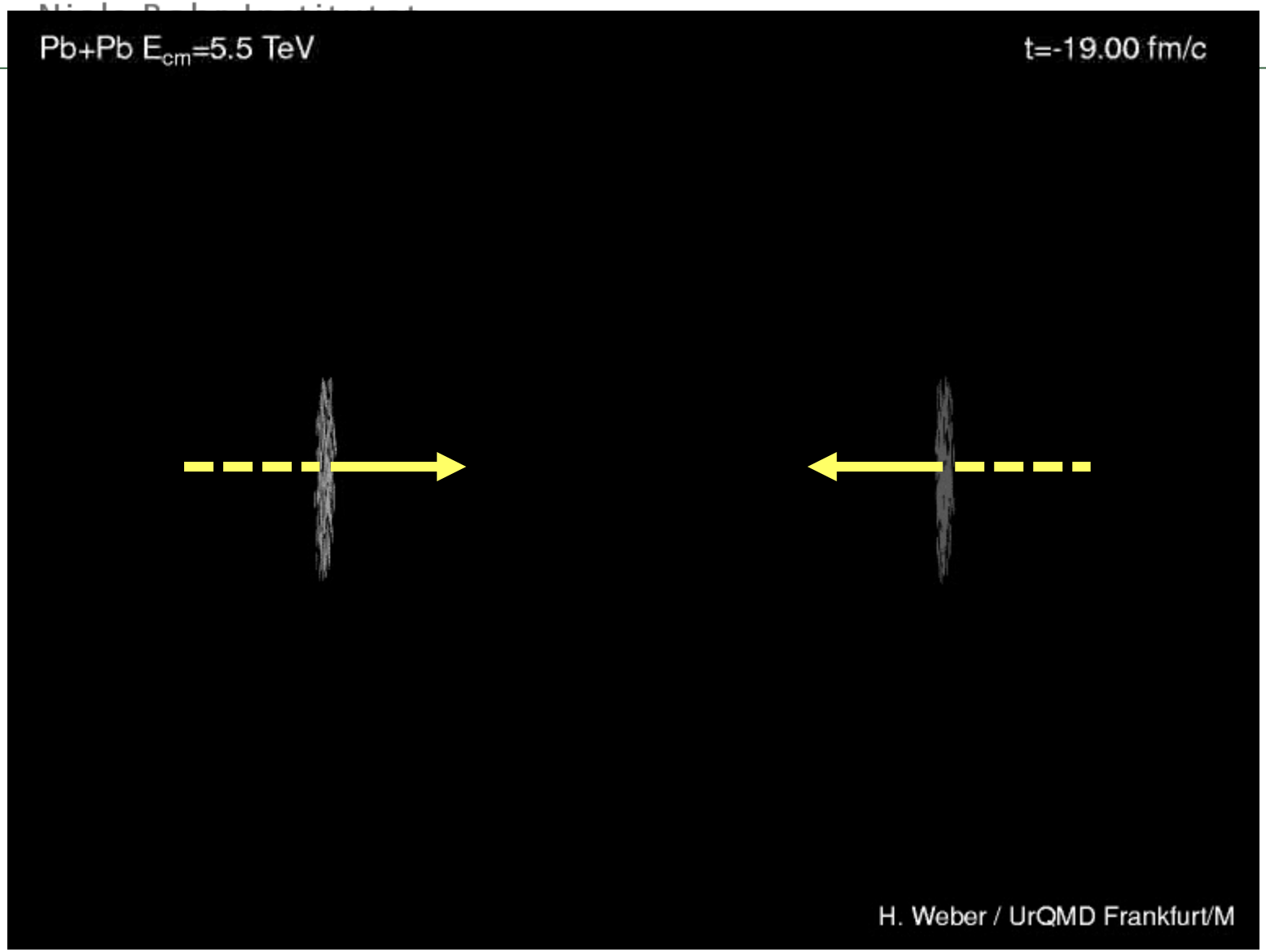
mini Big Bang



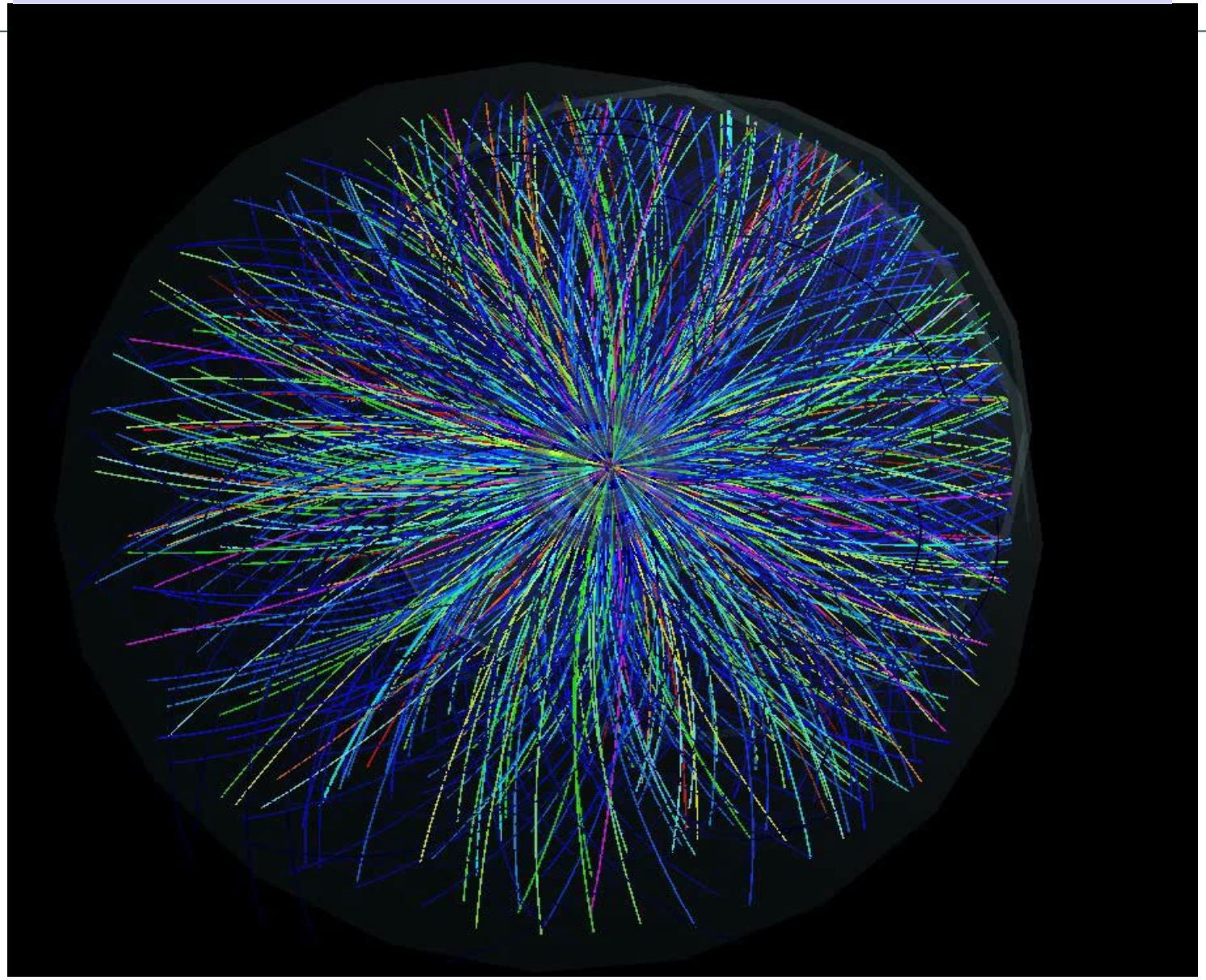


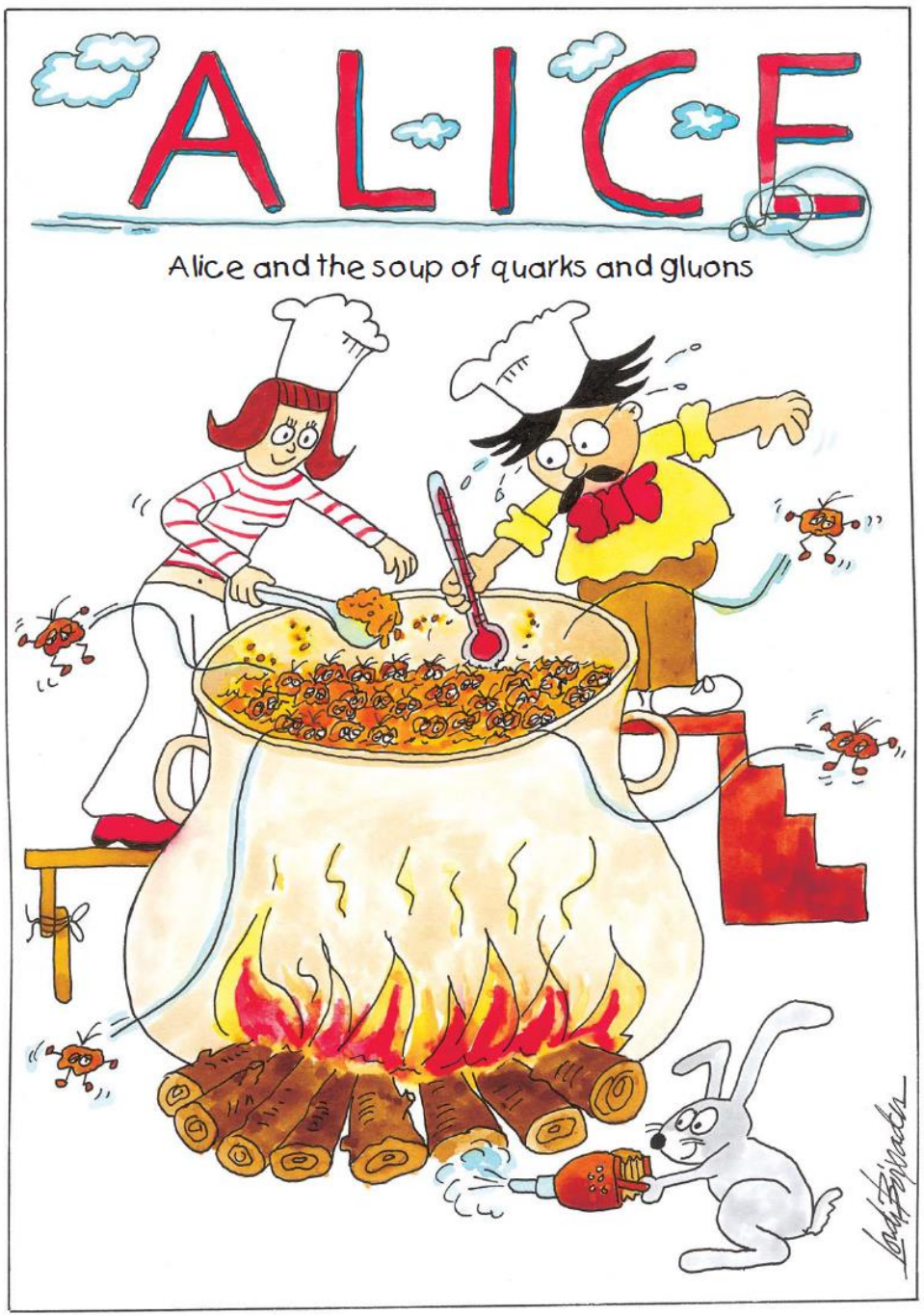
Tunge ioner i ALICE -- mini Big Bang




Pb+Pb E_{cm}=5.5 TeV
t=-19.00 fm/c
H. Weber / UrQMD Frankfurt/M

Pb-Pb sammenstød, 574 TeV, set i ALICE





Hvordan ved vi at kvarksuppen (QGP) dannes i partikel-sammenstød?

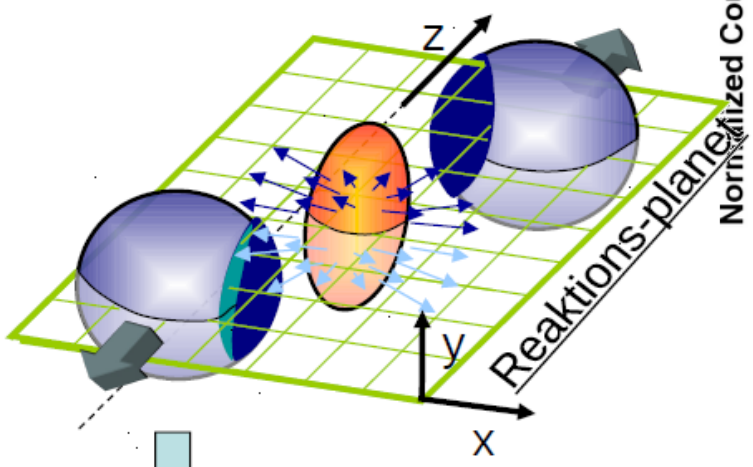
Hvordan ser suppen ud?

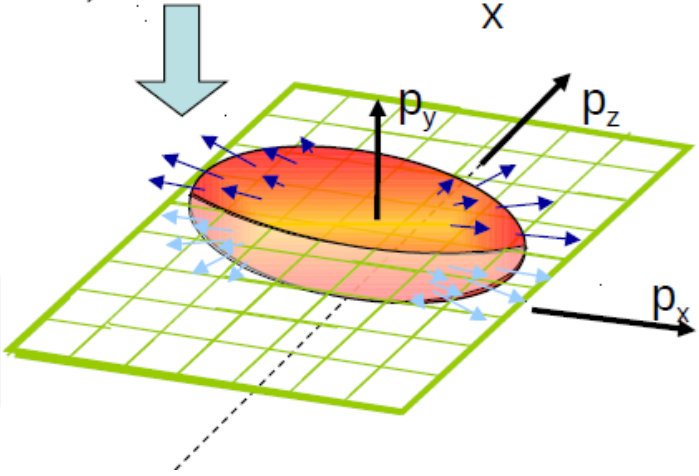
"Flow" i Pb-Pb kollisioner

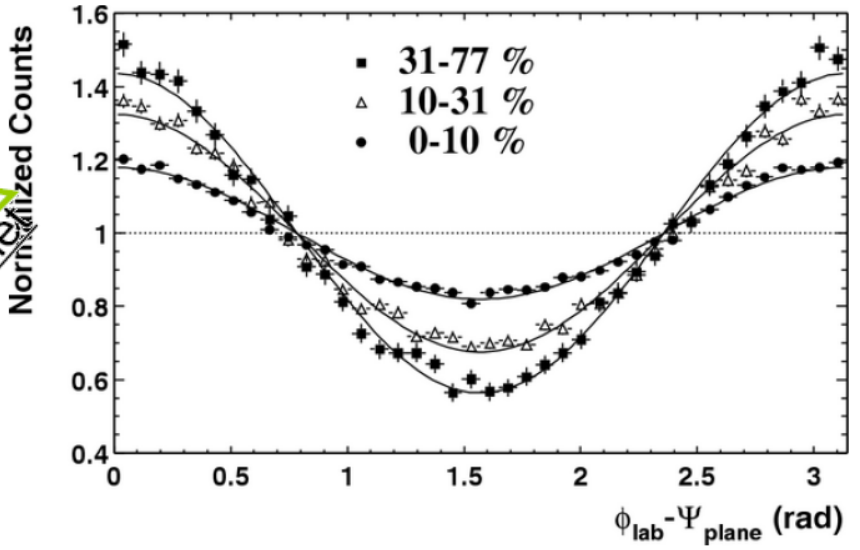
Rumlig asymmetri

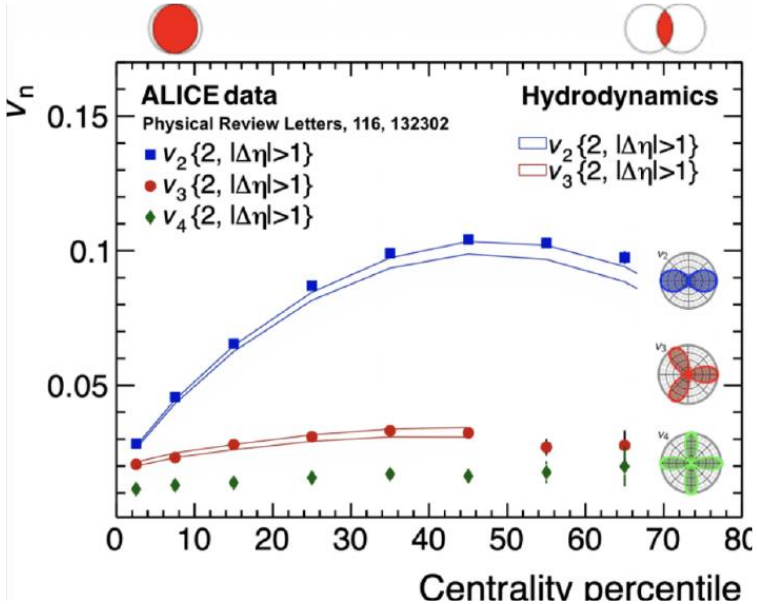
Store tryk gradienter

Azimutal anisotropi





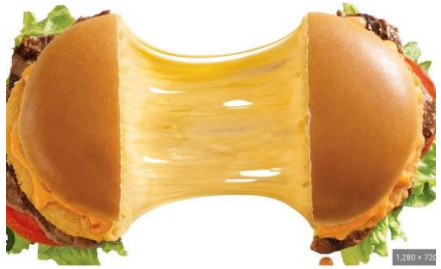




Flow målt ⇒ stoffet reagerer kollektivt
⇒ nukleonerne findes ikke mere

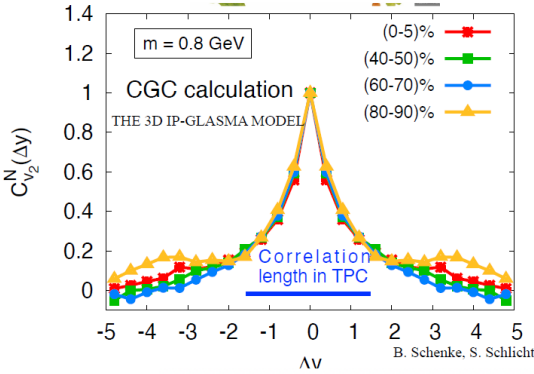
Hvad ved vi om kvarksuppen?

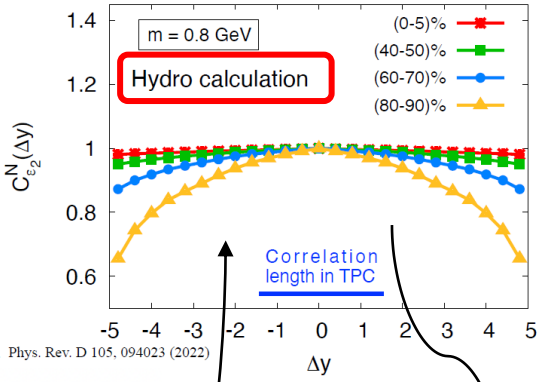
Flydende ost?



Suppe?

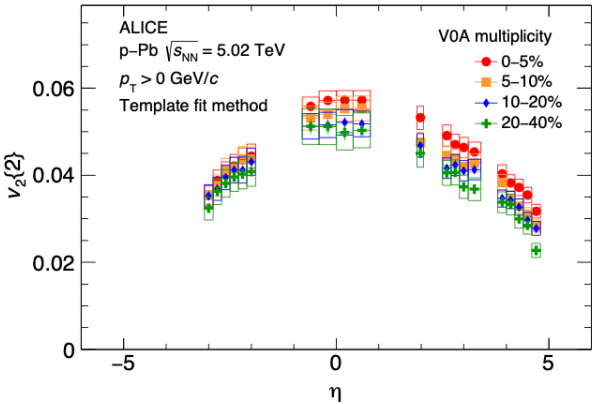
Model-beregninger:





B. Schenke, S. Schlichting, P. Singh; Phys. Rev. D 105, 094023 (2022)

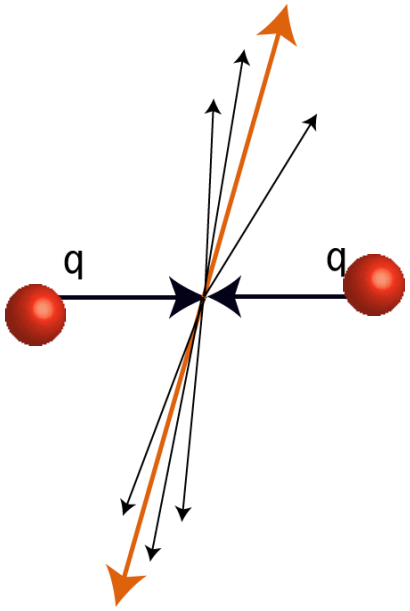
ALICE data:



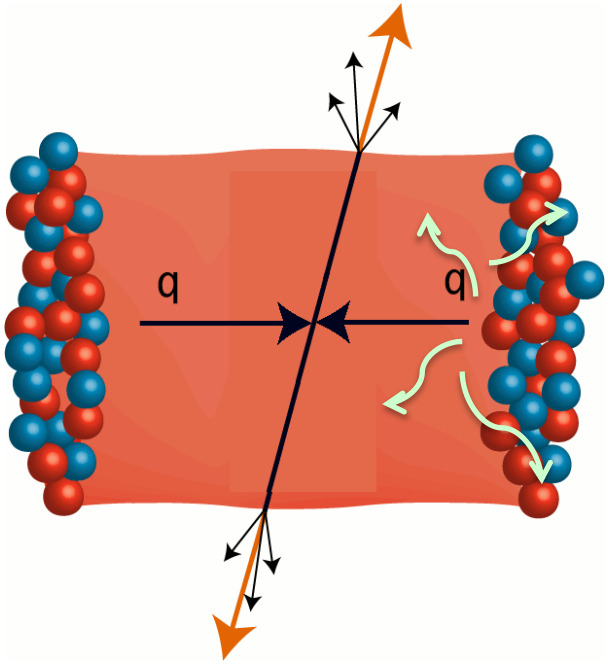
Konklusion:
Suppen har meget lav viskositet -- flydende

Tomografi af atomkerner: p+p vs. Pb+Pb kollisioner

p+p



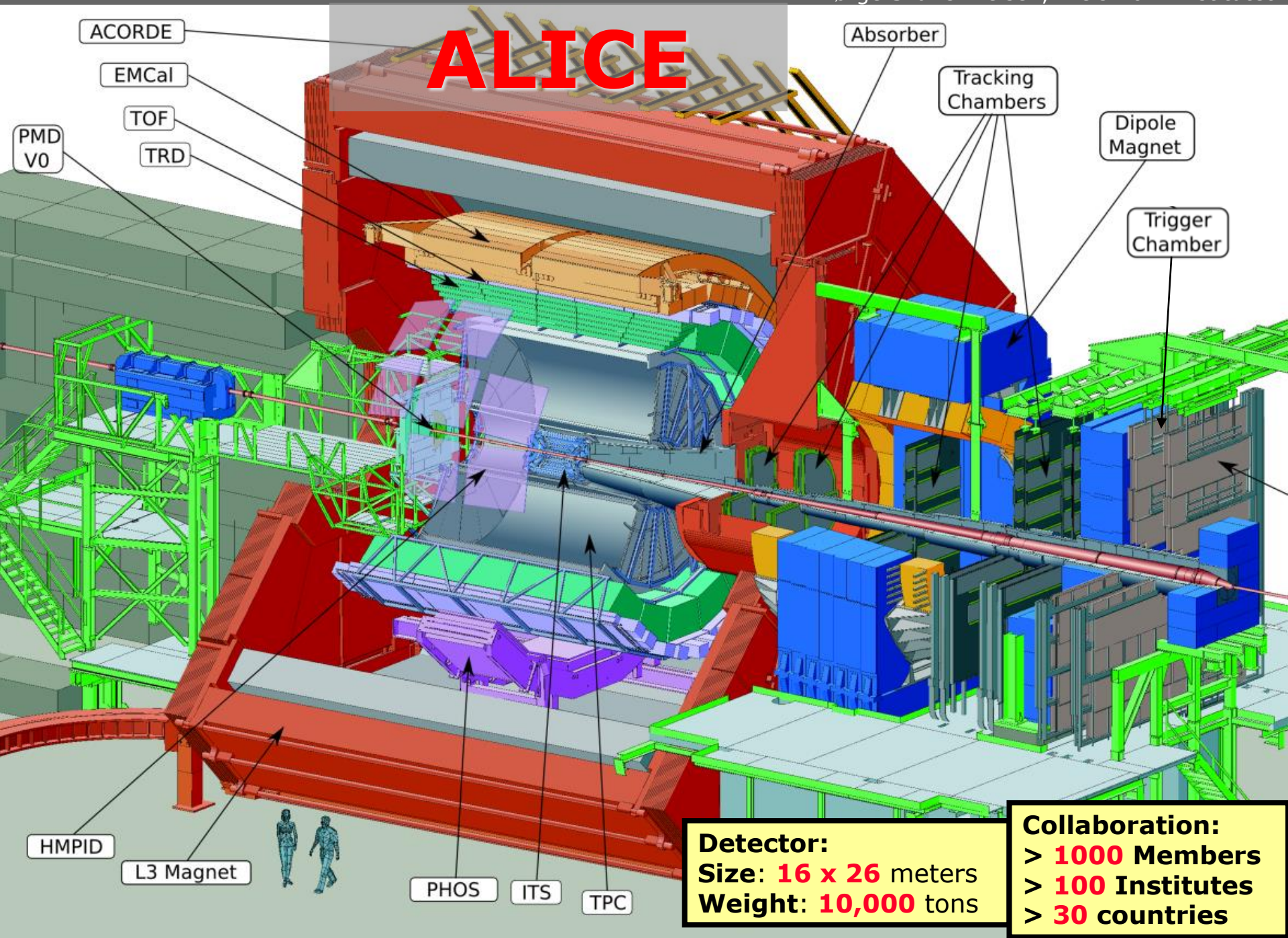
Pb+Pb



JETs kan modificeres eller undertrykkes p.gr.a. vekselvirkning af den spredte parton med 'farvet' medium, f.eks. via gluon bremsestråling.

ALICE har målt p+p ved samme energi som Pb+Pb (2.76 TeV) for at sammenligne direkte

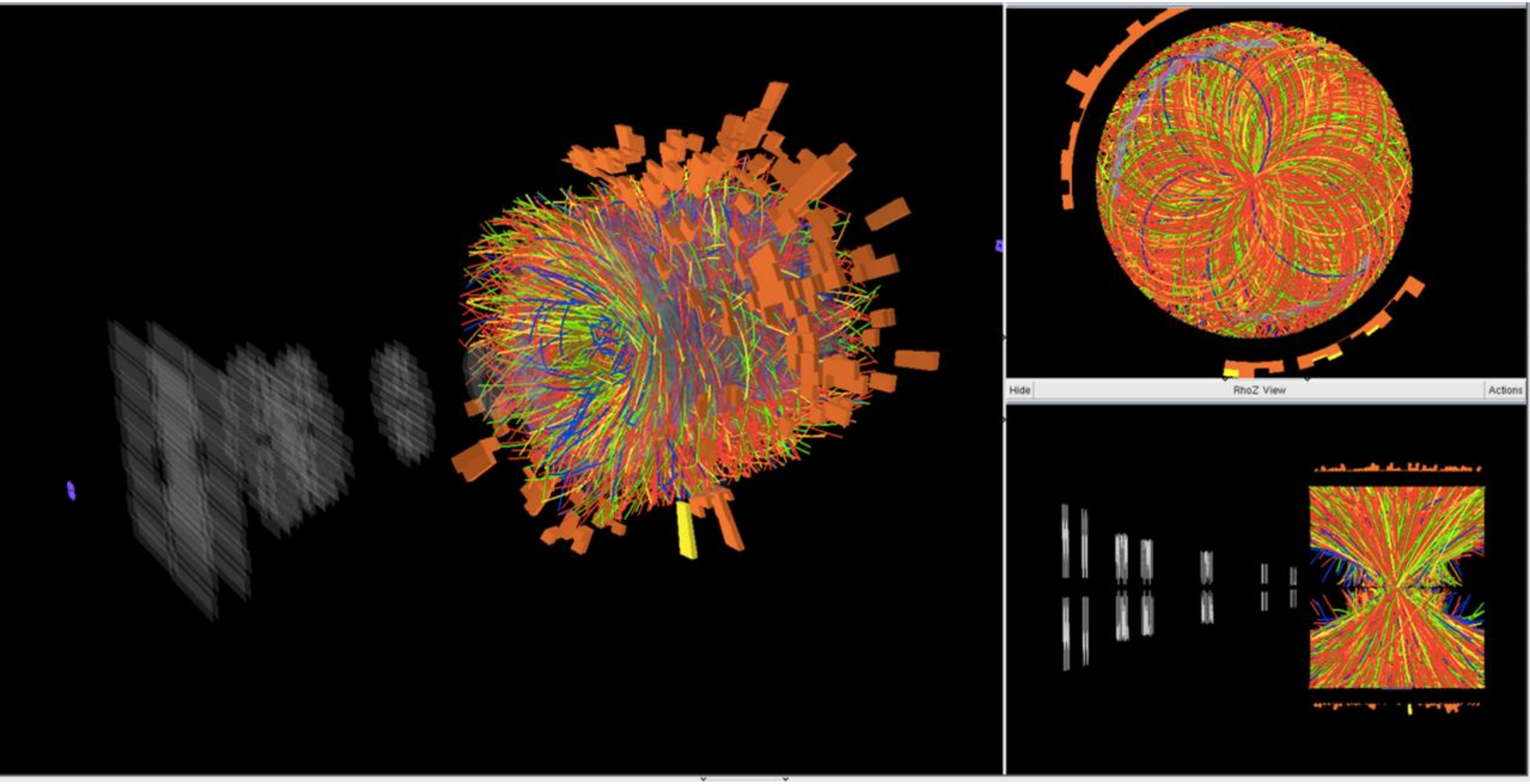
ALICE

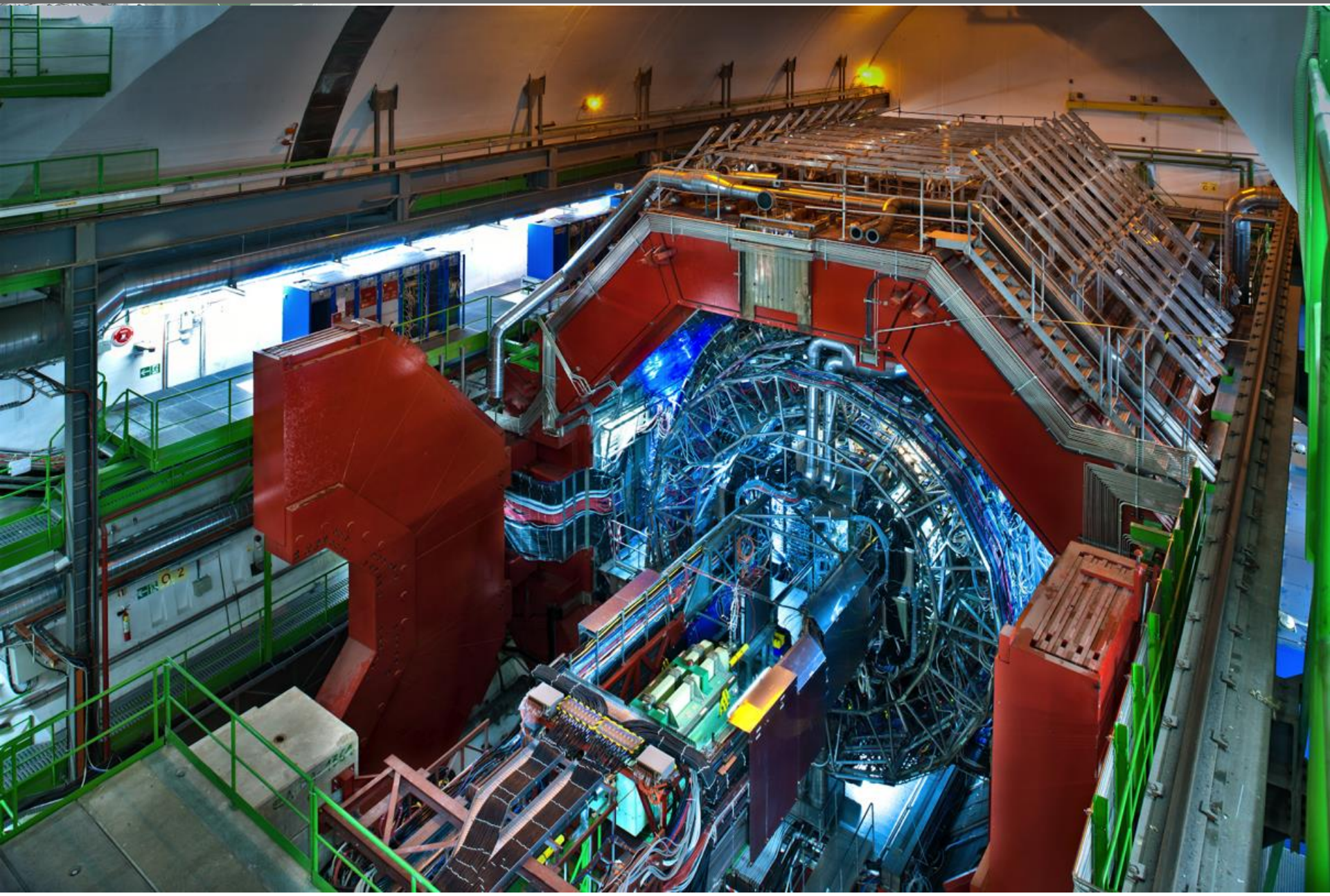


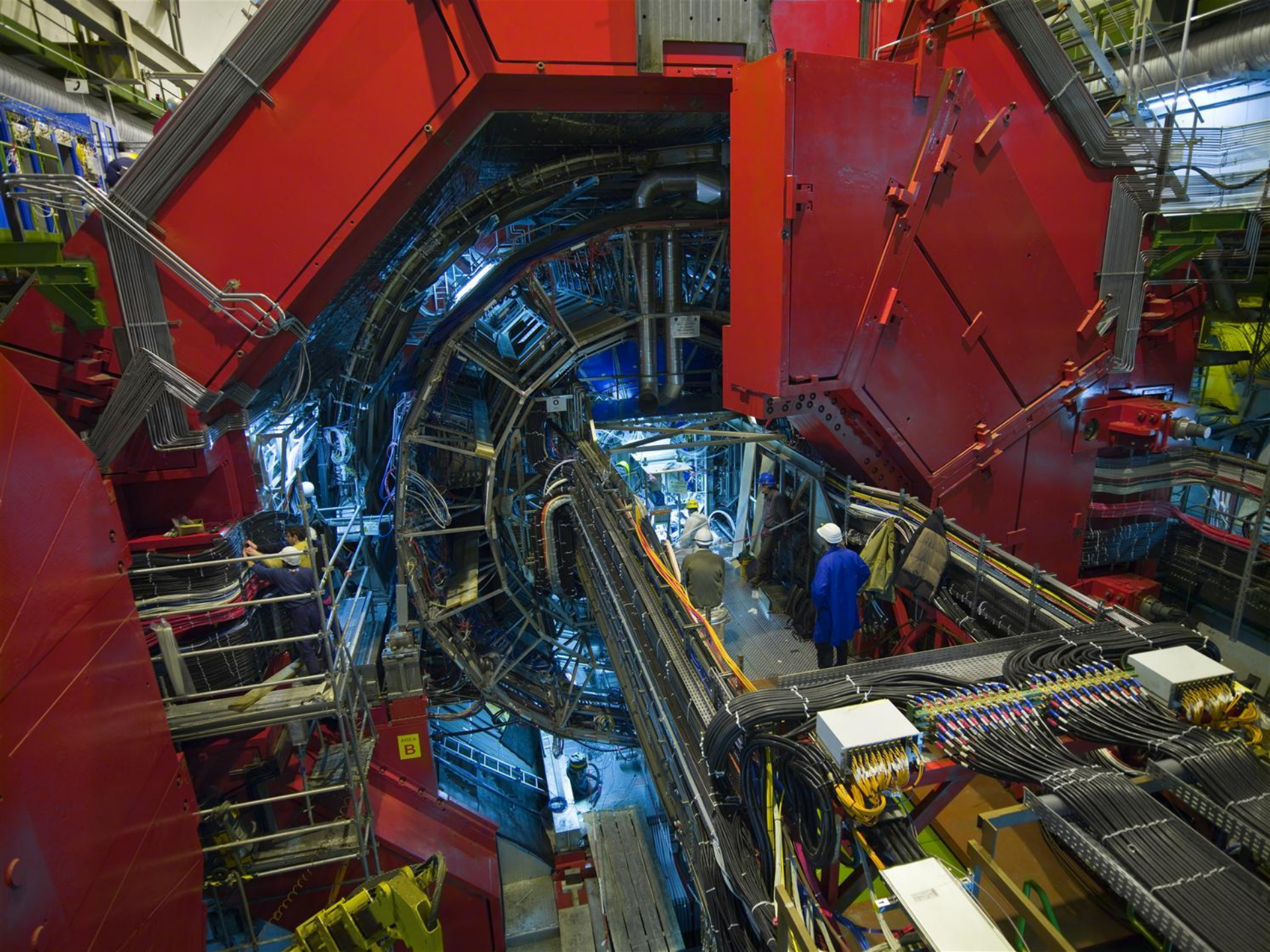
Detector:
Size: **16 x 26** meters
Weight: **10,000** tons

Collaboration:
> 1000 Members
> 100 Institutes
> 30 countries

Et af de første Pb-Pb sammenstød ved 1 PeV set i ALICE



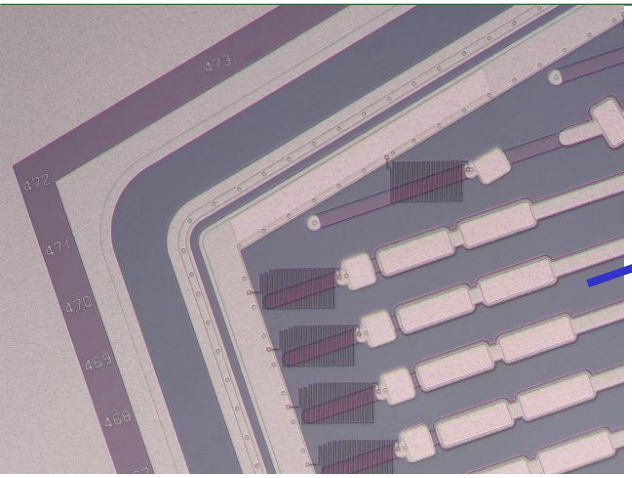


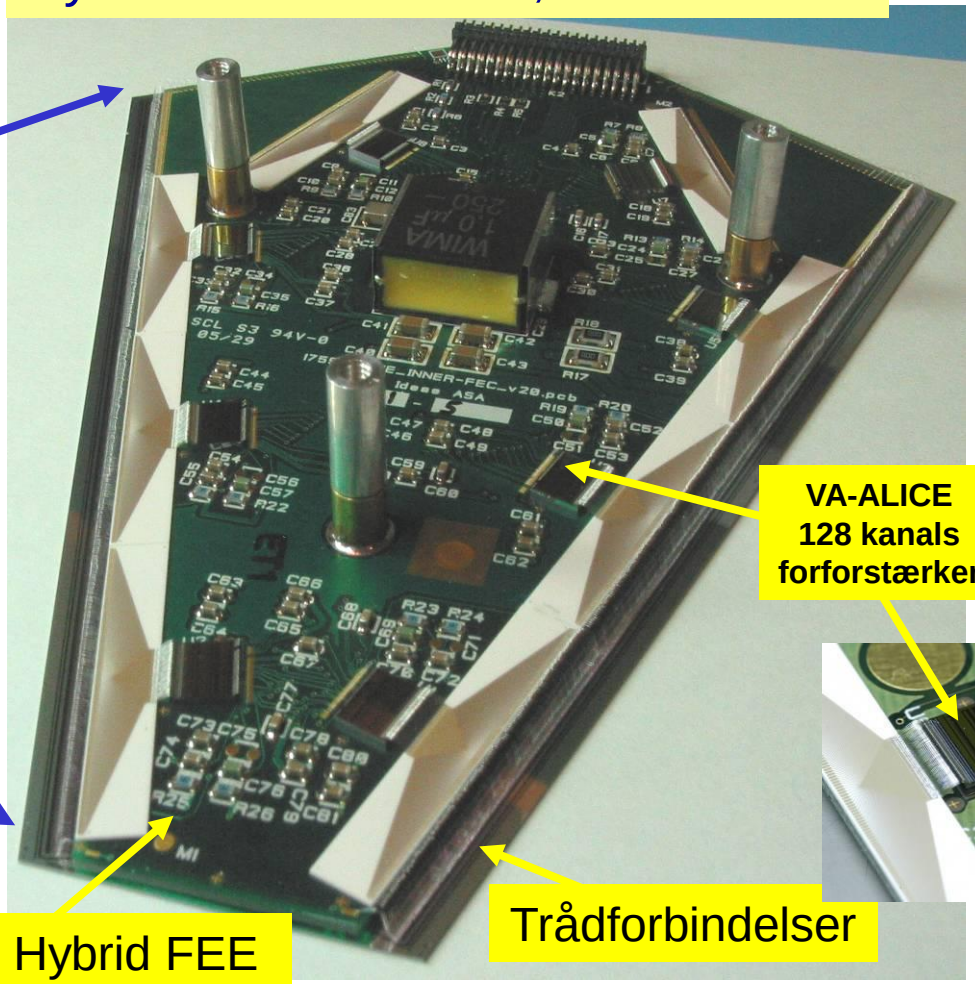

AREA
B

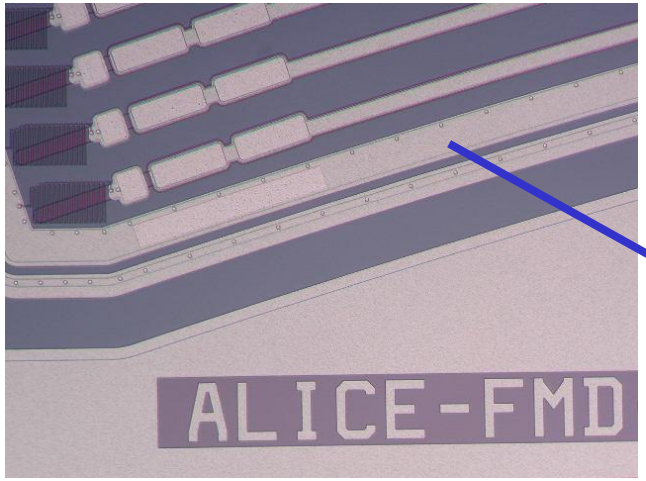

PR774

Silicium sensorer og hybrider

Sensorer fra Hamamatsu Photonics
Hybrider fra Ideas AS, Oslo







The principle of the laser system for the TPC

Support rings for
μ-mirror bundles

μ-mirror bundle

TPC volume

Central Electrode

Narrow laser beams:
20-40 μJ/pulse, ø 1 mm

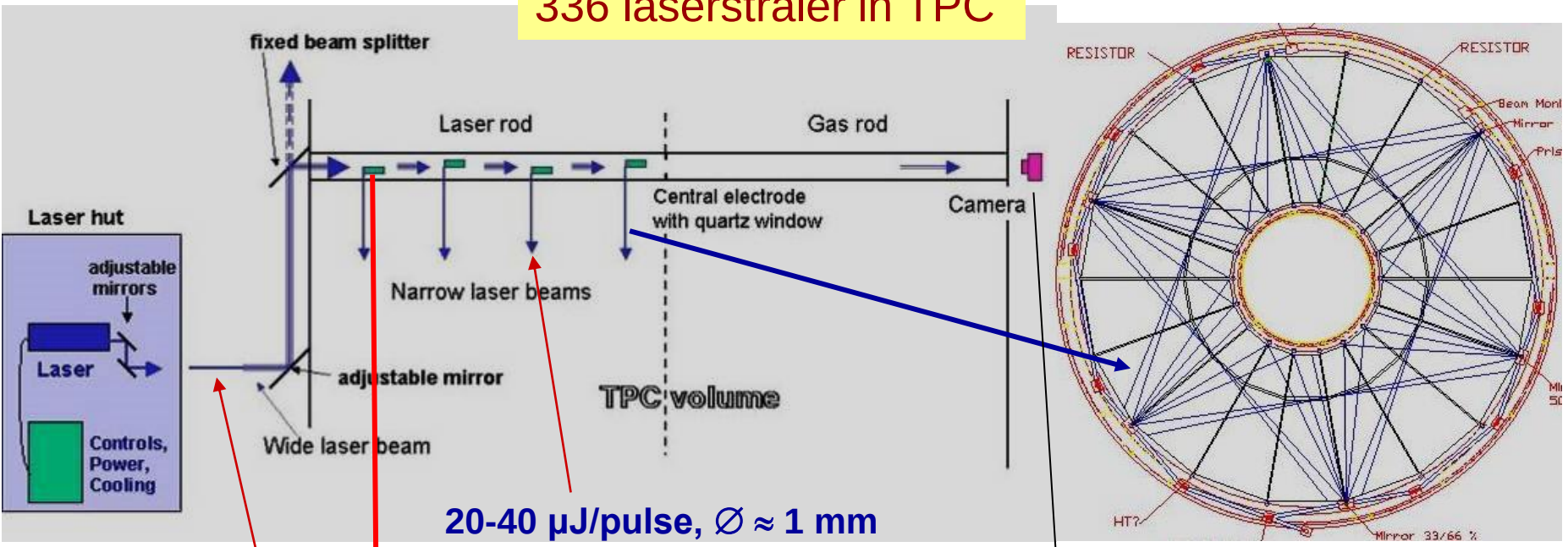
Four shadows of the
μ-mirror bundles

Wide laser beams: 266 nm,
100 mJ/pulse, 5 ns pulse, ø 25 mm

laser beam
splitter
adjustable mirror
prism
camera
rod

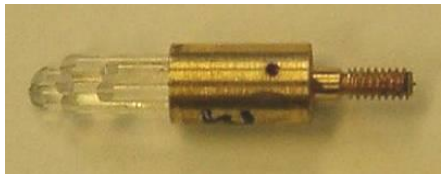
TPC laser kalibration

336 laserstråler in TPC

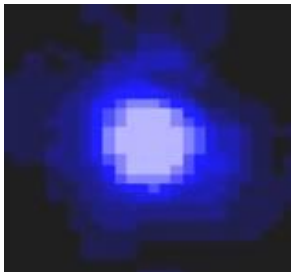


20-40 µJ/pulse, ∅ ≈ 1 mm

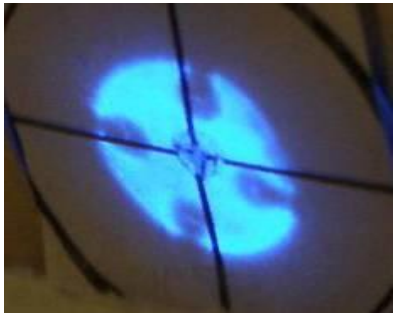
266 nm, 100 mJ/pulse, 5 ns pulse, ∅ ≈ 25 mm



1.5 mm



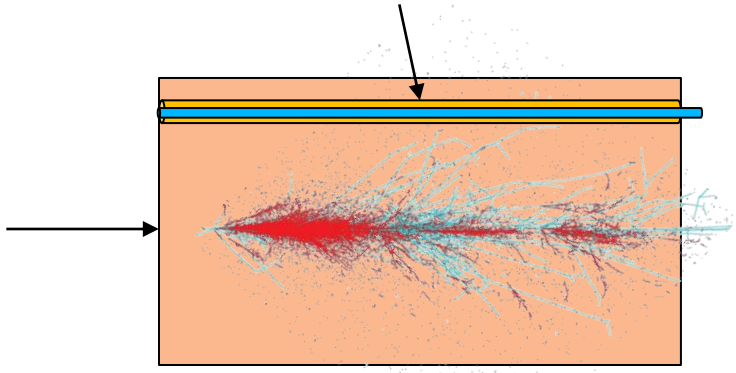
25 mm



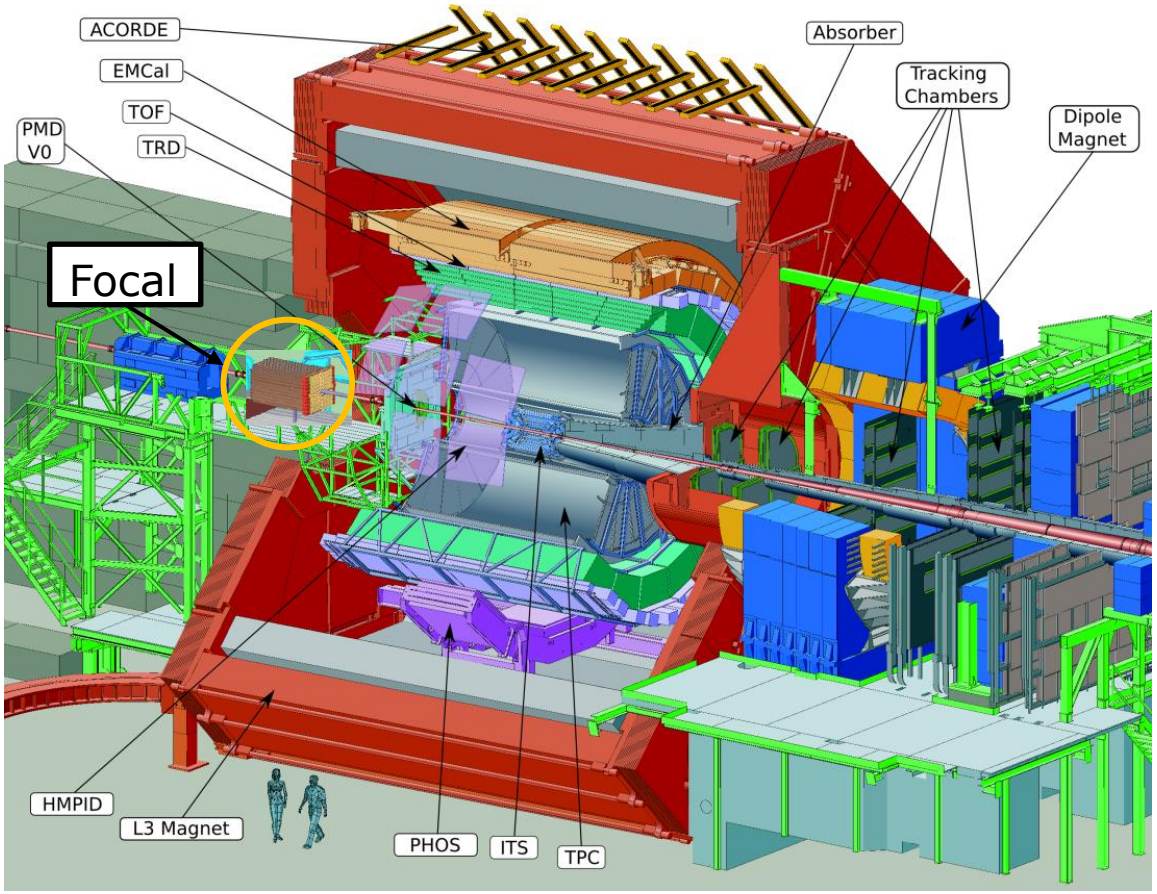
Focal-H: den nye danske detektor

Kobber-scintillator hadronisk kalorimeter

Kobberrør med scintillatorfiber

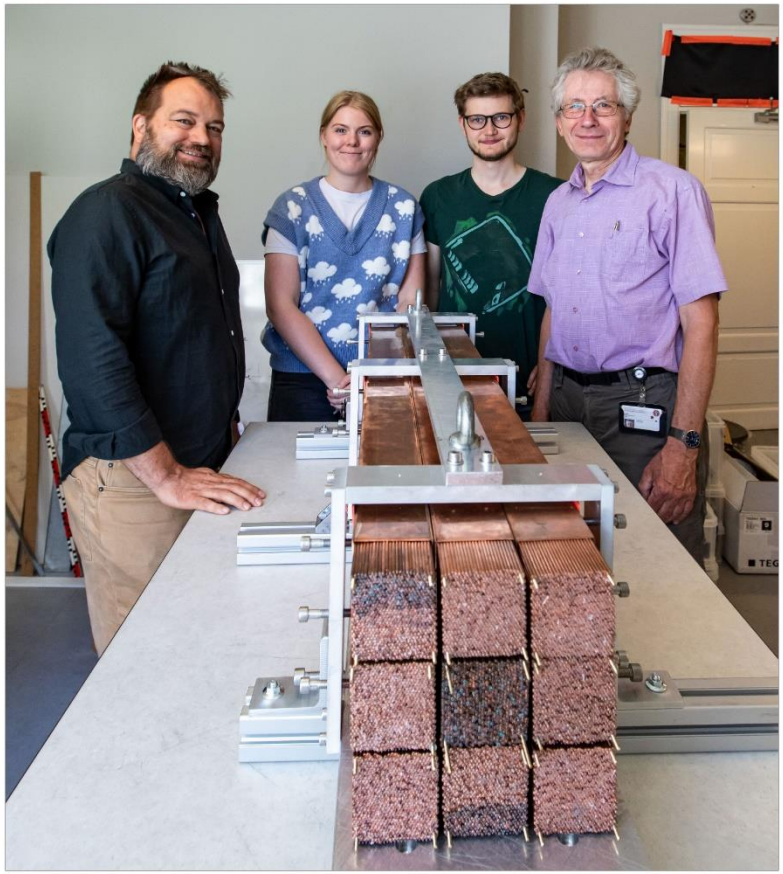


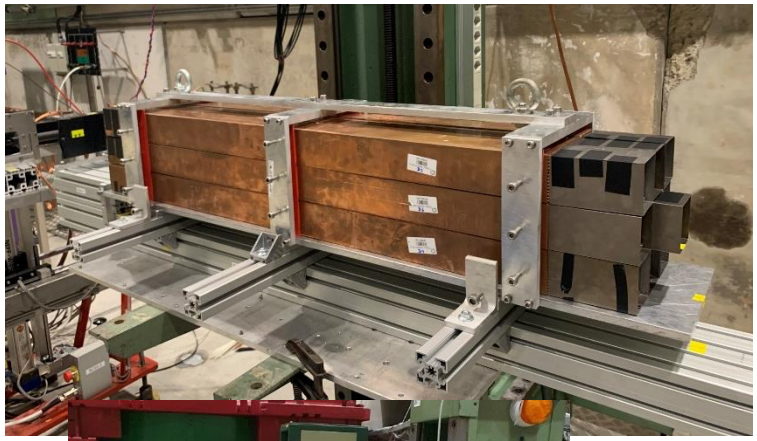
Måler lysglimt for enden af scintillerende fiber.
Lysmængden er proportionel med partiklens energi.

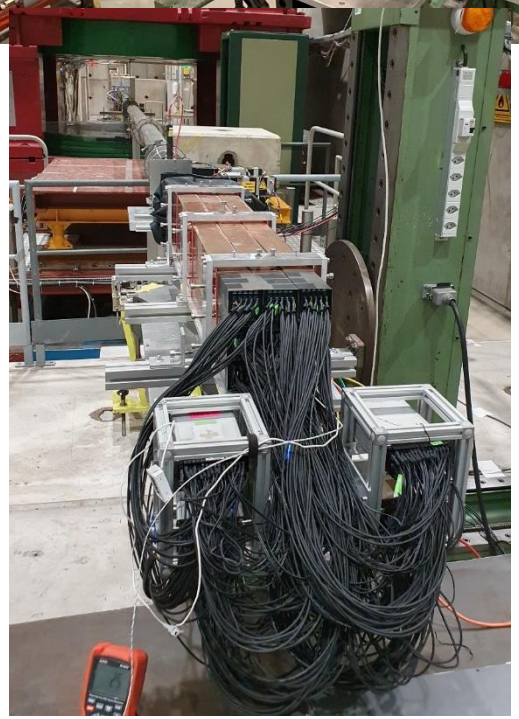


Focal-H: den nye danske detektor

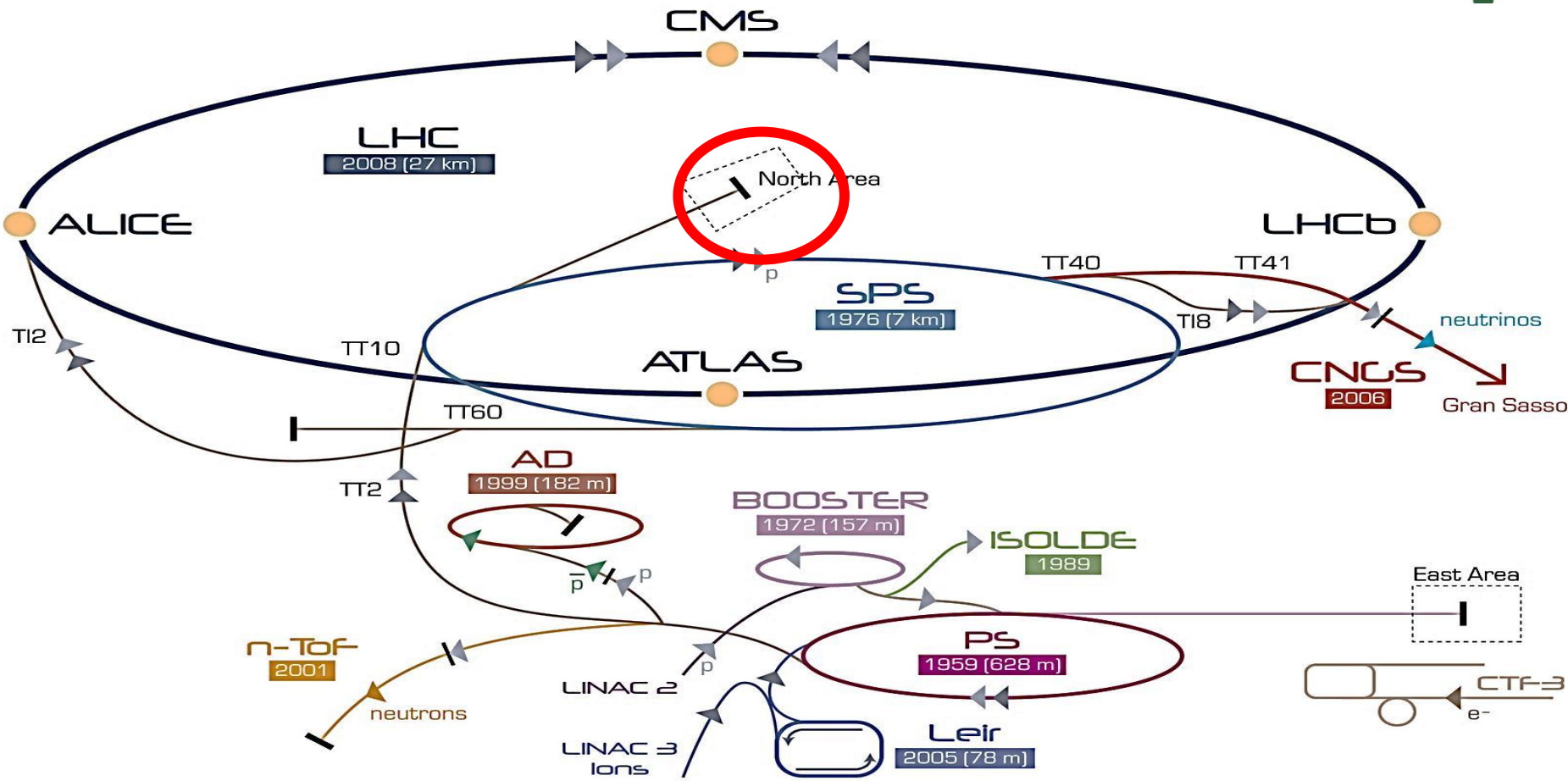
Kobber-scintillator hadronisk kalorimeter







Test beam i North Area

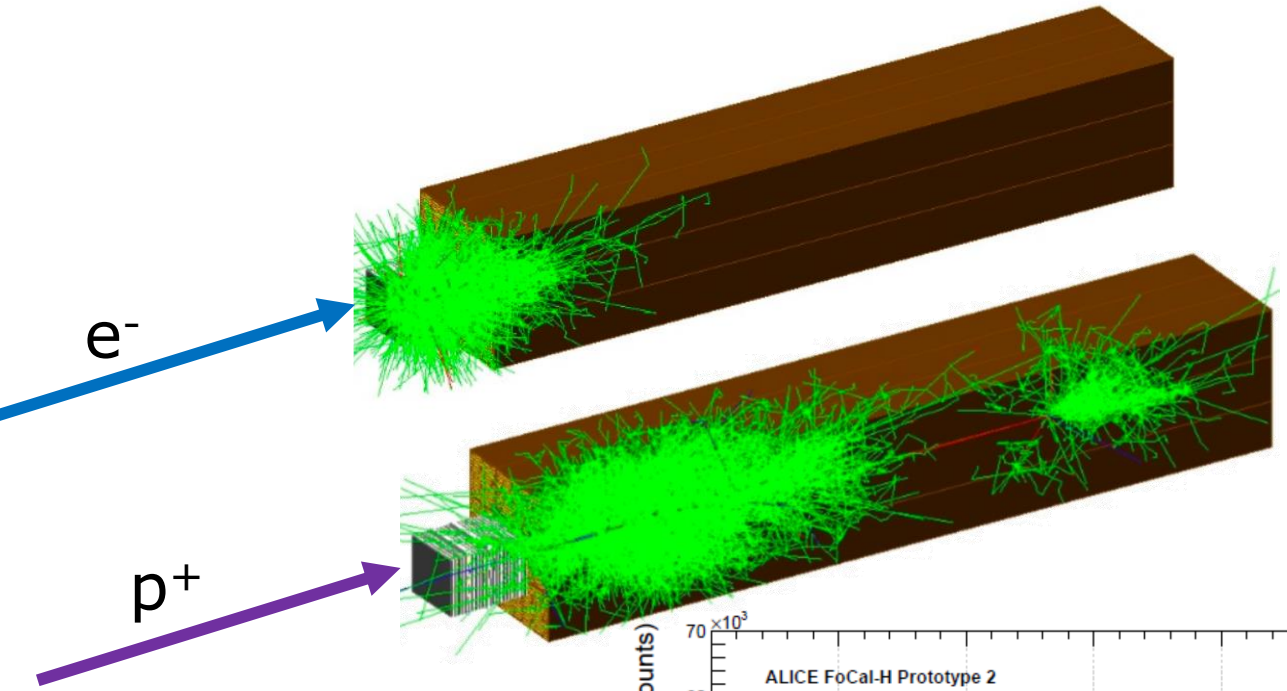


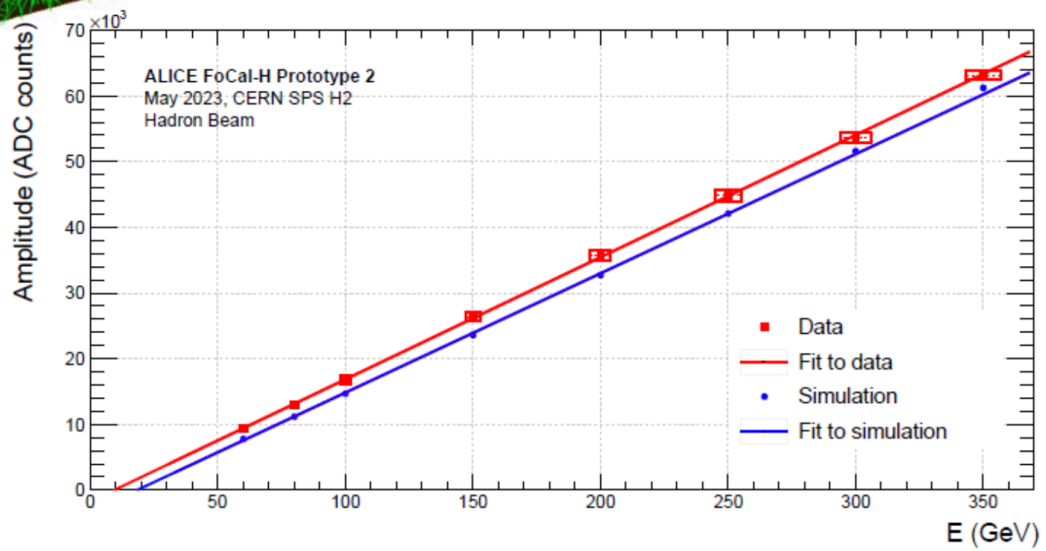
LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF-3 Clic Test Facility CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice

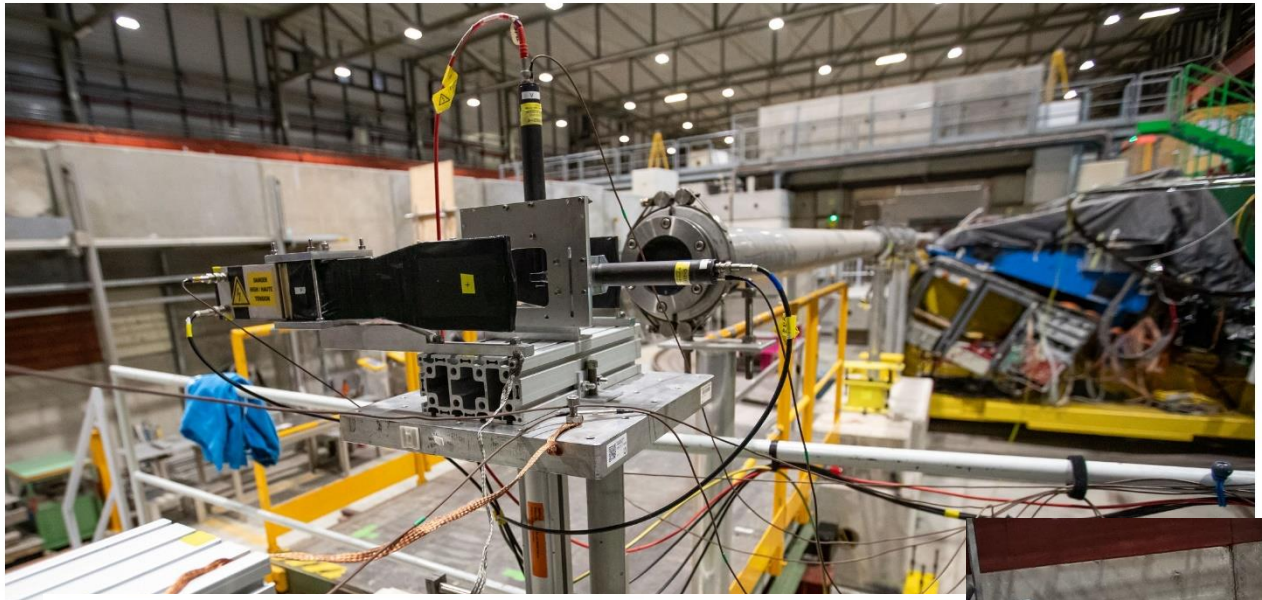
LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight

Focal = E + H kalorimeter





Test beam i North Area



Test beam i North Area

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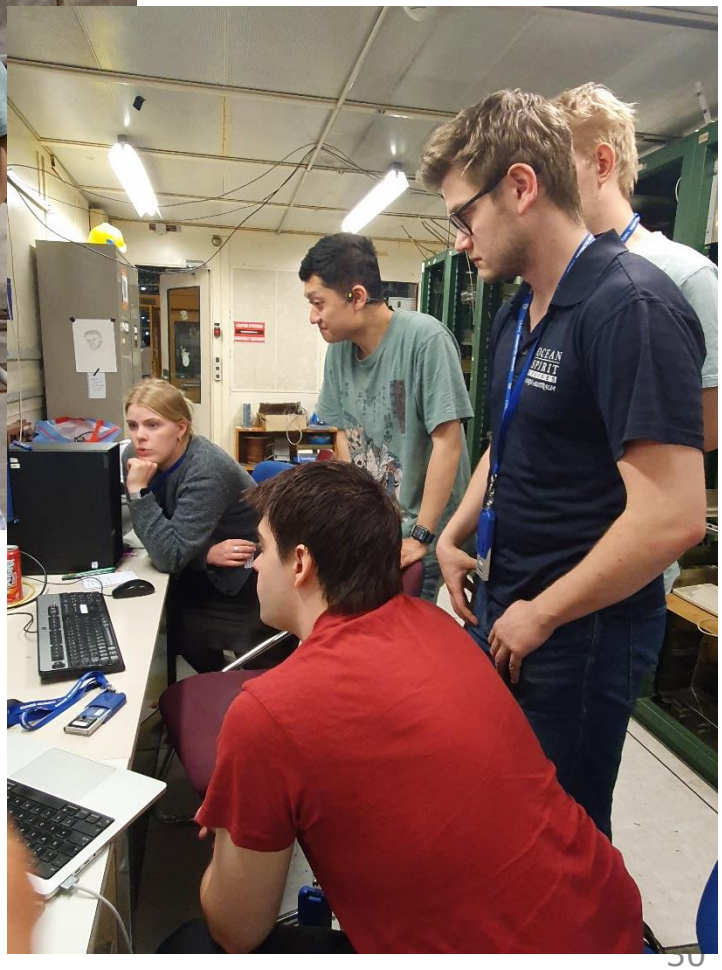

Lad os besøge ALICE ...