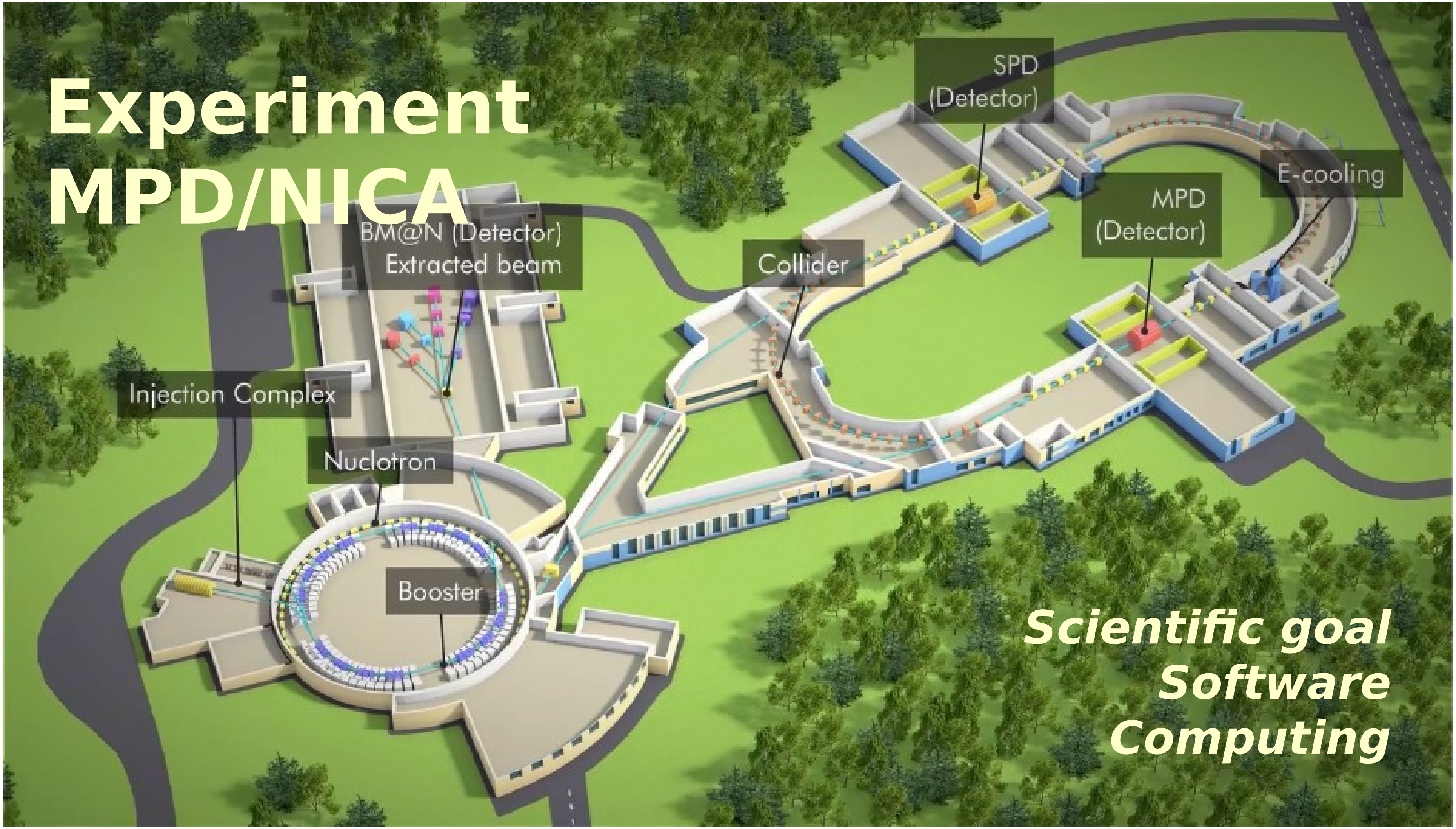
Experiment MPD/NICA

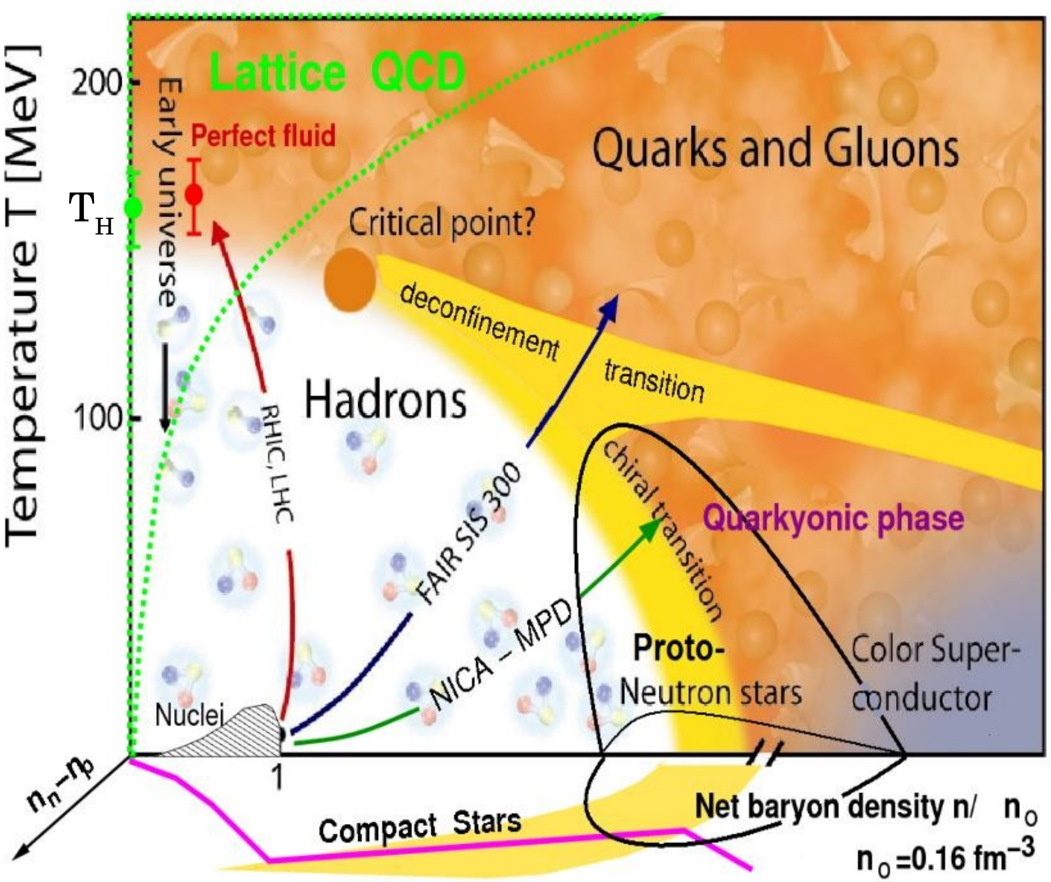


Scientific goal
Software
Computing

ROGACHEVSKY Oleg
rogachevsky@jinr.ru

AYSS-2022
16 July 2022
Lipnya

QGP phase diagram

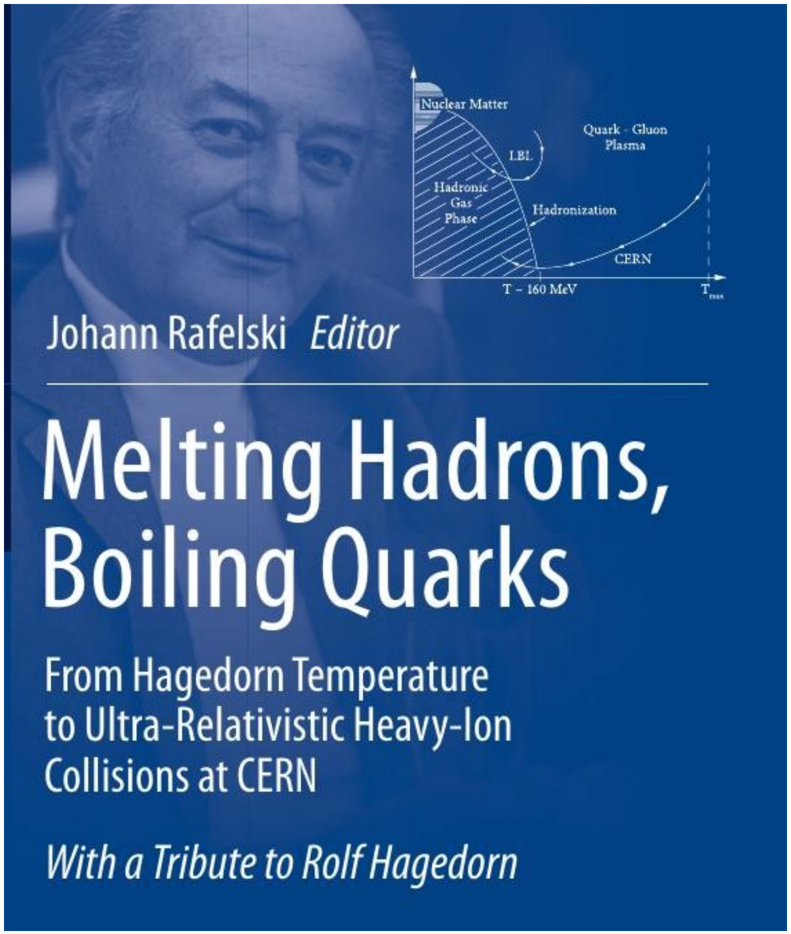


The collision of two heavy nuclei which approach and smash against each other with almost the speed of light. According to Einstein's theory of special relativity they look like thin pancakes. This "Little Bang" creates in the laboratory the primordial state of matter, called Quark-Gluon Plasma (QGP). The QGP expands like a fireball, cools and finally turns into ordinary matter, not unlike vapour turning into water

. The thousands of particles produced will be recorded by detectors. The tracks that those particles leave in the detectors will be analysed by modern powerful software tools.

The challenge is to infer the properties of the QGP state of matter by studying the different particles that arrive in the detectors.

Melting hadrons



What is Hagedorn Temperature?

Hagedorn temperature $T_H \approx 1.8\text{x}10^{12}$ K is the maximum temperature at which matter can exist in the usual form. At $T > T_H$ all individual material particles dissolve into the quark-gluon plasma. This transformation can occur at a lower temperature in the presence of dense nuclear matter. At densities an order of magnitude greater than the nuclear density this transformation probably can occur near to, or even at, zero temperature.
The value of T_H is measured by the way of the exponential growth of the hadron mass spectrum,

$$\rho(m) \propto m^{-a} \exp(m/T_H)$$

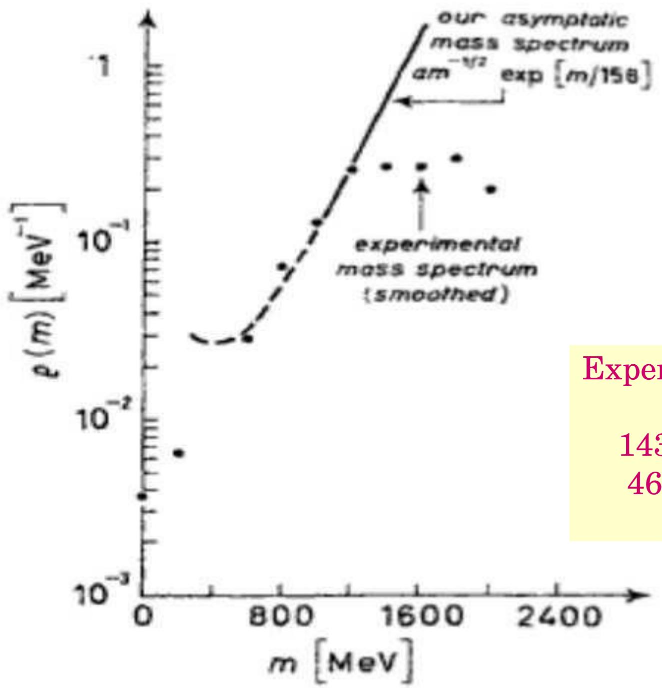
T_H is thus uniquely defined independent of the question, if the conversion of matter into quark-gluon plasma is a sharp boundary, or a continuous transformation.

Hagedorn temperature

Statistical Thermodynamics
of Strong Interactions at High Energies.

R. HAGEDORN
CERN - Geneva

(ricevuto il 12 Marzo 1965)



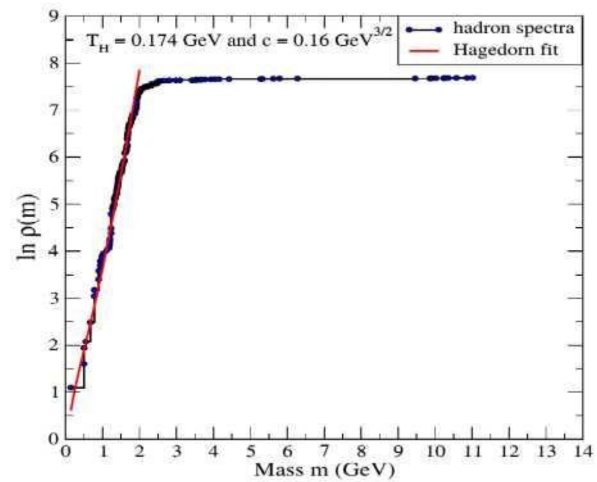
$$\bar{\varrho}_{\exp}(m) = \frac{1}{\sqrt{2\pi\tau^2}} \sum_{i=1}^{N} \nu_i \exp\left[-\frac{(m-m_i)^2}{2\tau^2}\right], \qquad \tau = 200 \text{ MeV},$$

where the sum goes from the pion mass
To the highest known resonances

Experimental data:

1432 states known in 1967;
4627 states of mid ’90s.

J. Cleymans and D. Worku
Modern Physics Letters A
Vol. 26, No. 16 (2011) 1197–1209

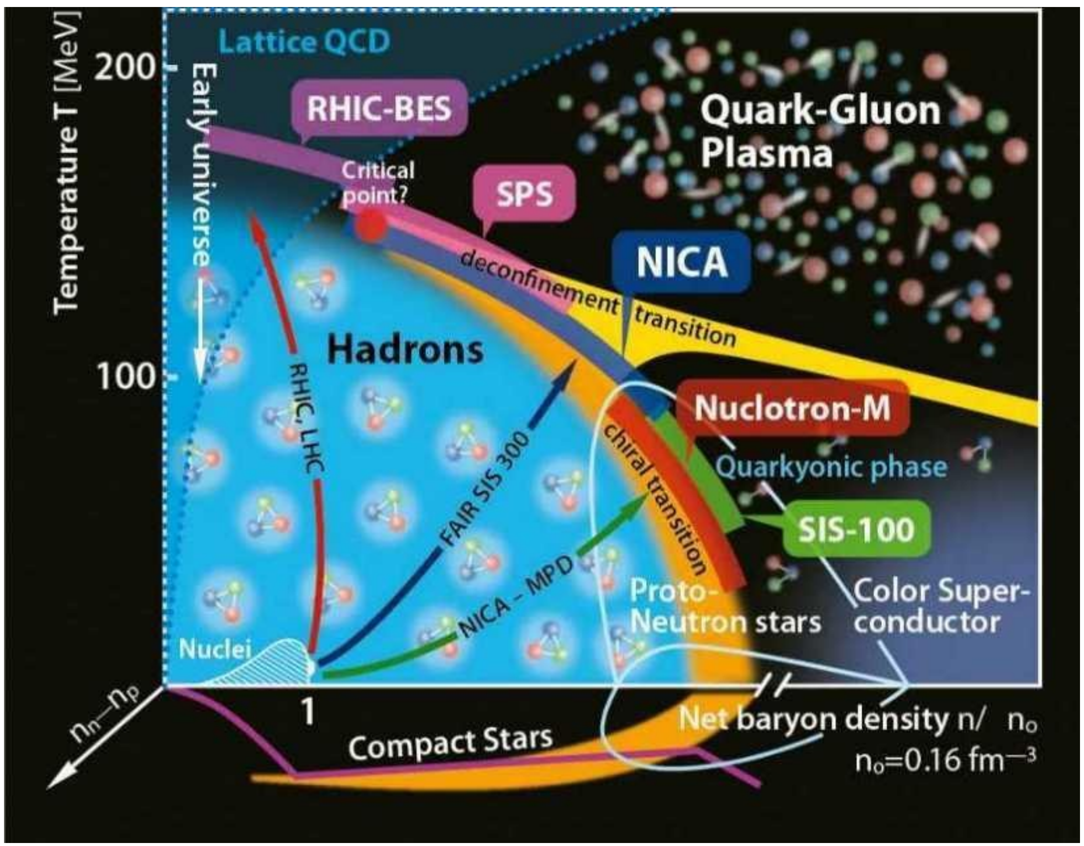


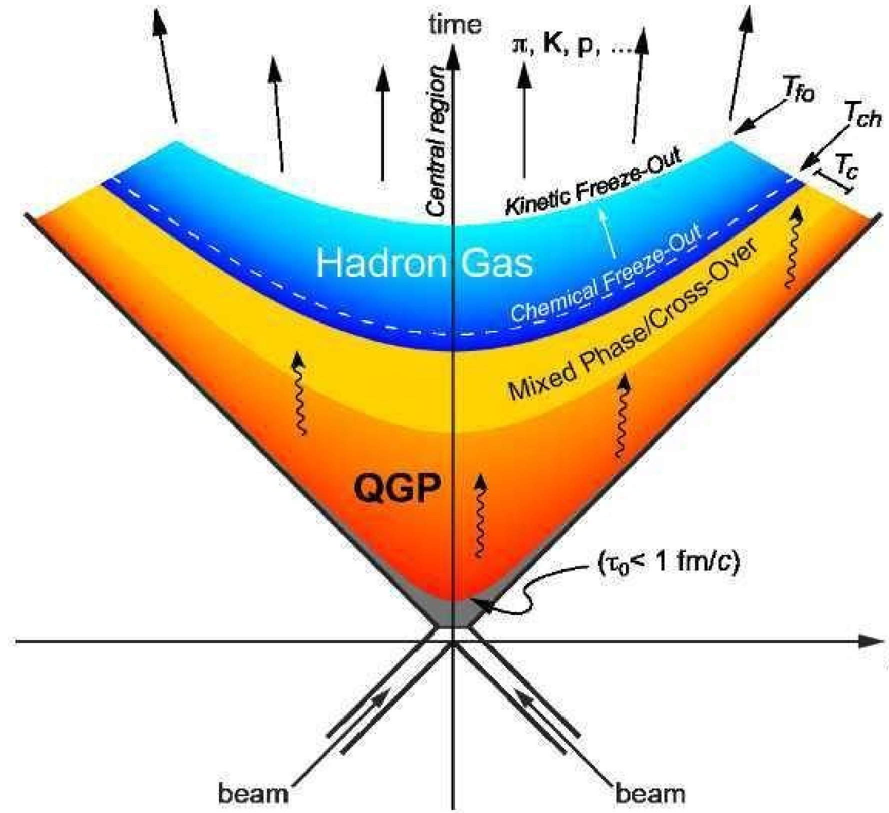
$$\rho_h(m) = \frac{c}{(m^2+m_0^2)^{5/4}} \exp\left(\frac{m}{T_{\mathrm{H}}}\right)$$

Parameter	
c (GeV)$^{3/2}$	0.16 ± 0.02
m_0 (GeV)	0.5
T_{H} (GeV)	0.174 ± 0.011

Bootstrap statistical model

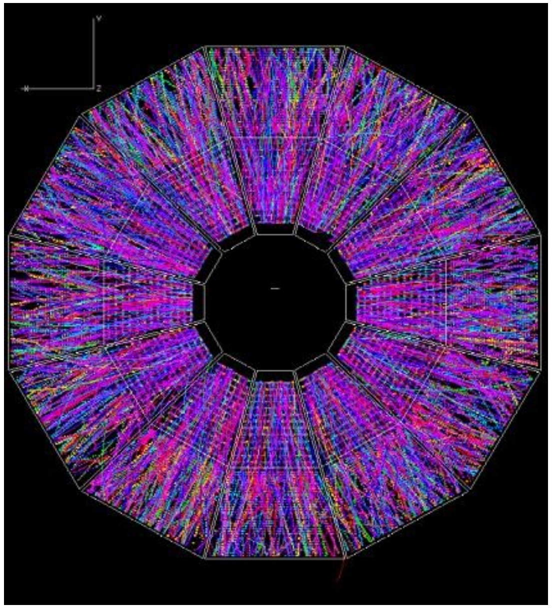
QGP in nucleus collisions



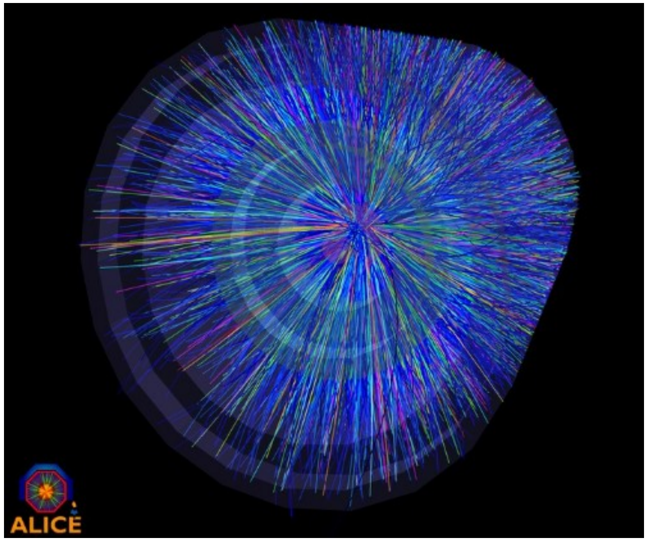


Heavy Ion collisions

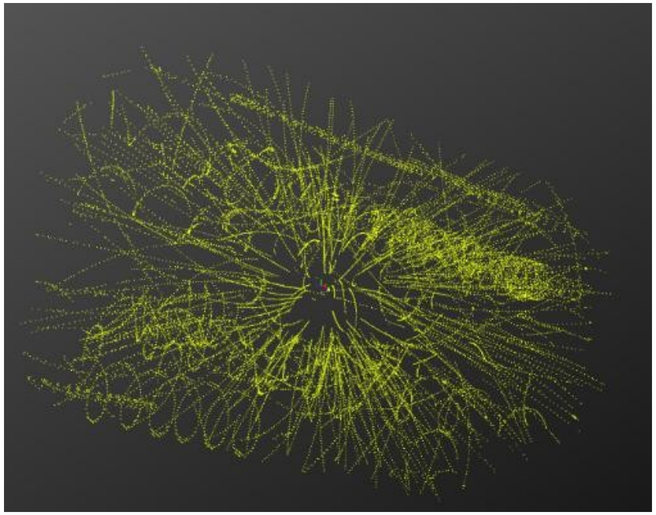
STAR AuAu √s=200 GeV
$N_{particles}$ ~ 2000



ALICE PbPb √s=2.76 TeV
$N_{particle}$ ~ 5000



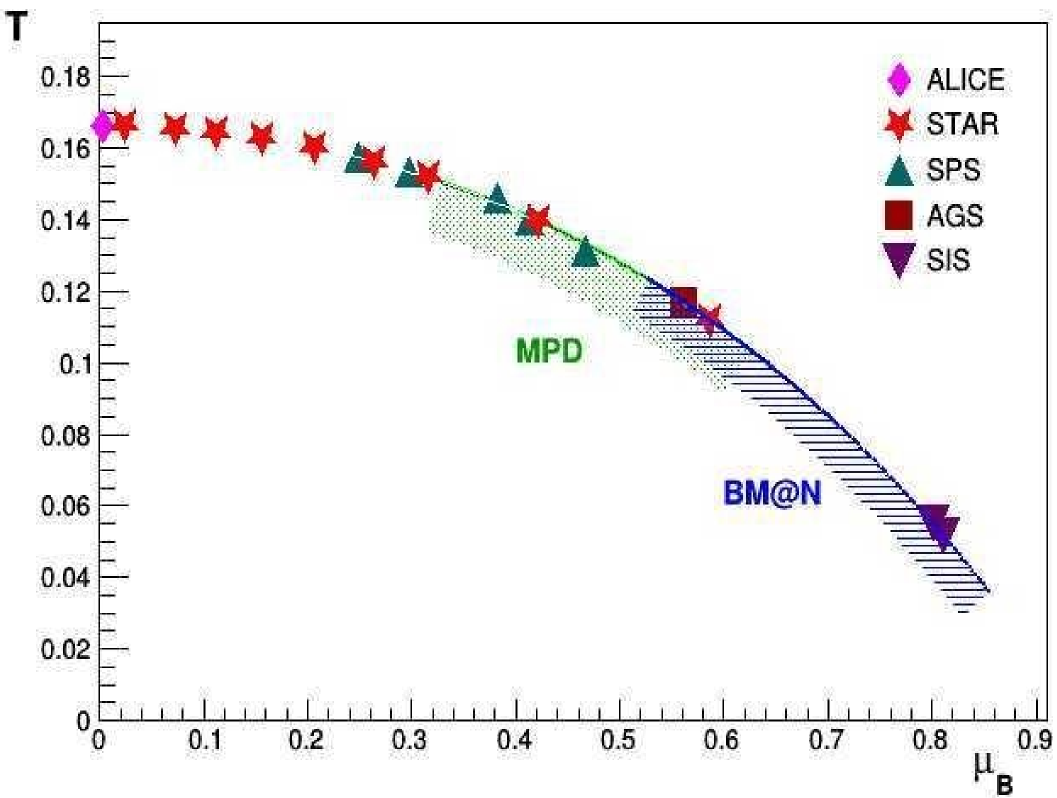
MPD AuAu √s=11 GeV
$N_{particle}$ ~ 1000

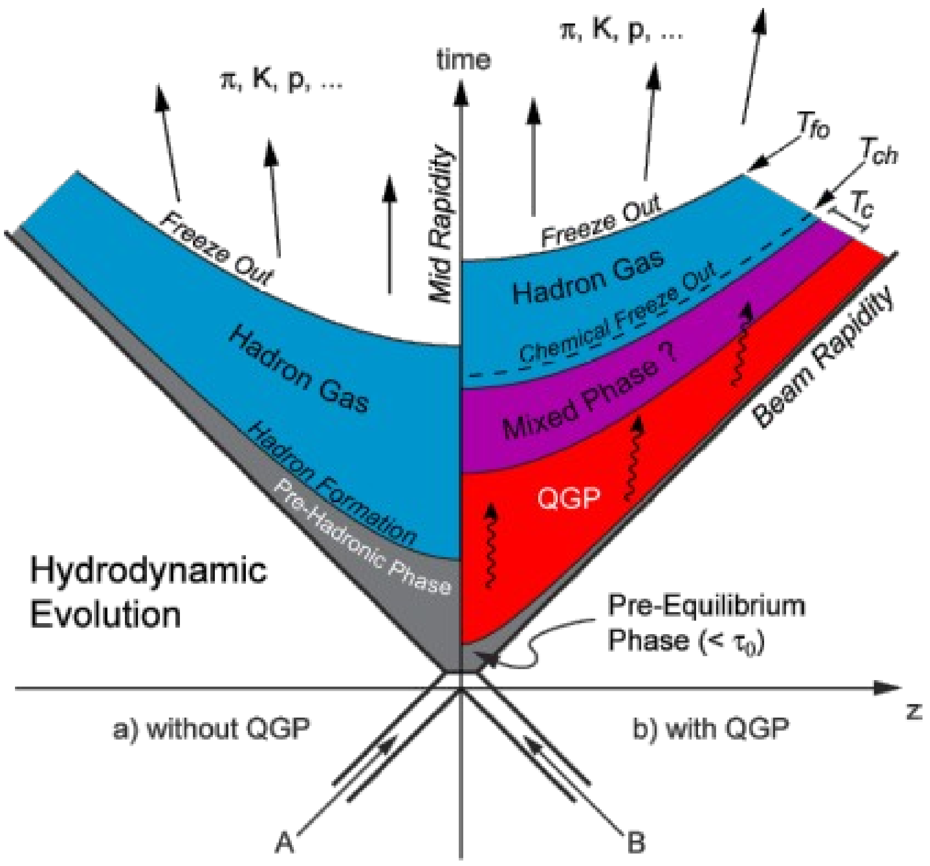


QCD Phase diagram for NICA

NICA energy scan:
- MPD $4 < \sqrt{s} < 11$ GeV/u
- BM@N $2.3 < \sqrt{s} < 3.4$ GeV/u
- p, C, …, Au

Cleymans parametrization

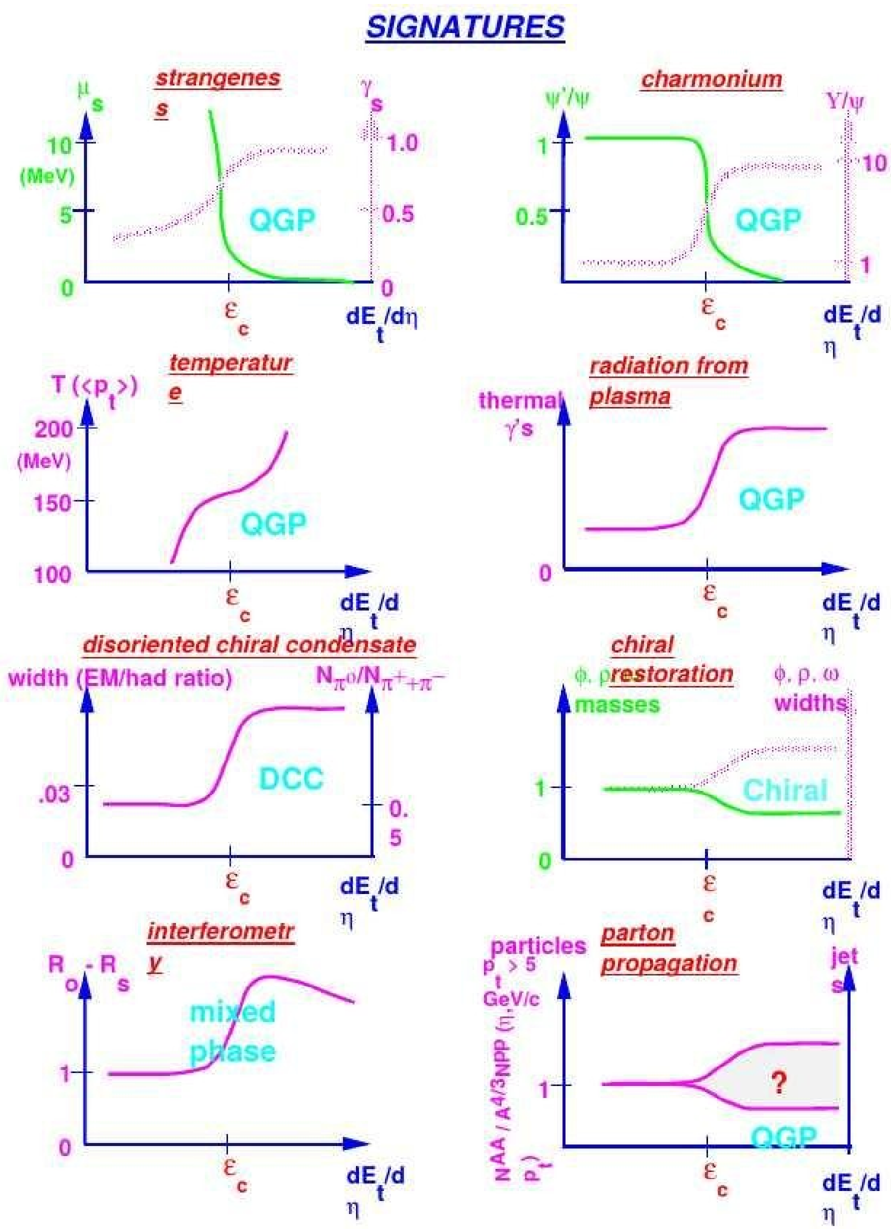




HIC studies

Accelerator	Place	Ion periods	Energy	Projectiles
Synchro- Phasatron	JINR Dubna	1971 - 1985	3.6 AGeV	d, He, C
Bevalac	LBNL Berkeley	1972 - 1984	< 2AGeV	C,Ca,Nb, Ni,Au,...
AGS	BNL, Brookhaven	1986 - 1994	14,5/11,5 AGeV	Si, Au
SPS	CERN, Geneva	1986 - 2002	200/158 AGeV	O,S,In,Pb
SIS 18	GSI,Darmstadt	1992 - today	2 AGeV	Kr,Au
Nuclotron	JINR Dubna	1993 - today	< 4.5 AGeV	p, d, He,C,Li, Mg, Kr
RHIC	BNL, Brookhaven	2000 - today	$\sqrt{S_{NN}}$ = 200 GeV	Cu, Au
LHC	CERN, Geneva	2010	$\sqrt{S_{NN}}$ = 5.5 TeV	Pb
NICA	JINR Dubna	202?	$\sqrt{S_{NN}}$ = 4 -11 GeV	p - Au
SIS 100	GSI,Darmstadt	2025	2 – 11 AGeV	Au

Theoretical predictions



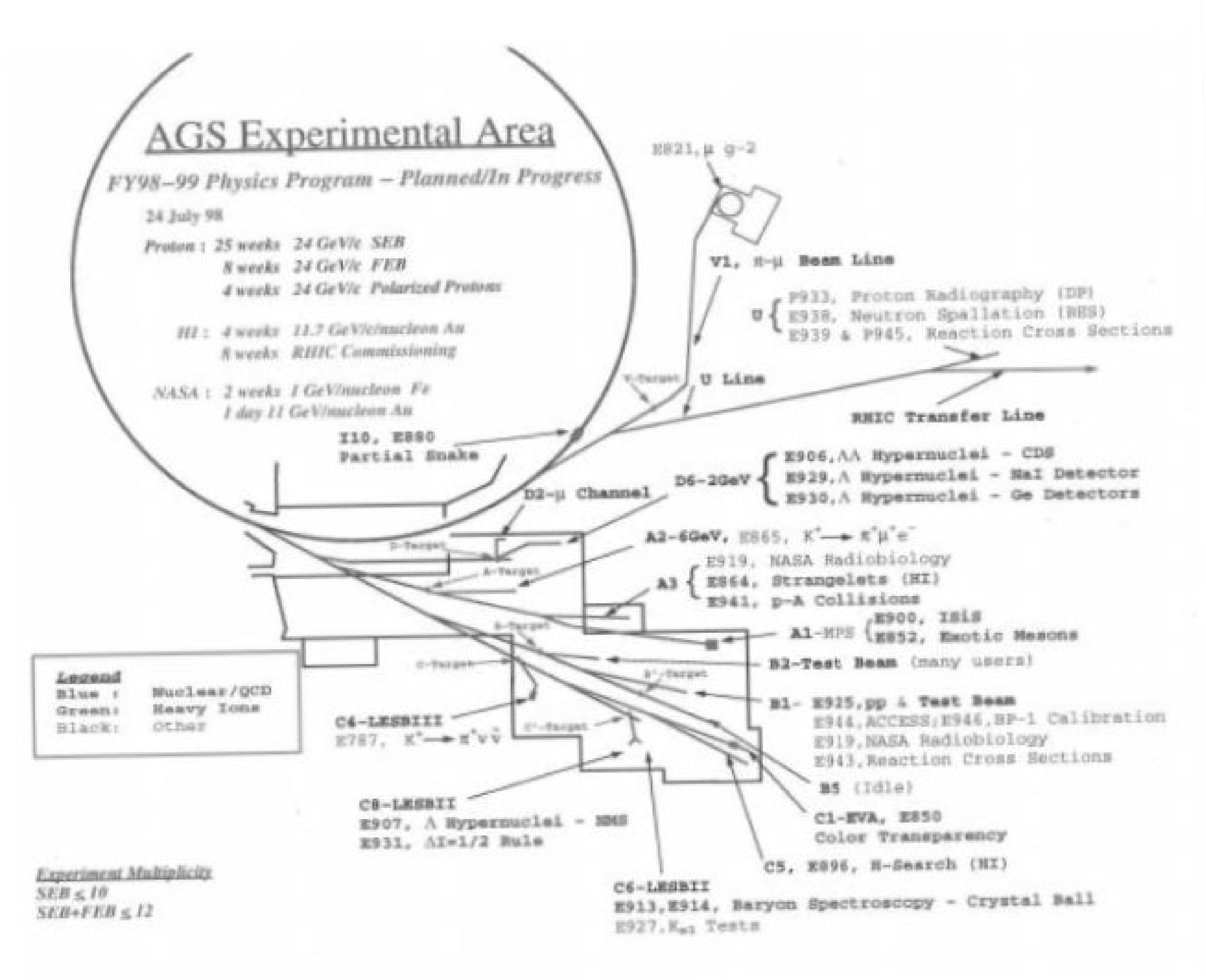
The Search for the Quark-Gluon Plasma

arXiv:hep-ph/9602235

John W. Harris, Berndt Müller

Signatures of quark-gluon plasma formation and the chiral phase transition. The expected behavior of the various signatures is plotted as a function of the measured transverse energy, which is a measure of the energy density, in the region around the critical energy density ε_c of the transition. When two curves are drawn, the hatched curve corresponds to the variable described by the hatched ordinate on the right. See text of review for details

AGS experiments



Strangeness enhancement

J. Rafelski and B. Müller, PRL 48, 1066 (1982)

Strangeness Production in the Quark-Gluon Plasma

Johann Rafelski and Berndt Müller
Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, D-6000 Frankfurt am Main, Germany
(Received 11 January 1982)

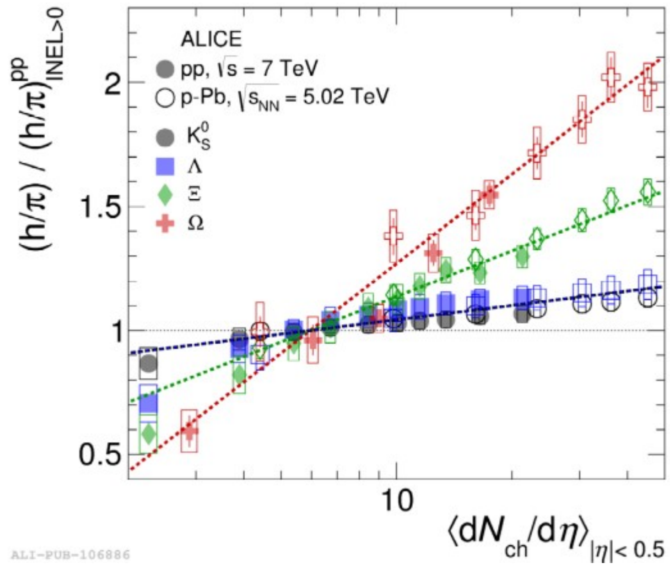
Rates are calculated for the processes $gg \to s\bar{s}$ and $u\bar{u}, d\bar{d} \to s\bar{s}$ in highly excited quark-gluon plasma. For temperature $T \geq 160$ MeV the strangeness abundance saturates during the lifetime ($\sim 10^{-23}$ sec) of the plasma created in high-energy nuclear collisions. The chemical equilibration time for gluons and light quarks is found to be less than 10^{-24} sec.

PACS numbers: 12.35.Ht, 21.65.+f

....

We thus conclude that strangeness abundance saturates in sufficiently excited quark-gluon plasma ($T > 160$ MeV, $E > 1$ GeV/fm^3), allowing us to utilize enhanced abundances of rare, strange hadrons ($\bar{\Lambda}$, $\bar{\Omega}$, etc.) as indicators for the formation of the plasma state in nuclear collisions.

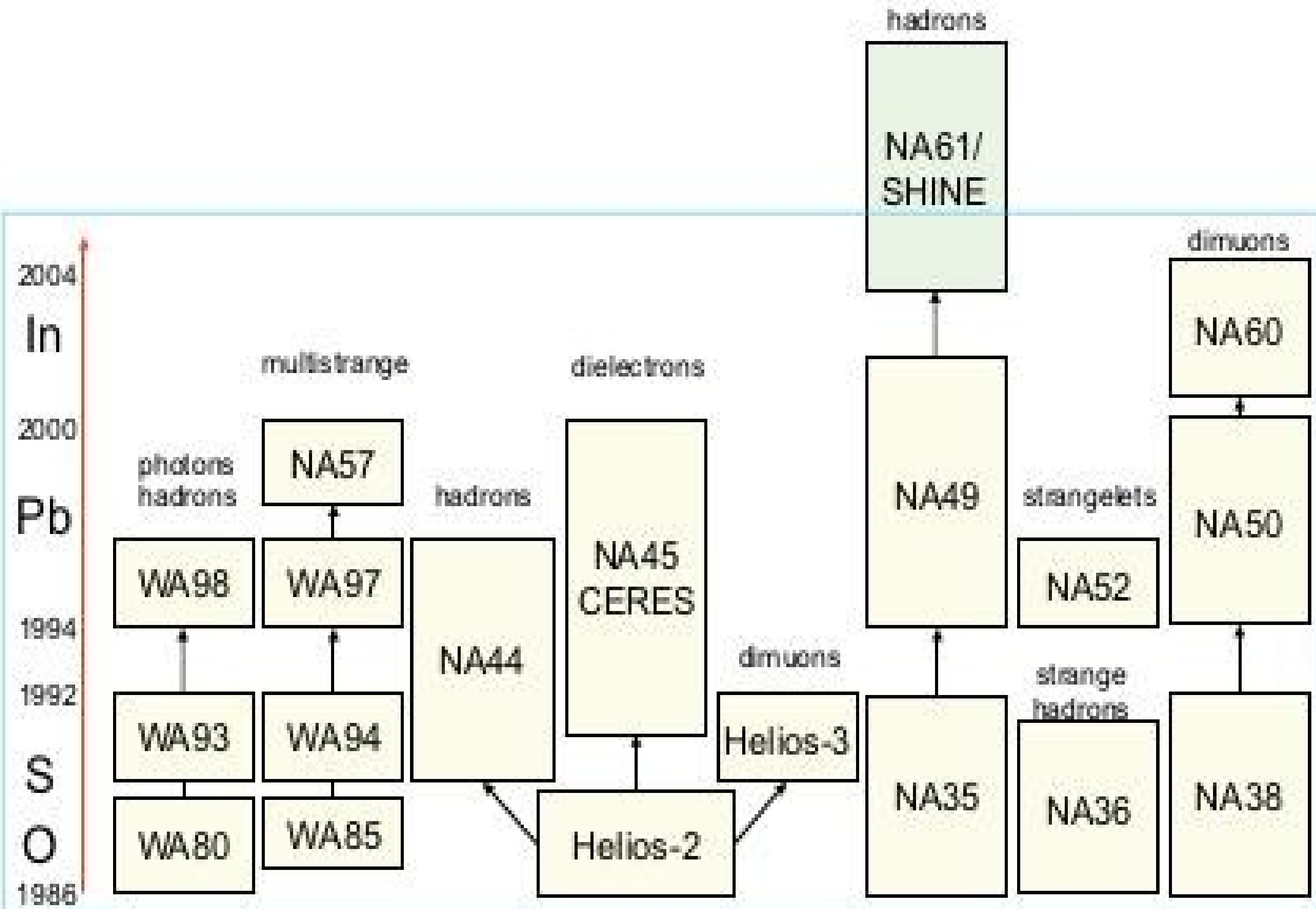
Nature Physics 13 (2017) 535



First observation of a multiplicity dependent strangeness enhancement in high-multiplicity pp collisions

- enhancement is due to strangeness content and not due to mass
- multiplicity dependence of the enhancement is strikingly similar in pp and p-Pb, and approaches values similar to those measured in central Pb-Pb
- QCD inspired MC generators fail to describe these observations
- measurements in pp @ 13 TeV seems to indicate that hadrochemistry is driven by event activity regardless of collision energy

SPS ion experiments



CERN 2000

January 31, 2000

Evidence for a New State of Matter:
An Assessment of the Results from the CERN Lead Beam Programme

Ulrich Heinz and Maurice Jacob
Theoretical Physics Division, CERN, CH-1211 Geneva 23, Switzerland

A common assessment of the collected data leads us to conclude that we now have compelling evidence that a new state of matter has indeed been created, at energy densities which had never been reached over appreciable volumes in laboratory experiments before and which exceed by more than a factor 20 that of normal nuclear matter. The new state of matter found in heavy ion collisions at the SPS features many of the characteristics of the theoretically predicted quark-gluon plasma.

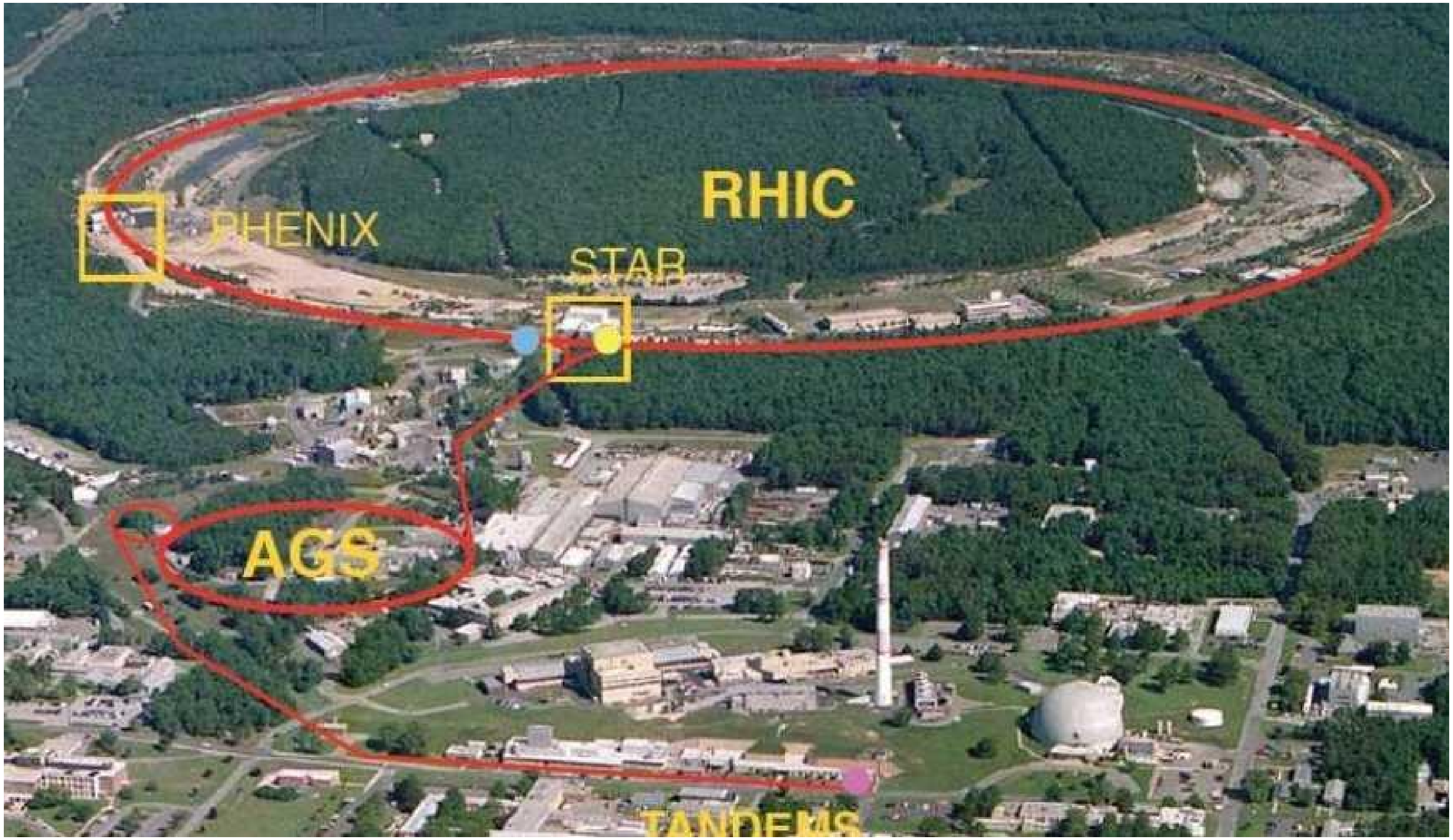
arXiv:nucl-th/0002042v1 16 Feb 2000

RHIC

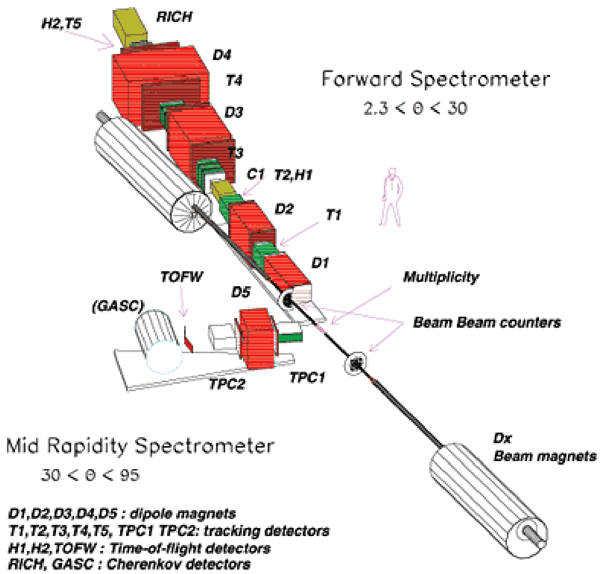
BNL - RHIC (from 2000):

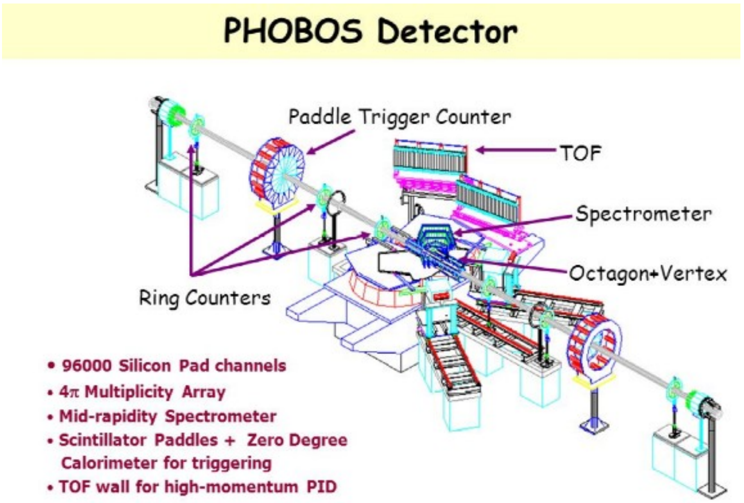
$\sqrt{s}$ = 200 GeV, Au + Au collisions

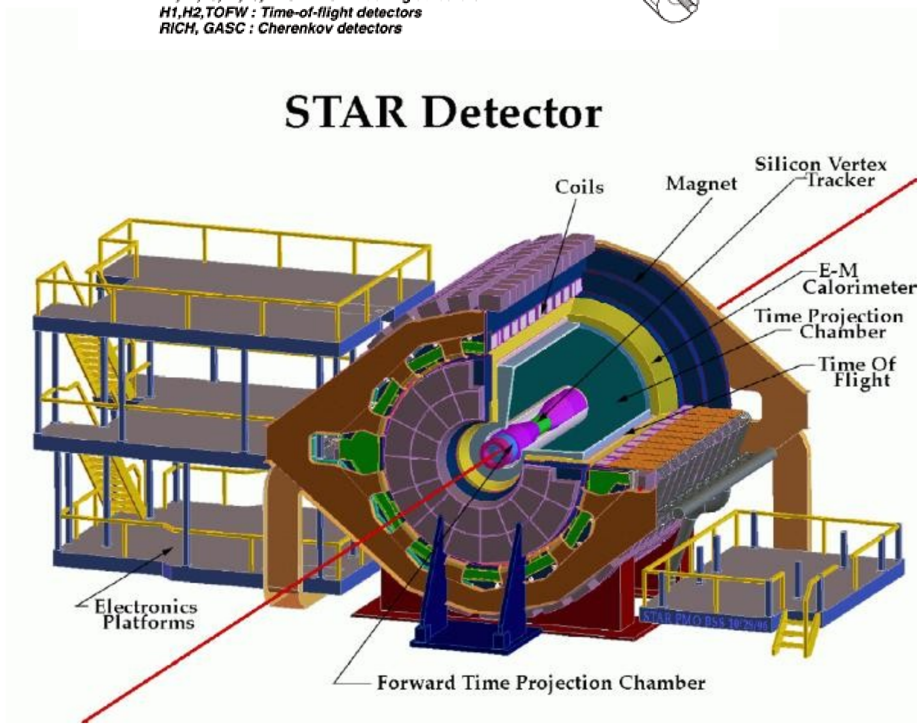
4 large experiments: BRAHMS, PHENIX, PHOBOS, STAR.

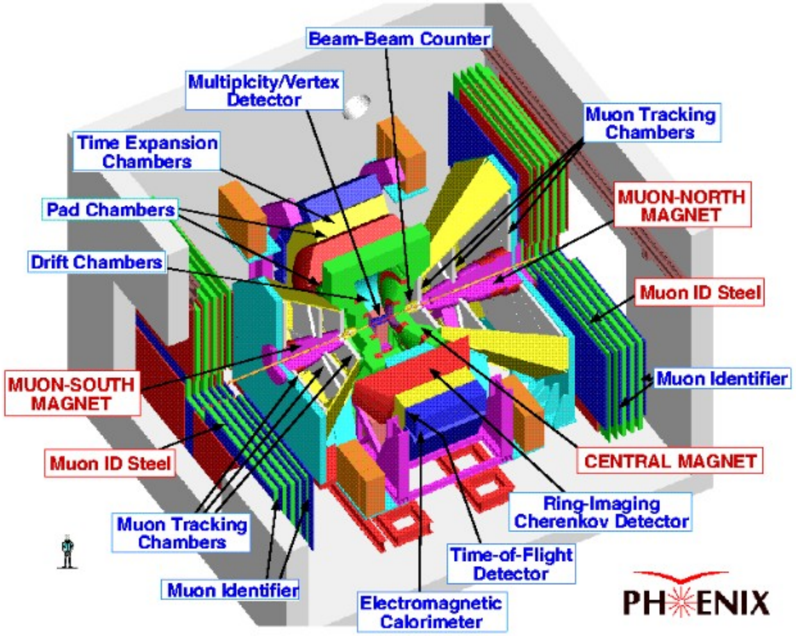


RHIC experiments









The Quark-Gluon-Plasma is Found at RHIC

NICA

BNL -73847-2005
Formal Report

Hunting the Quark Gluon Plasma

RESULTS FROM THE FIRST 3 YEARS AT RHIC

ASSESSMENTS BY THE EXPERIMENTAL COLLABORATIONS

April 18, 2005

Relativistic Heavy Ion Collider (RHIC) • Brookhaven National Laboratory, Upton, NY 11974-5000

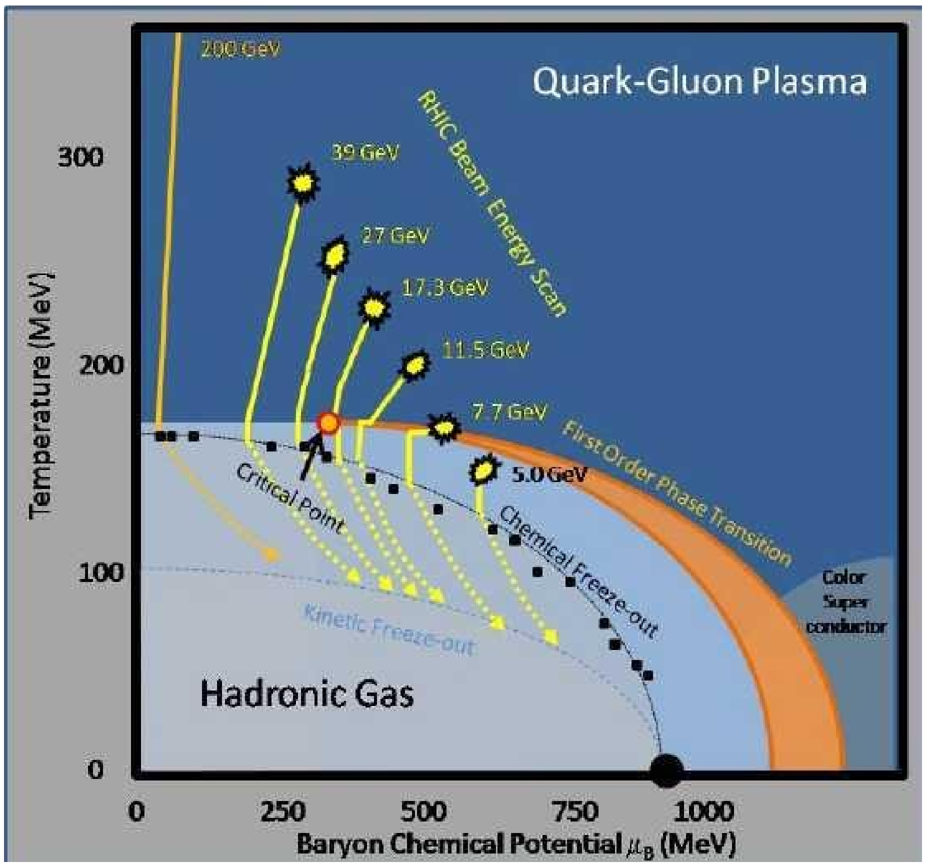
Office of Science U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY

CONTENTS

The early measurements have revealed compelling evidence for the existence of a new form of nuclear matter at extremely high density and temperature – a medium in which the predictions of QCD can be tested, and new phenomena explored, under conditions where the relevant degrees of freedom, over nuclear volumes, are expected to be those of quarks and gluons, rather than of hadrons. This is the realm of the quark gluon plasma, the predicted state of matter whose existence and properties are now being explored by the RHIC experiments.

STAR BES program



Experimental Study of the QCD Phase Diagram and Search for the Critical Point: Selected Arguments for the Run-10 Beam Energy Scan at RHIC

The STAR Collaboration (B. I. Abelev et al.)

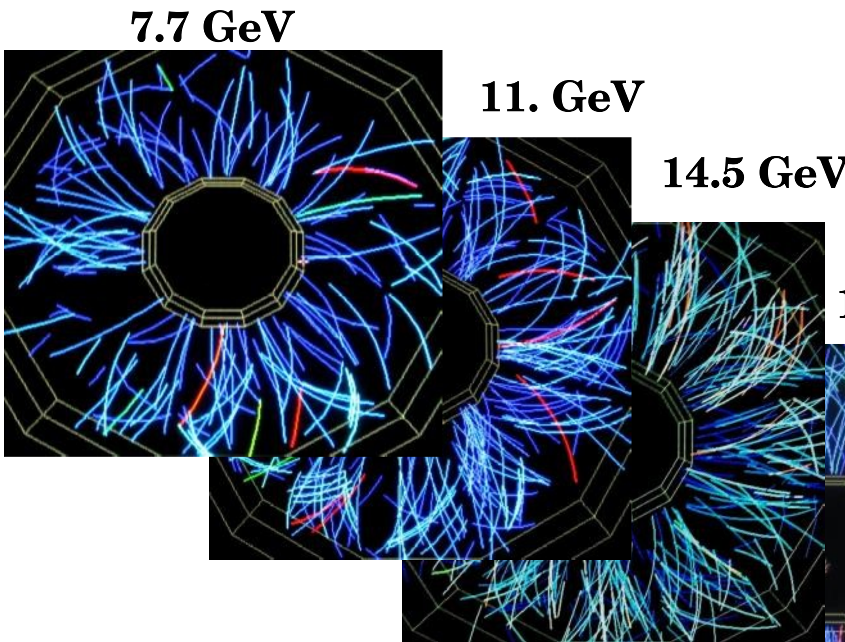
Introduction & Summary

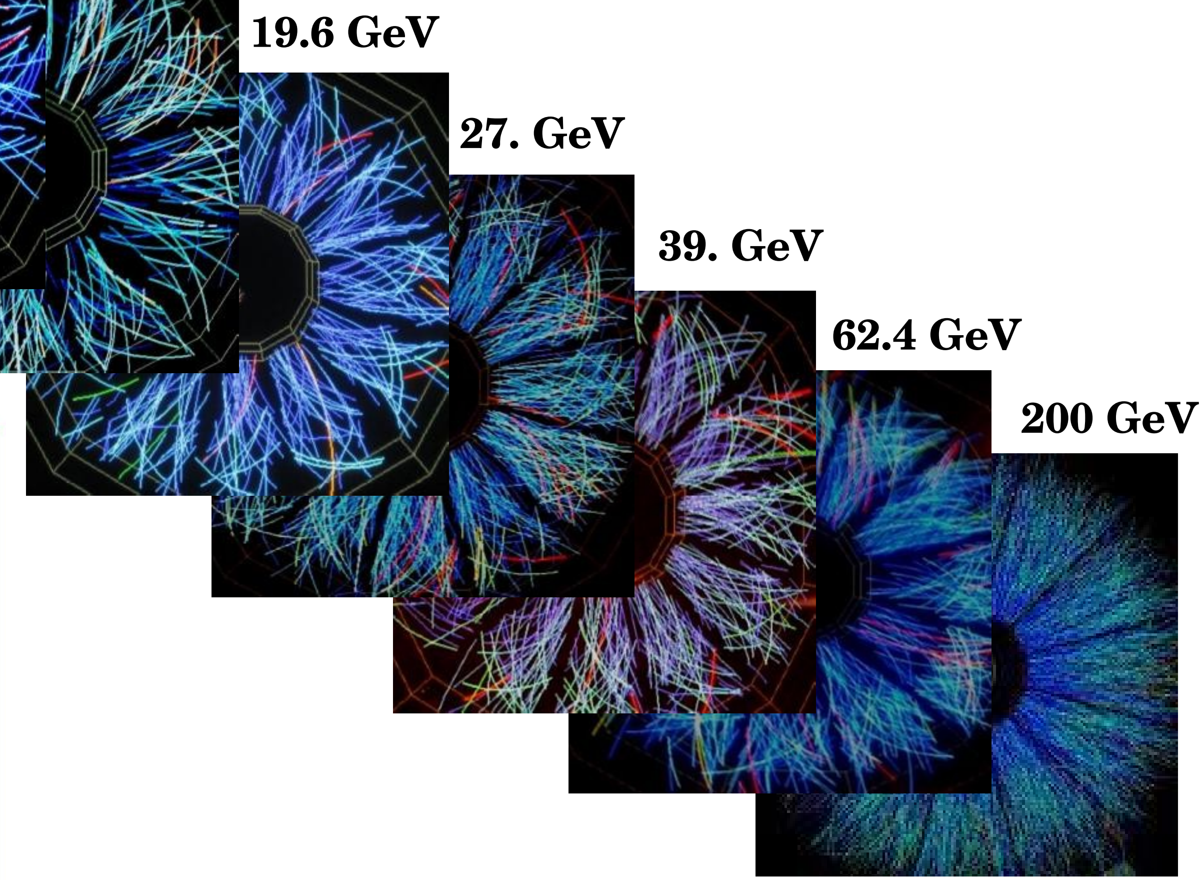
We present an overview of the main ideas that have emerged from discussions within STAR for the Beam Energy Scan (BES). The formulation of this concise and abridged document is facilitated by the existence of a much longer and more comprehensive companion document entitled *Experimental Exploration of the QCD Phase Diagram: Search for the Critical Point* [1]. The compelling arguments and motivations for the physics of our proposed Beam Energy Scan program, which have a particular role in guiding the run plan (see p. 13) as set out in our discussion of Tables 1 and 2, are (not in order of priority):

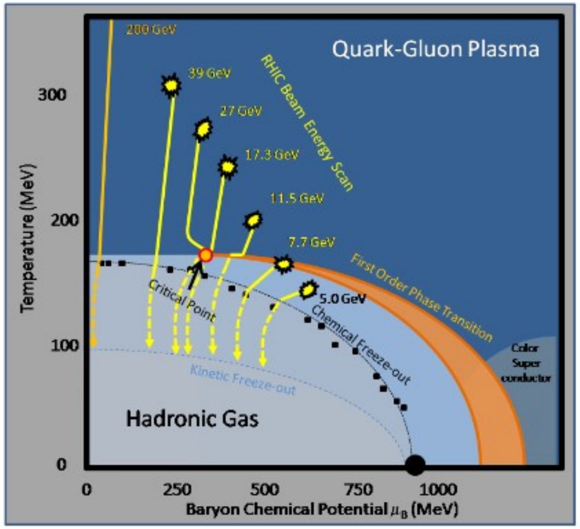
A. A search for turn-off of new phenomena already established at higher RHIC energies; QGP signatures are the most obvious example, but we define this category more broadly. If our current understanding of RHIC physics and these signatures is correct, a turn-off must be observed in several signatures, and such corroboration is an essential part of the "unfinished business" of QGP discovery [2]. The particular observables that STAR has identified as the essential drivers of our run plan are:
   - (A-1) Constituent-quark-number scaling of v_2, indicating partonic degrees of freedom;
   - (A-2) Hadron suppression in central collisions as characterized by the ratio R_{CP};
   - (A-3) Untriggered pair correlations in the space of pair separation in azimuth and pseudorapidity, which elucidate the ridge phenomenon;
   - (A-4) Local parity violation in strong interactions, an emerging and important RHIC discovery in its own right, is generally believed to require deconfinement, and thus also is expected to turn-off at lower energies.

B. A search for signatures of a phase transition and a critical point. The particular observables that we have identified as the essential drivers of our run plan are:
   - (B-1) Elliptic & directed flow for charged particles and for identified protons and pions, which have been identified by many theorists as highly promising indicators of a "softest point" in the nuclear equation of state;
   - (B-2) Azimuthally-sensitive femtoscopy, which adds to the standard HBT observables by allowing the tilt angle of the ellipsoid-like particle source in coordinate space to be measured; these measurements hold promise for identifying a softest point, and complements the momentum-space information revealed by flow measurements, and
   - (B-3) Fluctuation measures, indicated by large jumps in the baryon, charge and strangeness susceptibilities, as a function of system temperature – the most obvious expected manifestation of critical phenomena.

STAR beam energy scan

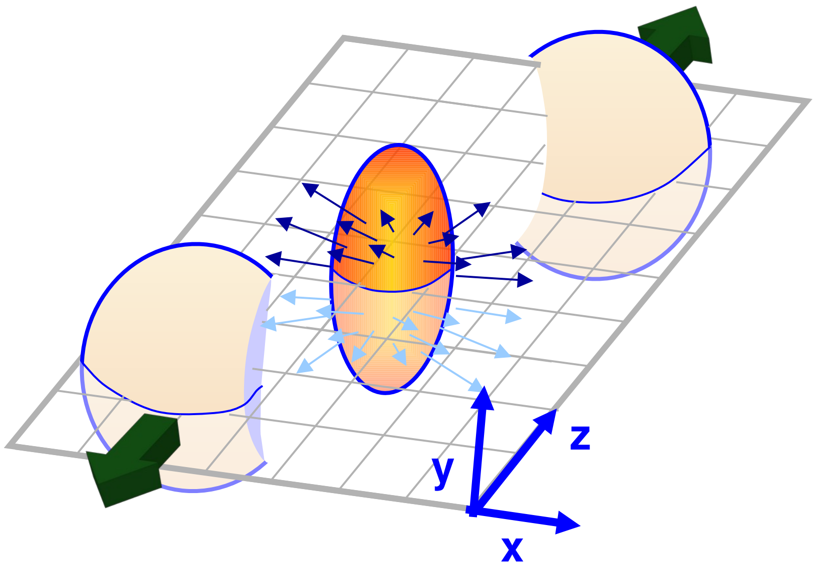


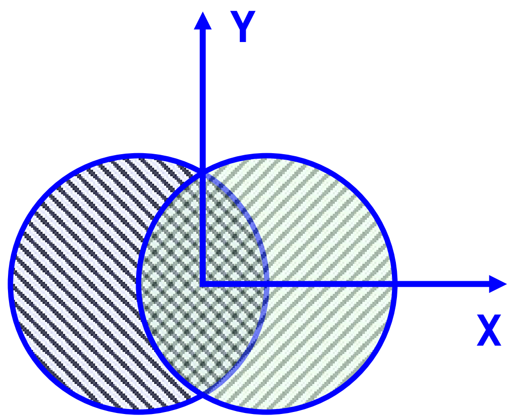




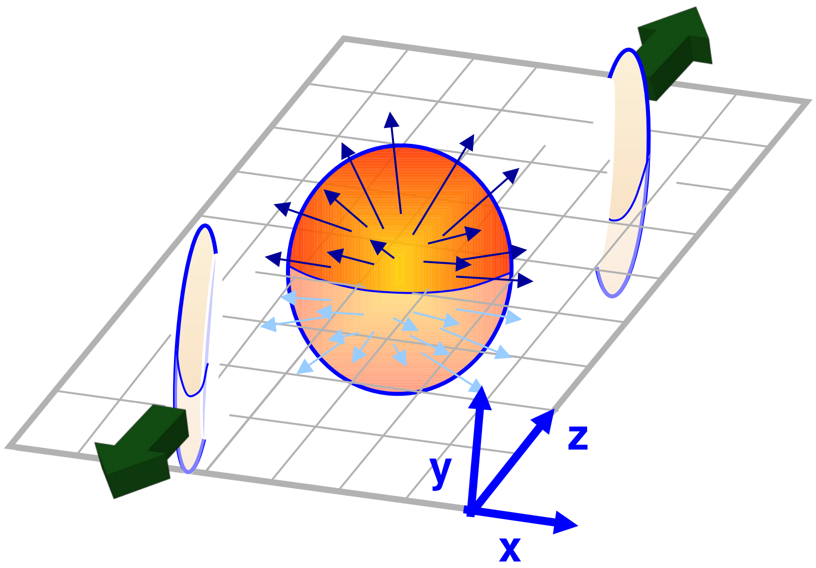
Nucleus collisions

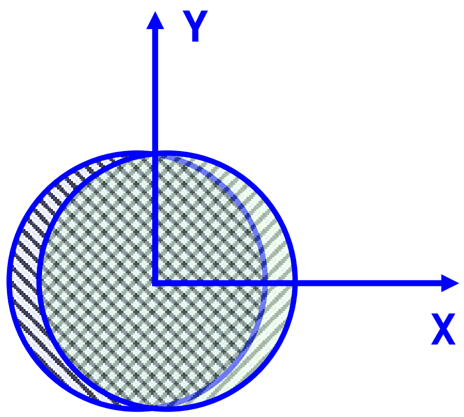
Peripheral Collision





(near) Central Collision

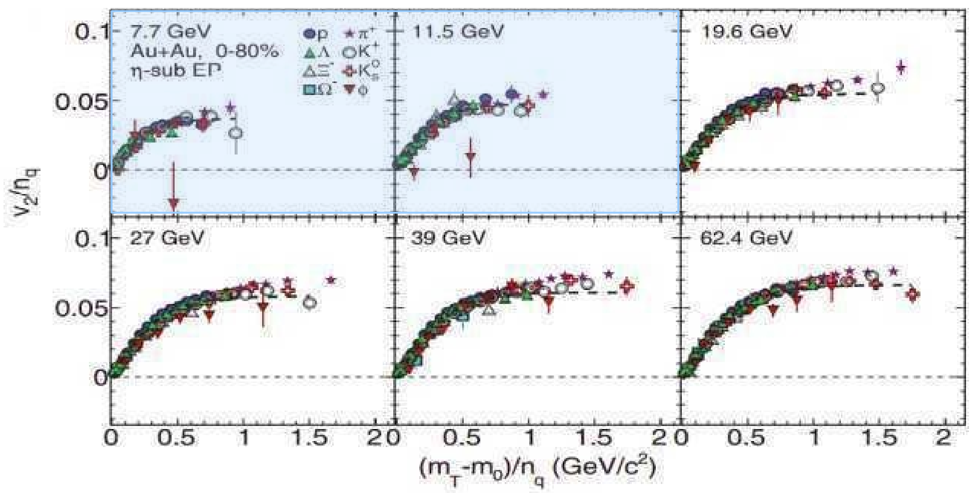




STAR Beam Energy Scan results

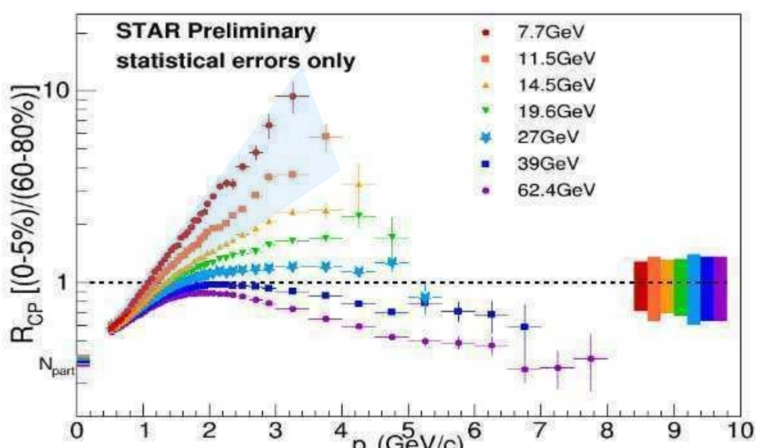
Number of constituent quarks scaling

Phys. Rev. C88, (2013), 014902

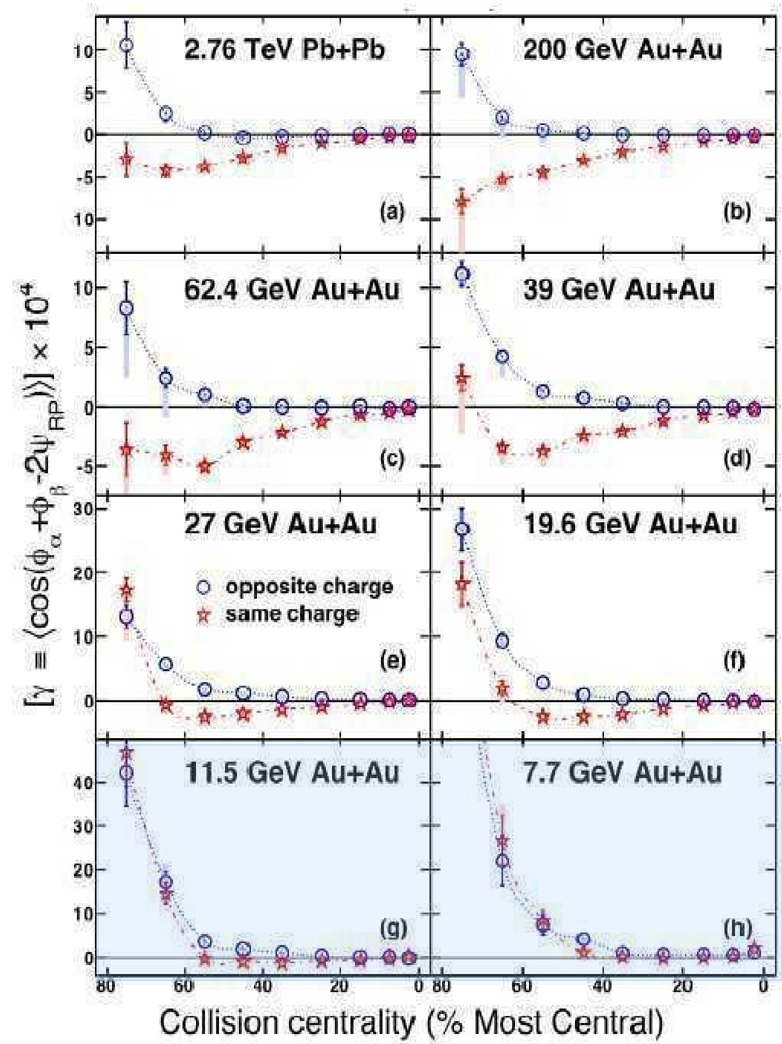


High P_T suppression

Stephen Horvat Quark Matter 2015



Chiral Magnetic Effect

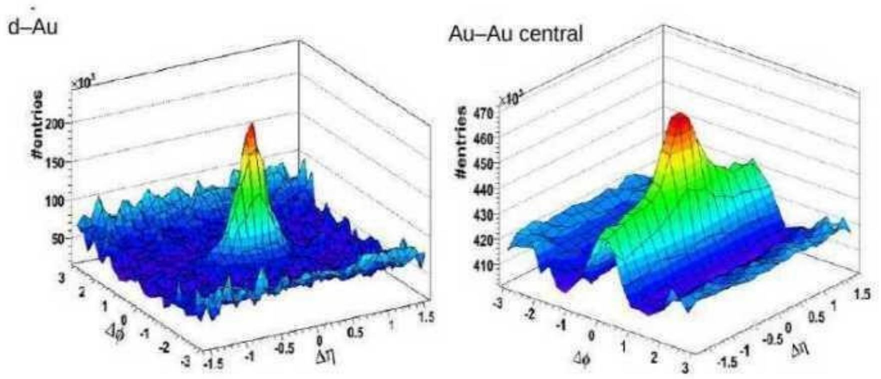


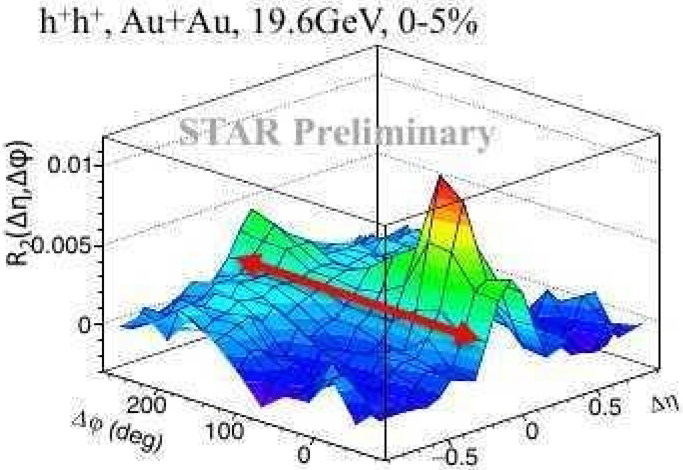
STAR BES I results

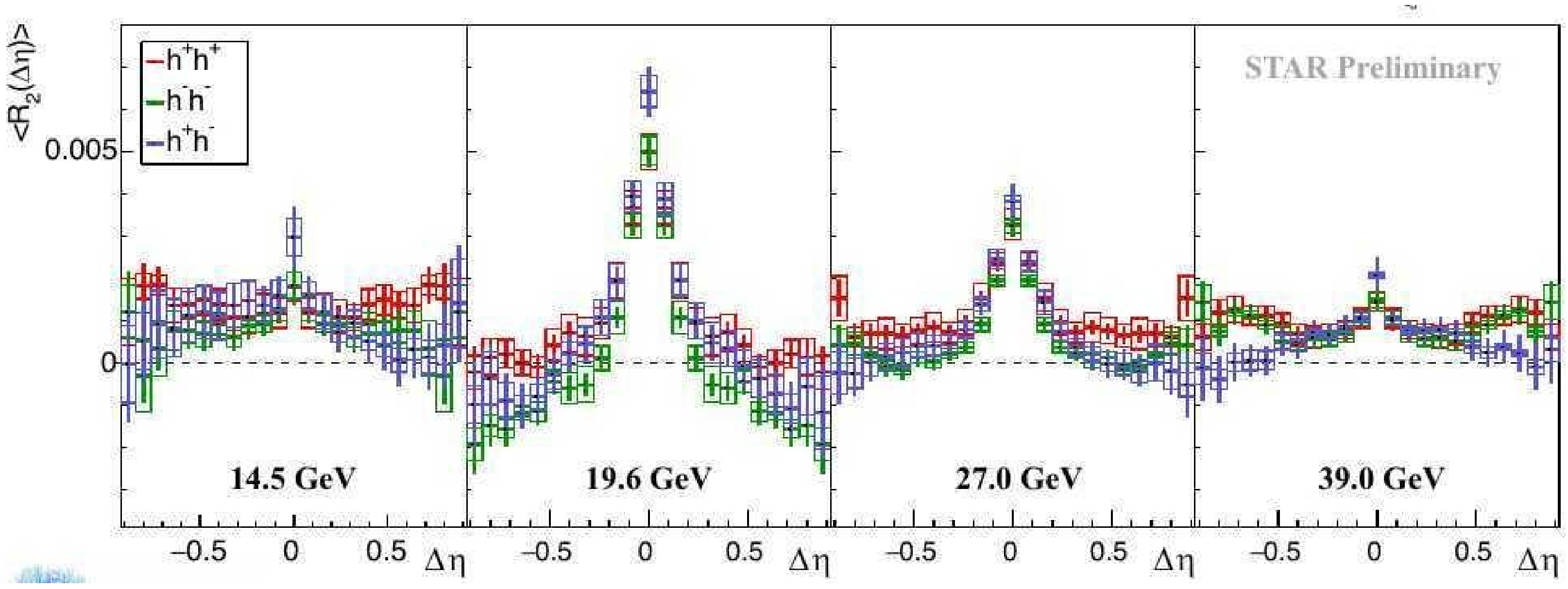
S. Jowzaee, Quark Matter 2017

Ridge effect

B. Abelev et al., Phys. Rev. C80, 064912 (2009).







STAR Beam Energy Scan program

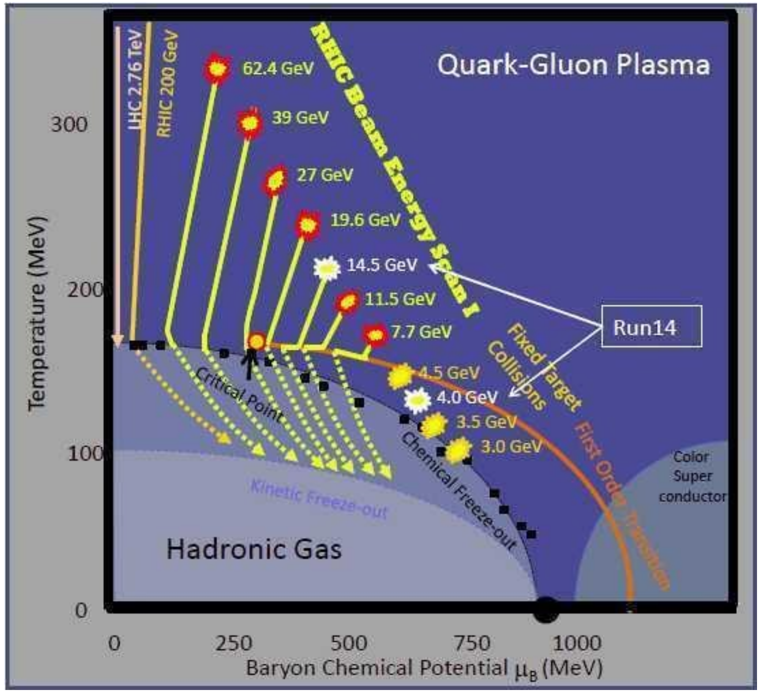
NICA

BES I

$\sqrt{s_{NN}}$ (GeV)	μ_B (MeV)	MinBias Events (10^6)	Time (weeks)	Year
7.7	420	4.3	4	2010
11.5	315	11.7	2	2010
14.5	**260**	**24.0**	**3**	**2014**
19.6	205	35.8	1.5	2011
27.0	155	70.4	1	2011
39.0	115	130.4	2	2010
62.4	70	67.3	1.5	2010

BES II

$\sqrt{s_{NN}}$ (GeV)	μ_B (MeV)	Needed Events (10^6)
7.7	420	100
9.1	370	160
11.5	315	230
14.5	**260**	**300**
19.6	205	400



Year	System and Energy	Physics/Observables	Upgrade
2017	• p+p @ 500 GeV • Au+Au @ 62.4 GeV	• Spin sign change diffractive • Jets	FMS post-shower, EPD (1/8[th]), eTOF prototype
2018	• Zr+Zr, Ru+Ru @ 200 GeV • Au+Au @ 27 GeV	• CME, di-leptons • CVE	Full EPD? eTOF prototype
2019	Au+Au @ 14.5-20 GeV + fixed target	• QCD critical point • Phase transition • CME, CVE,…	Full iTPC, eTOF, and EPD
2020	Au+Au @ 7-11 GeV + fixed target	• QCD critical point • Phase transition • CME, CVE,…	
2020+	• Au+Au @ 200 GeV • p+A/p+p @ 200 GeV	• Unbiased jets, open beauty • PID FF, Drell-Yan, longitudinal correlations	• HFT+ • FCS, FTS

NICA complex

Beams – p,d(h)..$^{197}Au^{79+}$

Collision energy √s= **4-11** GeV/u (Au), **12-27** (p)

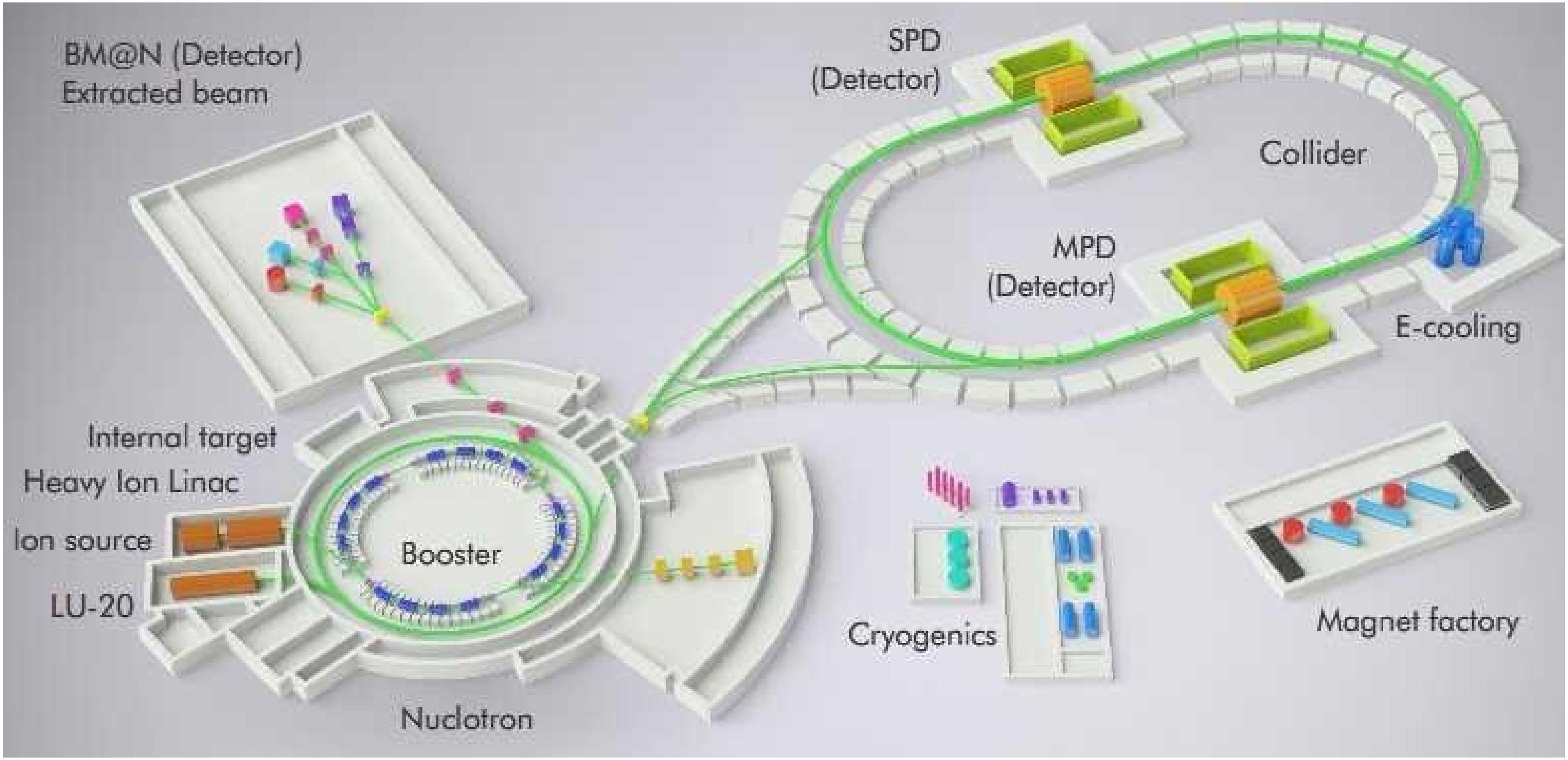
Beam energy (fixed target) - **1-6** GeV/u

Luminosity: 10^{27} cm^{-2}s^{-1}(Au), 10^{32} (p)

Experiments:

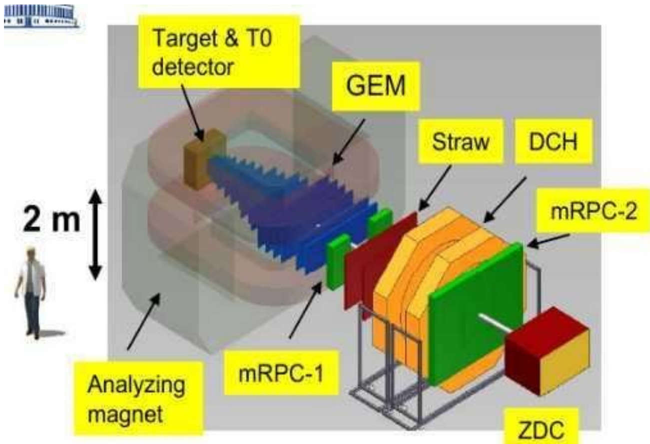
2 Interaction points – **MPD** and SPD

Fixed target experiment **BM@N**

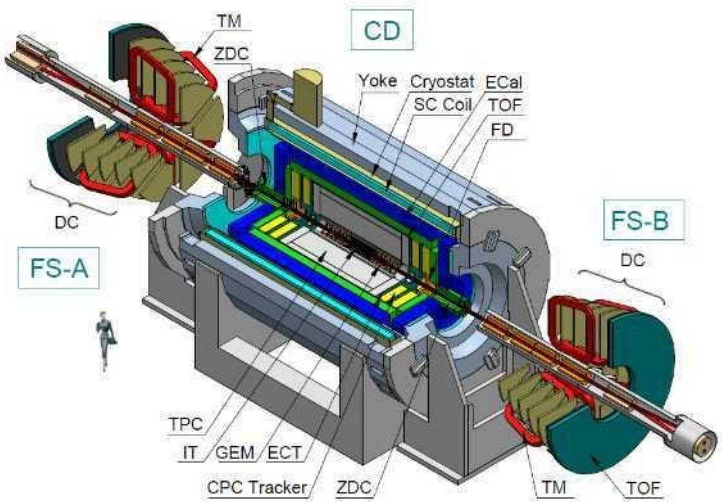


NICA experiments

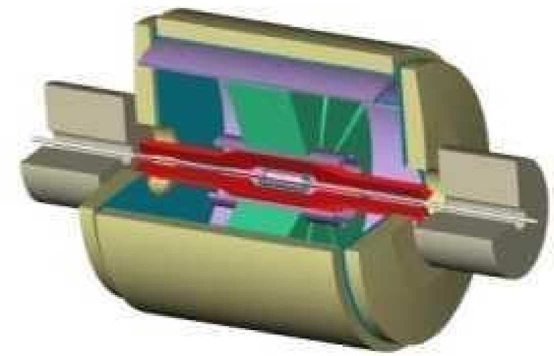
Baryonic Matter BM@N at Nuclotron



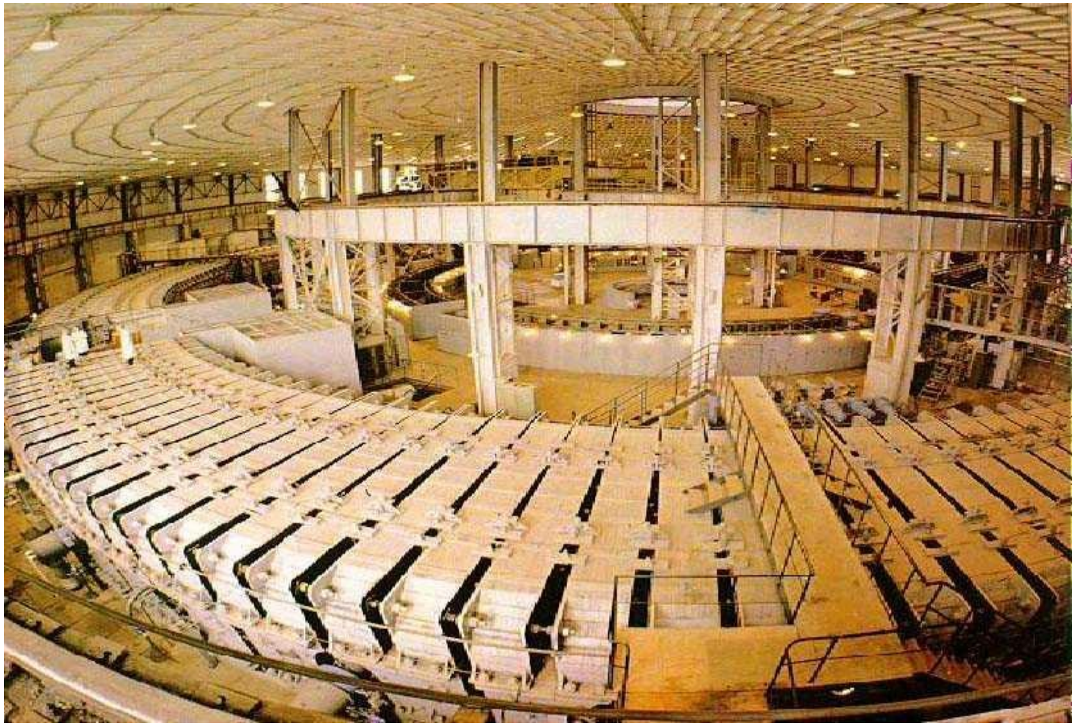
MPD

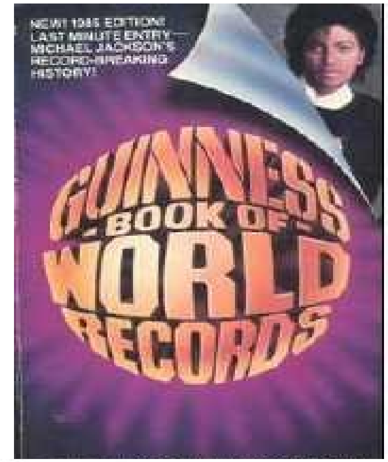


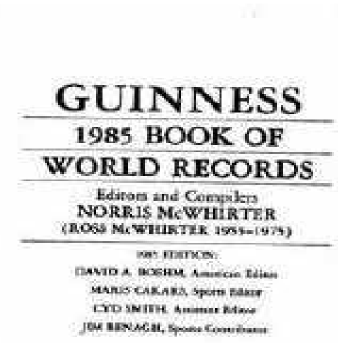
SPD

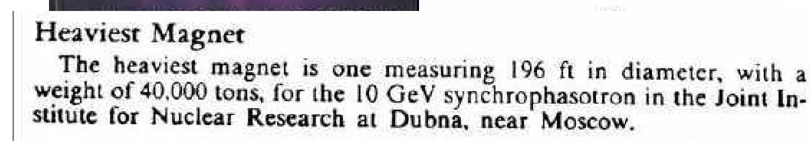


Nuclotron, buster, ...






GUINNESS
1985 BOOK OF
WORLD RECORDS
Editors and Compilers
NORRIS McWHIRTER
(ROSS McWHIRTER 1955–1975)

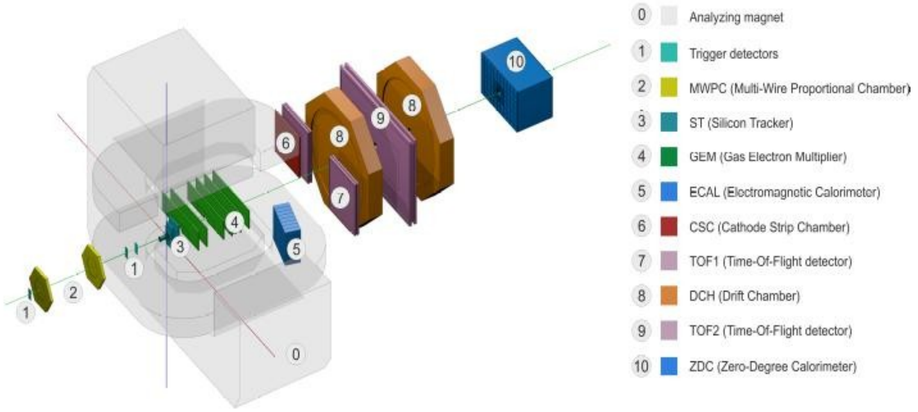

Heaviest Magnet

The heaviest magnet is one measuring 196 ft in diameter, with a weight of 40,000 tons, for the 10 GeV synchrophasotron in the Joint Institute for Nuclear Research at Dubna, near Moscow.

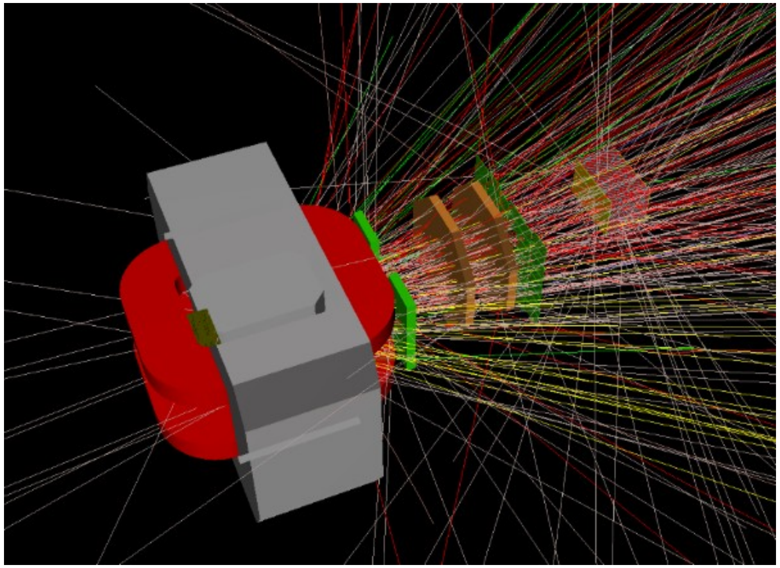
NICA storage rings

May 2022

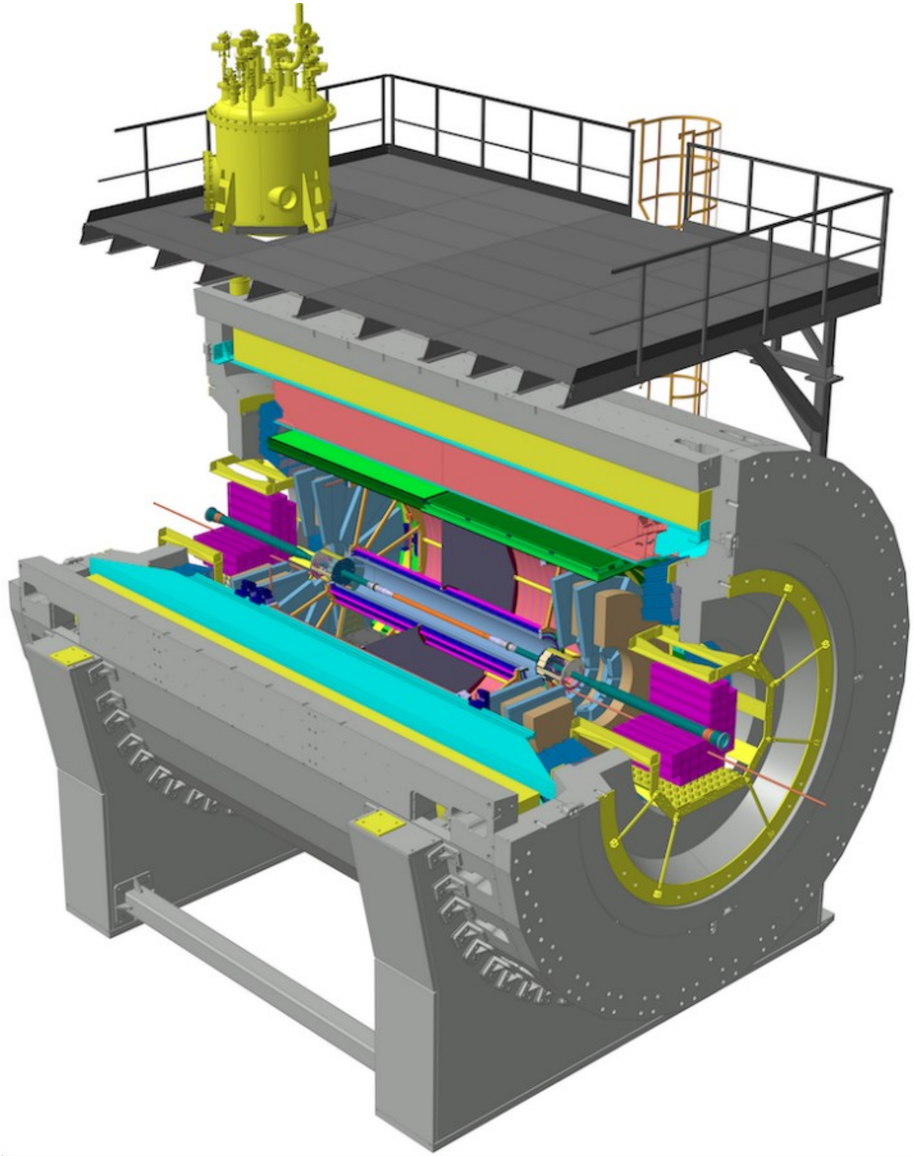
BM@N experiment at Nuclotron



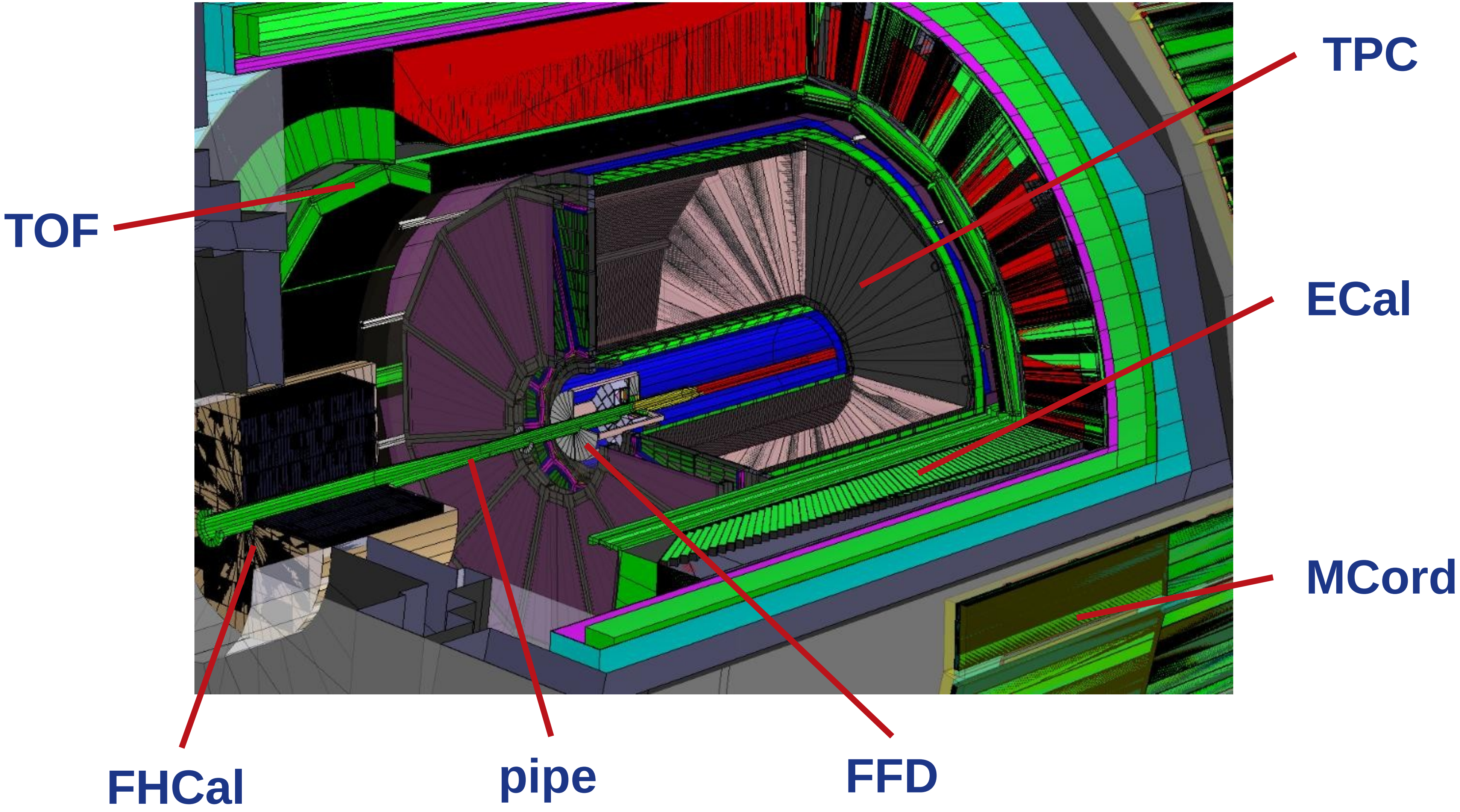
AuAu E_{beam} = 4 GeV



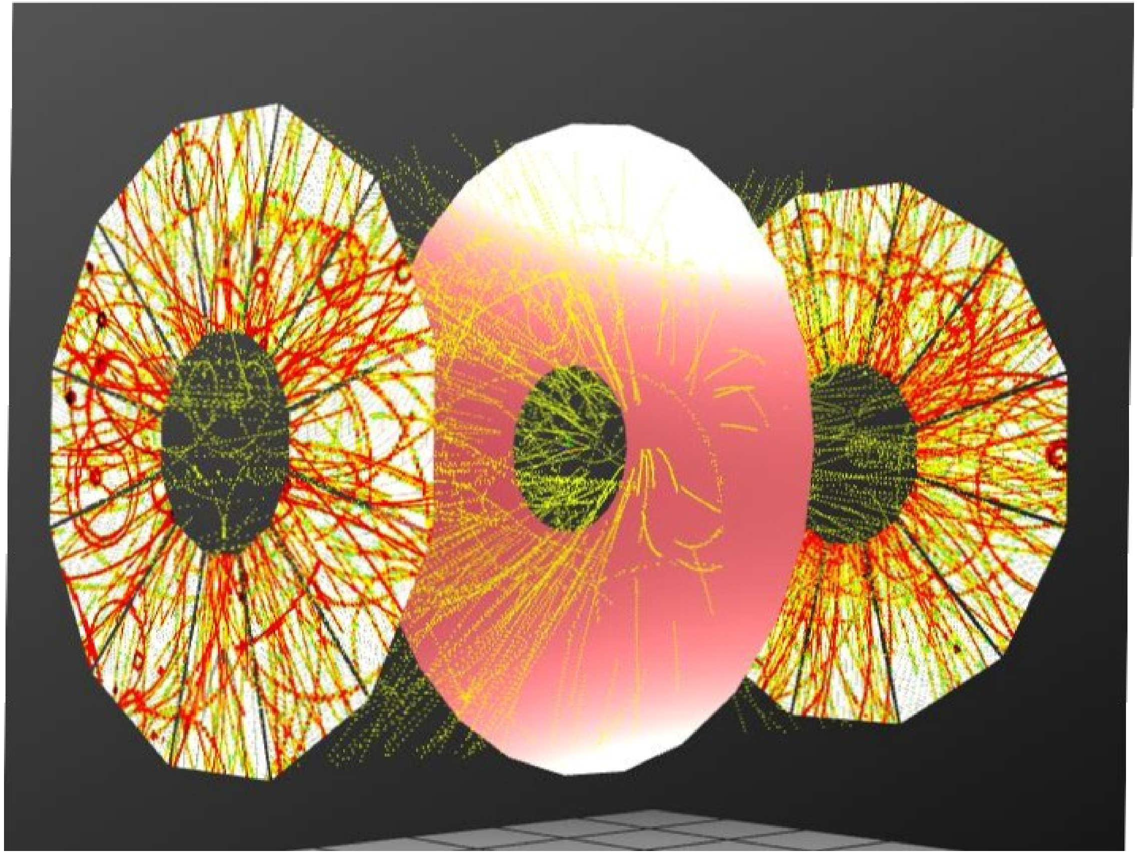
MPD experiment at collider



MPD geometry for stage 1

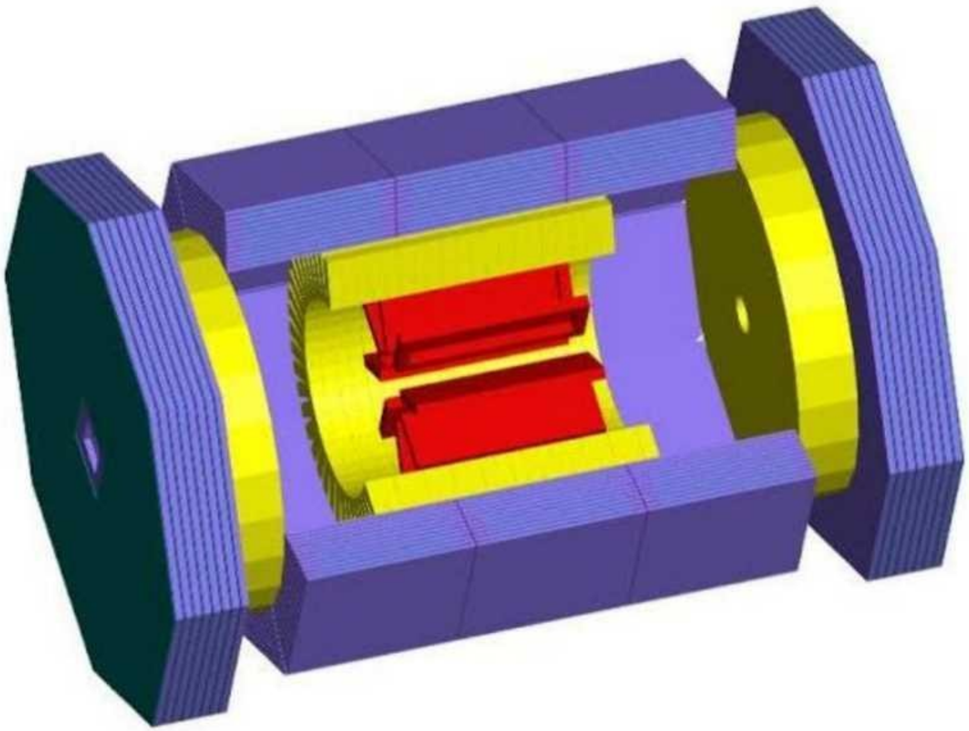


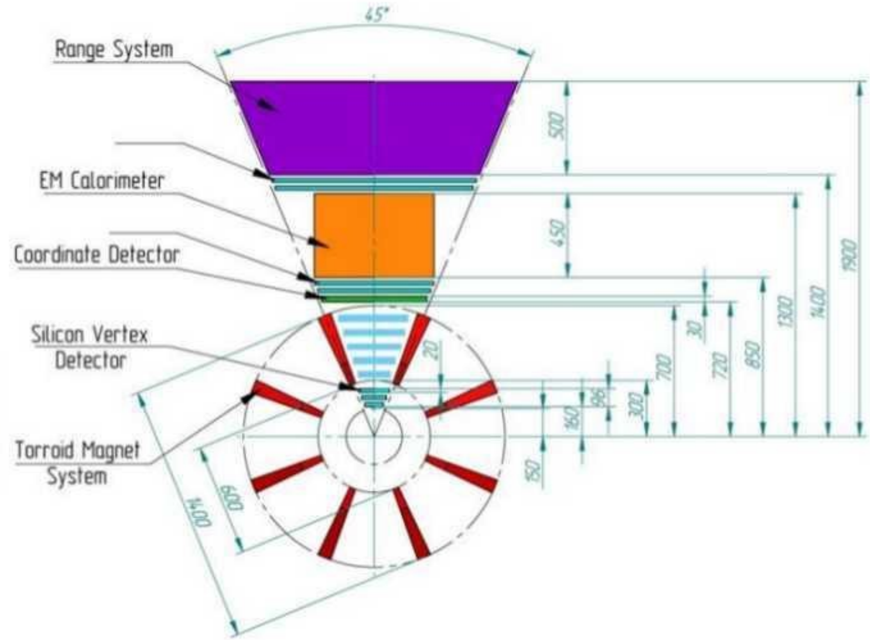
MPD Time Projection Chamber



Item	Dimension
Length of the TPC	340cm
Outer radius of vessel	140cm
Inner radius of vessel	27 cm
Outer radius of the drift volume	133cm
Inner radius of the drift volume	34cm
Length of the drift volume	170cm (of each half)
HV electrode	Membrane at the center of the TPC
Electric field strength	~140V/cm;
Magnetic field strength	0.5 Tesla
Drift gas	90% Ar+10% Methane, Atmospheric pres. + 2 mbar
Gas amplification factor	~ 10^4
Drift velocity	5.45 cm/μs;
Drift time	< 30μs;
Temperature stability	< 0.5°C
Number of readout chambers	24 (12 per each end-plate)
Segmentation in φ	30°
Pad size	5x12mm^2 and 5x18mm^2
Number of pads	95232
Pad raw numbers	53
Pad numbers after zero suppression	< 10%
Maximal event rate	< 7 kHz (Lum. 10^{27})
Electronics shaping time	~180 ns (FWHM)
Signal-to-noise ratio	30:1
Signal dynamical range	10 bits
Sampling rate	10 MHz
Sampling depth	310 time buckets

Spin Physics Detector

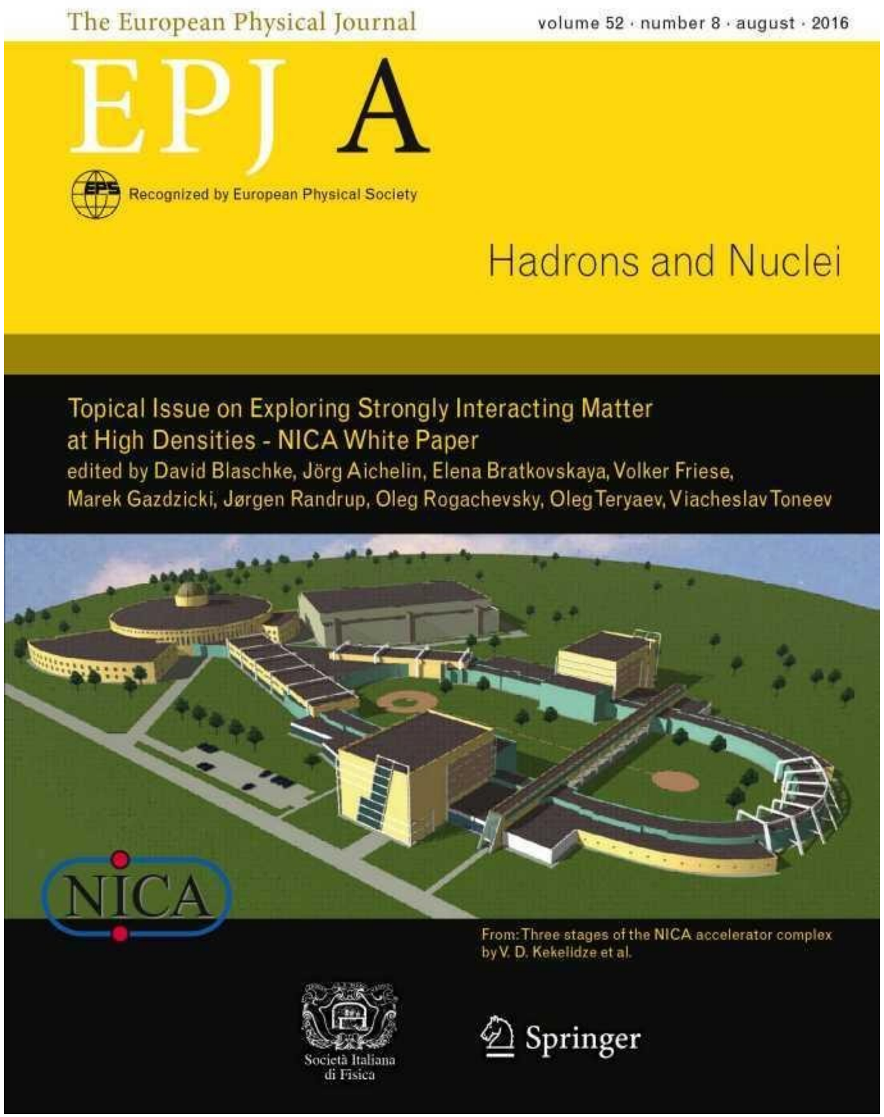




Spin program with polarized beams

The spin program is an important and integral part of the NICA project. Indeed, ever since the "spin crisis" of 1987, the composition of the nucleon spin in terms of the fundamental constituents – quarks and gluons – remains in the focus of attention of many physicists. The highlights of the NICA spin program include measurements of Drell-Yan processes with longitudinally polarized proton and deuteron beams, spin effects in inclusive and exclusive production of baryons, light and heavy mesons and direct photons, and studies of helicity amplitudes and double spin asymmetries in elastic scattering. The SPD detector at NICA would allow to contribute significantly to the current and planned international program in spin physics.

NICA White Paper



ФИЗИКА ЭЛЕМЕНТАРНЫХ ЧАСТИЦ И АТОМНОГО ЯДРА
2016. Т. 47. ВЫП. 4

FEASIBILITY STUDY OF HEAVY ION PHYSICS PROGRAM AT NICA

P. N. Batyuk [1,*], *V. D. Kekelidze* [1], *V. I. Kolesnikov* [1], *O. V. Rogachevsky* [1], *A. S. Sorin* [1,2], *V. V. Voronyuk* [1]
on behalf of the BM@N and MPD collaborations

[1] Joint Institute for Nuclear Research, Dubna
[2] National Research Nuclear University "Moscow Engineering Physics Institute" (MEPhI), Moscow

There is strong experimental and theoretical evidence that in collisions of heavy ions at relativistic energies the nuclear matter undergoes a phase transition to the deconfined state — Quark–Gluon Plasma. The caused energy region of such a transition was not found at high energy at SPS and RHIC, and search for this energy is shifted to lower energies, which will be covered by the future NICA (Dubna), FAIR (Darmstadt) facilities and BES II at RHIC. Fixed target and collider experiments at the NICA facility will work in the energy range from a few AGeV up to $\sqrt{s_{NN}} = 11$ GeV and will study the most interesting area on the nuclear matter phase diagram.

The most remarkable results were observed in the study of collective phenomena occurring in the early stage of nuclear collisions. Investigation of the collective flow will provide information on Equation of State (EoS) for nuclear matter. Study of the event-by-event fluctuations and correlations can give us signals of critical behavior of the system. Femtoscopy analysis provides the space-time history of the collisions. Also, it was found that baryon stopping power revealing itself as a "wiggle" in the excitation function of curvature of the (net) proton rapidity spectrum relates to the order of the phase transition.

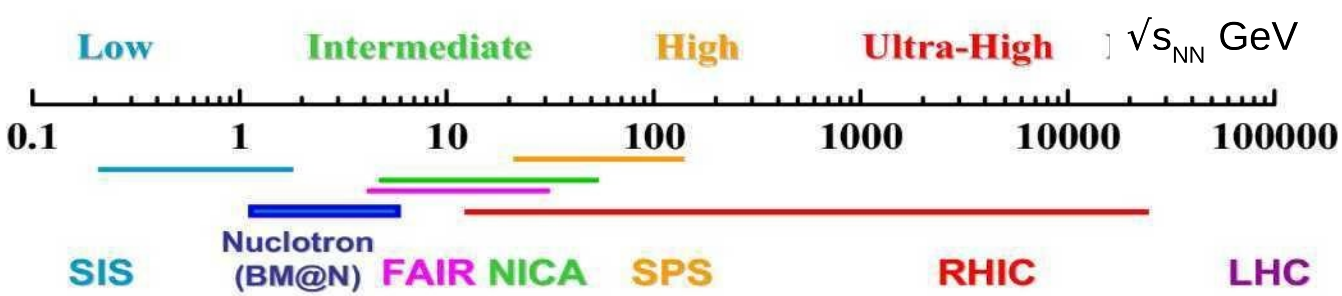
The available observations of an enhancement of dilepton rates at low invariant masses may serve as a signal of the chiral symmetry restoration in hot and dense matter. Due to this fact, measurements of the dilepton spectra are considered to be an important part of the NICA physics program. The study of strange particles and hypernuclei production gives additional information on the EoS and "strange" axis of the QCD phase diagram.

In this paper a feasibility of the considered investigations is shown by the detailed Monte Carlo simulations applied to the planned experiments (BM@N, MPD) at NICA.

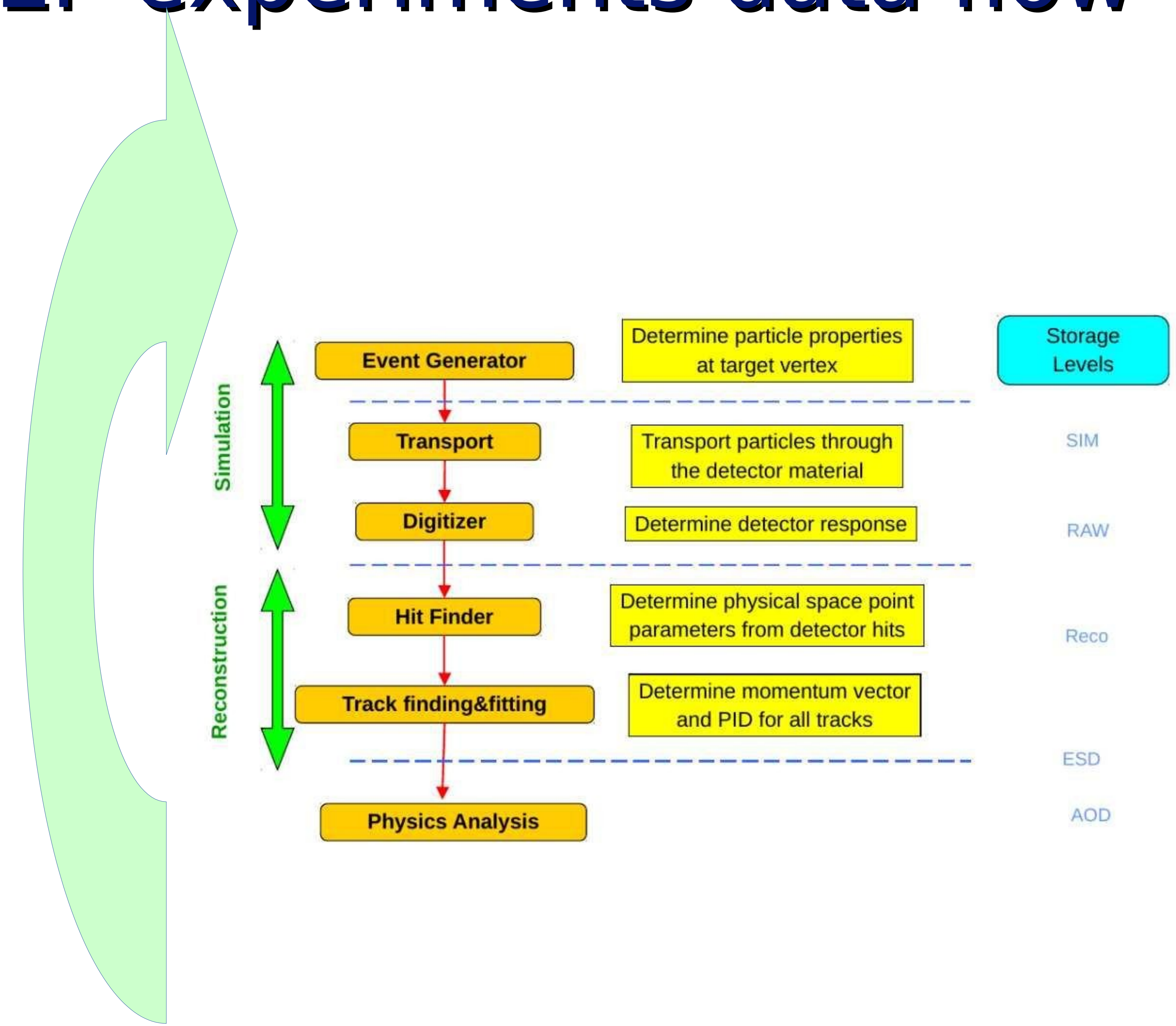
Current & future HI experiments

Facility	SPS	RHIC BES II	Nuclotron-M	NICA	SIS/100 (500 ?)	LHC
Laboratory	CERN Geneva	BNL Brookhaven	JINR Dubna	JINR Dubna	FAIR GSI Darmstadt	CERN Geneva
Experiment	NA61 SHINE	STAR PHENIX	BM@N	MPD	HADES CBM	ALICE ATLAS CMS
Start of data taking	2011	2010	2015	2023	2025	2009
$\sqrt{s_{NN}}$	4.9 – 17.3	7.7 – 200	< 3.5	4 - 11	2.3 – (4.5)	up to 5500
Physics	CP & OD	CP & OD	HDM	OD & HDM	OD & CP	PDM

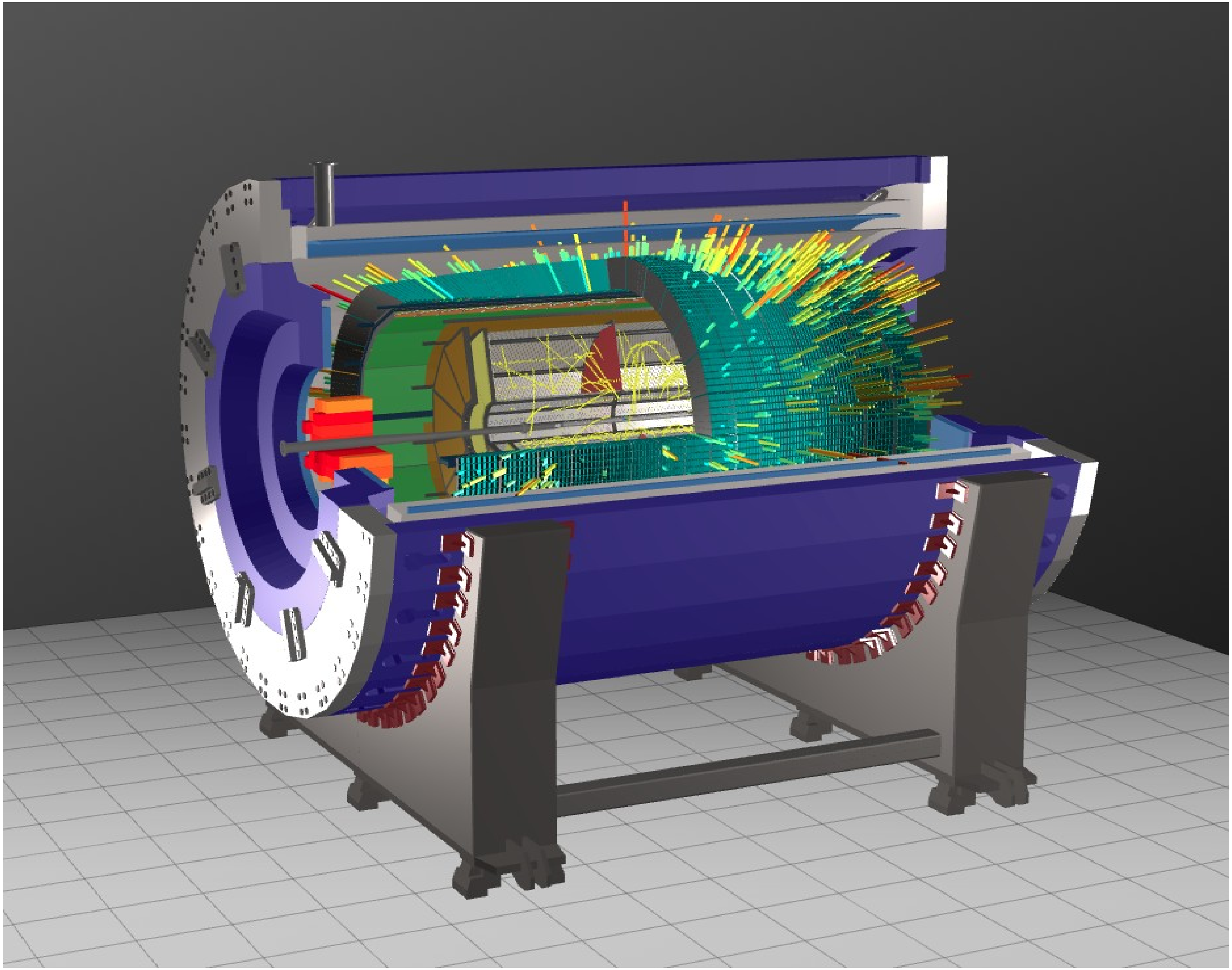
CP — critical point
OD — onset of deconfinement, mixed phase, 1st order phase transition
HDM — hadrons in dense matter
PDM — properties of deconfined matter



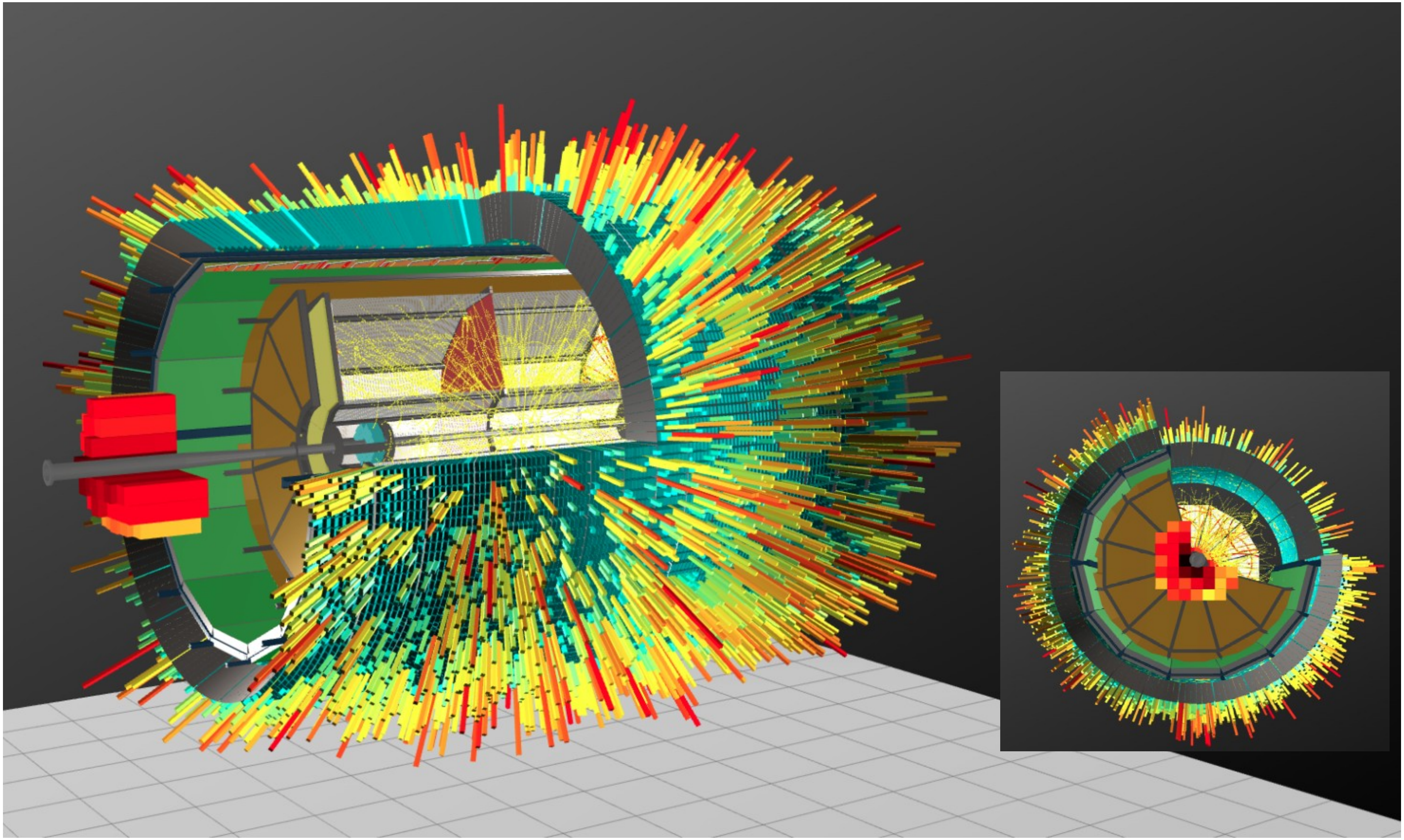
HEP experiments data flow



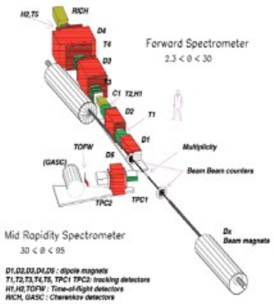
Detectors geometry

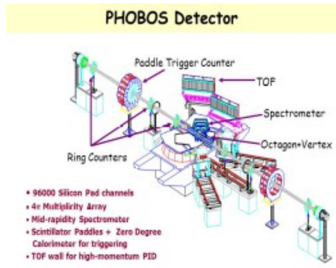


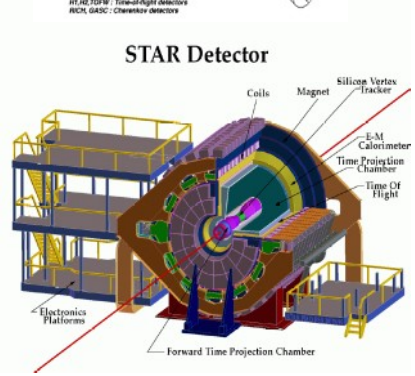
Detectors responses

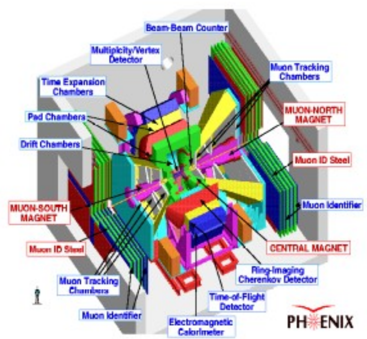


HEP experiments framework



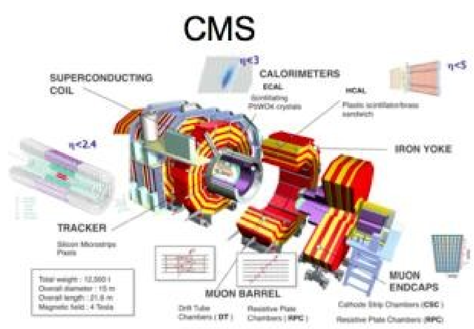


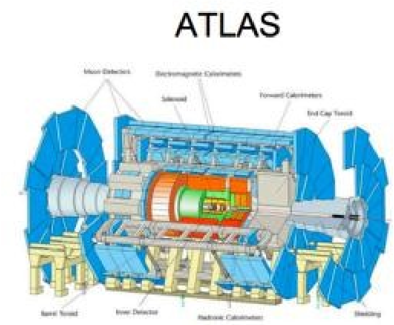


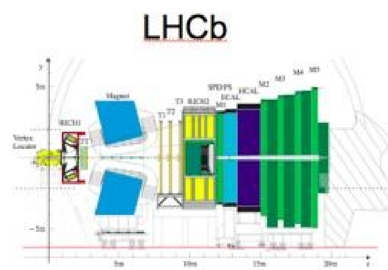


- STAR – root4star
- PHENIX – PISA/Fun4all
- PHOBOS – Phobos Analysis Toolkit
- BRAMS –

- ATLAS – ATHENA
- CMS – cmssw
- ALICE – aliroot
- LHCb – GAUDI







CBMroot → FairRoot

https://fairroot.gsi.de

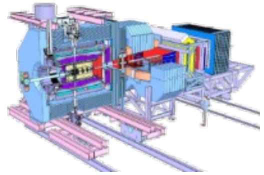
The FairRoot framework is an object oriented simulation, reconstruction and data analysis framework based on ROOT. It includes core services for detector simulation and offline analysis. The framework delivers base classes which enable the users to easily construct their experimental setup in a fast and convenient way. By using the Virtual Monte Carlo concept it is possible to perform the simulations using either Geant3 or Geant4 without changing the user code or the geometry description.

The basic idea of FairRoot is to provide a unified package with generic mechanisms to deal with most commonly used tasks in HEP. FairRoot allow the physicist to:

- ✗ Focus on physics deliverables while reusing pre-tested software components.
- ✗ Do not submerge into low-level details, use pre-built and well-tested code for common tasks.
- ✗ Allows physicists to concentrate on detector performance details, avoiding purely software
- ✗ engineering issues like storage, retrieval, code organization etc.

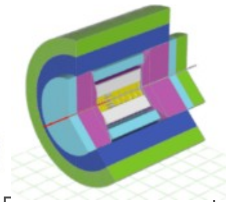
MpdRoot history

Start testing the VMC concept for CBM

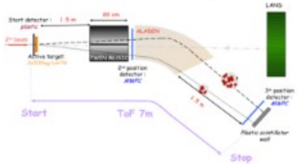


Panda decided to join → oct.
FairRoot: base package for experiments

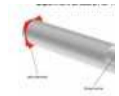
R3B joined



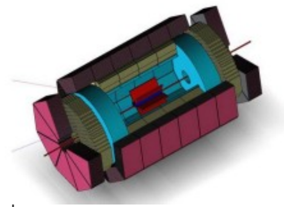
EIC (Electron Ion Collider BNL)



SOFIA (Studies On Fission with Aladin)



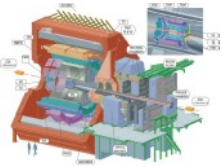
SHIP (Search for Hidden Particles)



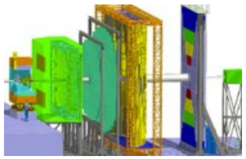
SPD@NICA joined

2004 | 2006 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015

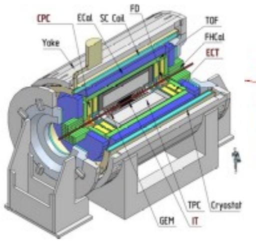
ALICE
FAIR



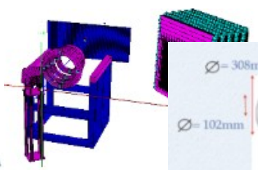
First Release of CbmRoot



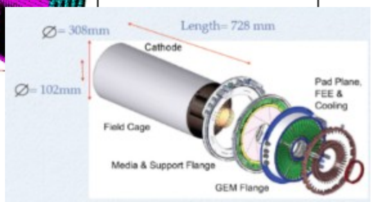
MPD@NICA started with FairRoot



ASYEOS joined

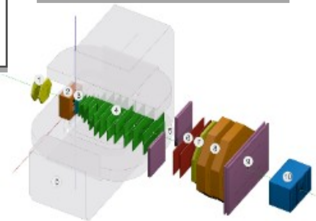


GEM-TPC separated from PANDA branch



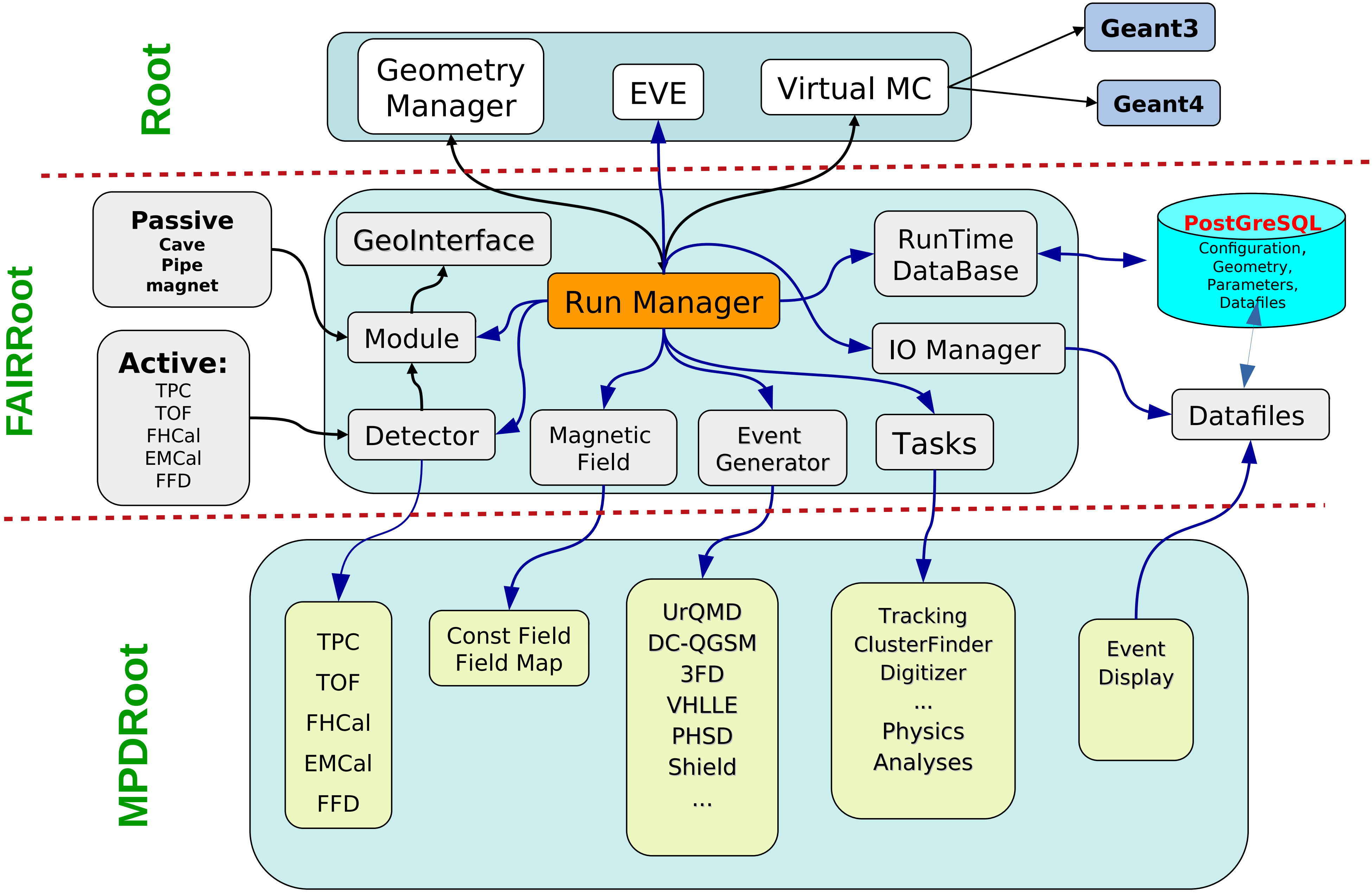
ENSAR-ROOT
Collection of modules used by structural nuclear physics exp.

BM@N@NICA started with FairRoot



2007 Letter of Intent
2014 Conceptual Design Report
2015 … Detectors TDRs

MpdRoot structure



Mpdroot program git repository

NICA

Name	Last commit	Last update
cmake	Removed shield_pack. Default generator for ...	6 days ago
config	moving file eventdisplay.xml where it belong...	3 months ago
core	Fixed formatting in mpdPassive	1 month ago
detectors	Fix of header files not being copied mention...	1 week ago
doxygen	Removed shield_pack. Default generator for ...	6 days ago
gconfig	commenting out libraries which do not exist	3 months ago
geometry	Magnet geometry version 6	3 months ago
input	add_new_calibration	1 week ago
macro	Renamed .cxx files to .C to stress that they a...	6 days ago
macros/common	Removed shield_pack. Default generator for ...	6 days ago
physics	Moved generators to simulation/generators	1 month ago
reconstruction/tracking	Moved lhetrack to reconstruction/tracking/l...	1 month ago
scripts	remove old tests from the governor	4 days ago
simulation	Removed shield_pack. Default generator for ...	6 days ago
tools	Added check whether ROOT used has been ...	6 days ago
.clang-format	add stylefile from cern	4 months ago
.gitignore	Resolve "Add CentOS7 and CentOS8 pipeline...	4 months ago
.gitlab-ci.yml	removing global before script in pipeline	4 days ago
.gitmodules	updating to the last version of the NICA-Sch...	3 months ago
CMakeLists.txt	Resolve "Proper CMake failure during non-SI...	4 months ago
CODEOWNERS	Moved ./kalman to ./reconstruction/tracking...	1 month ago
README.md	Added copying of eventDisplay configuration...	1 week ago
SetEnv.sh	Revert "Added newReadDST.C file which is n...	5 months ago

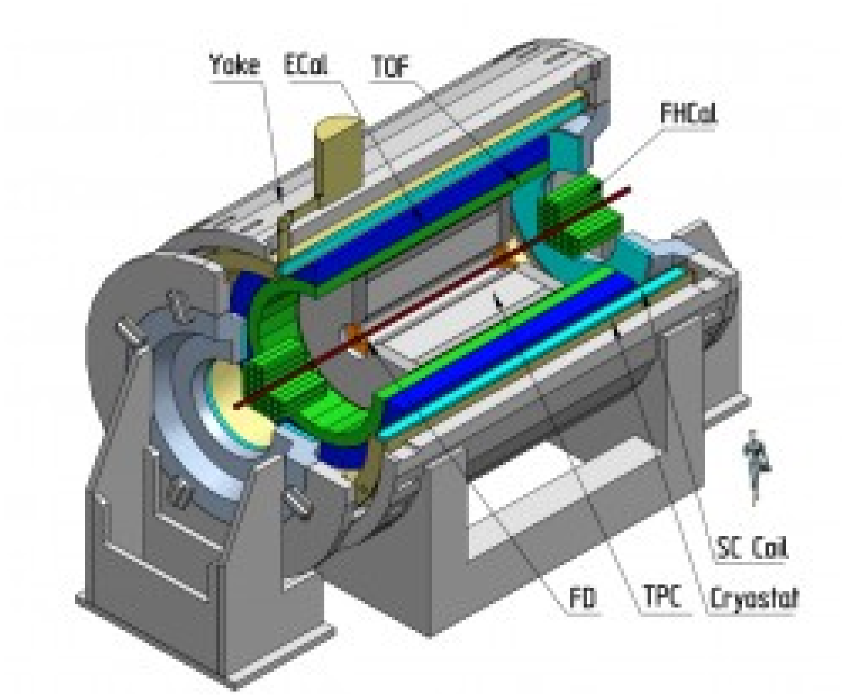
Name	Last commit	Last update
..		
mpdBase	Moved directory ./mcstack ./simulation/mcStack	1 month ago
mpdDst	Moved lhetrack to reconstruction/tracking/lheTrack	1 month ago
mpdField	Fixed formatting of directories core/mpdBase and core/mpdField	1 month ago
mpdPassive	Fixed formatting in mpdPassive	1 month ago
mpdPid	Added Base as a dependency of mpdPid	1 month ago

Name	Last commit	Last update
..		
bbc	Moved directory ./mcstack ./simulation/mcStack	1 month ago
bmd	Moved directory ./mcstack ./simulation/mcStack	1 month ago
emc	Moved ./kalman to ./reconstruction/tracking/kalman	1 month ago
etof	Moved lhetrack to reconstruction/tracking/lheTrack	1 month ago
ffd	Moved directory ./mcstack ./simulation/mcStack	1 month ago
mcord	Moved directory ./mcstack ./simulation/mcStack	1 month ago
sts	Moved directory ./mcstack ./simulation/mcStack	1 month ago
tof	Moved ./kalman to ./reconstruction/tracking/kalman	1 month ago
tpc	Files inside simulation/generators moved to simulation/generators/mpdGen	1 week ago
zdc	Fix of header files not being copied mentioned in #95	1 week ago

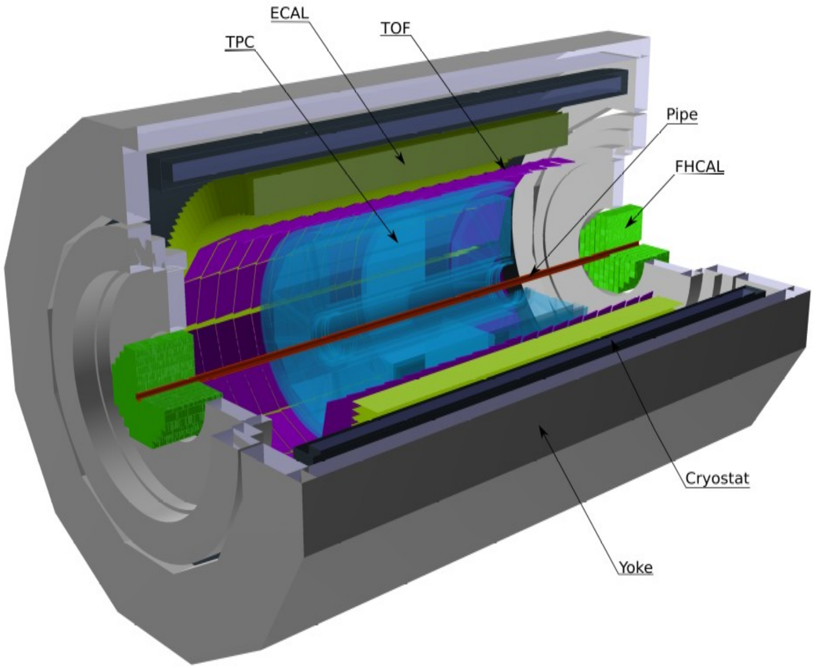
Name	Last commit	Last update
..		
ebye	Moved ./kalman to ./reconstruction/tracking/kalman	1 month ago
femto	Moved mpddst with subdirectories to core/mpdDst	1 month ago
nicafemto	Moved generators to simulation/generators	1 month ago
photons	Moved lhetrack to reconstruction/tracking/lheTrack	1 month ago
CMakeLists.txt	Moved ./kalman to ./reconstruction/tracking/kalman	1 month ago
MpdAnalysisEvent.cxx	Analysis manager framework implemented	7 months ago
MpdAnalysisEvent.h	Analysis manager framework implemented	7 months ago
MpdAnalysisManager.cxx	Analysis manager framework implemented	7 months ago
MpdAnalysisManager.h	Analysis manager framework implemented	7 months ago
MpdAnalysisTask.cxx	Analysis manager framework implemented	7 months ago
MpdAnalysisTask.h	Analysis manager framework implemented	7 months ago
MpdPhysicsLinkDef.h	Analysis manager framework implemented	7 months ago
MpdRoInvMassTask.cxx	fixed conflict mcstack with fairroot examples	2 years ago
MpdRoInvMassTask.h	small resctructuring according to the found dependancy errors	3 years ago
README.md	Analysis manager framework implemented	7 months ago

MPD detectors geometry

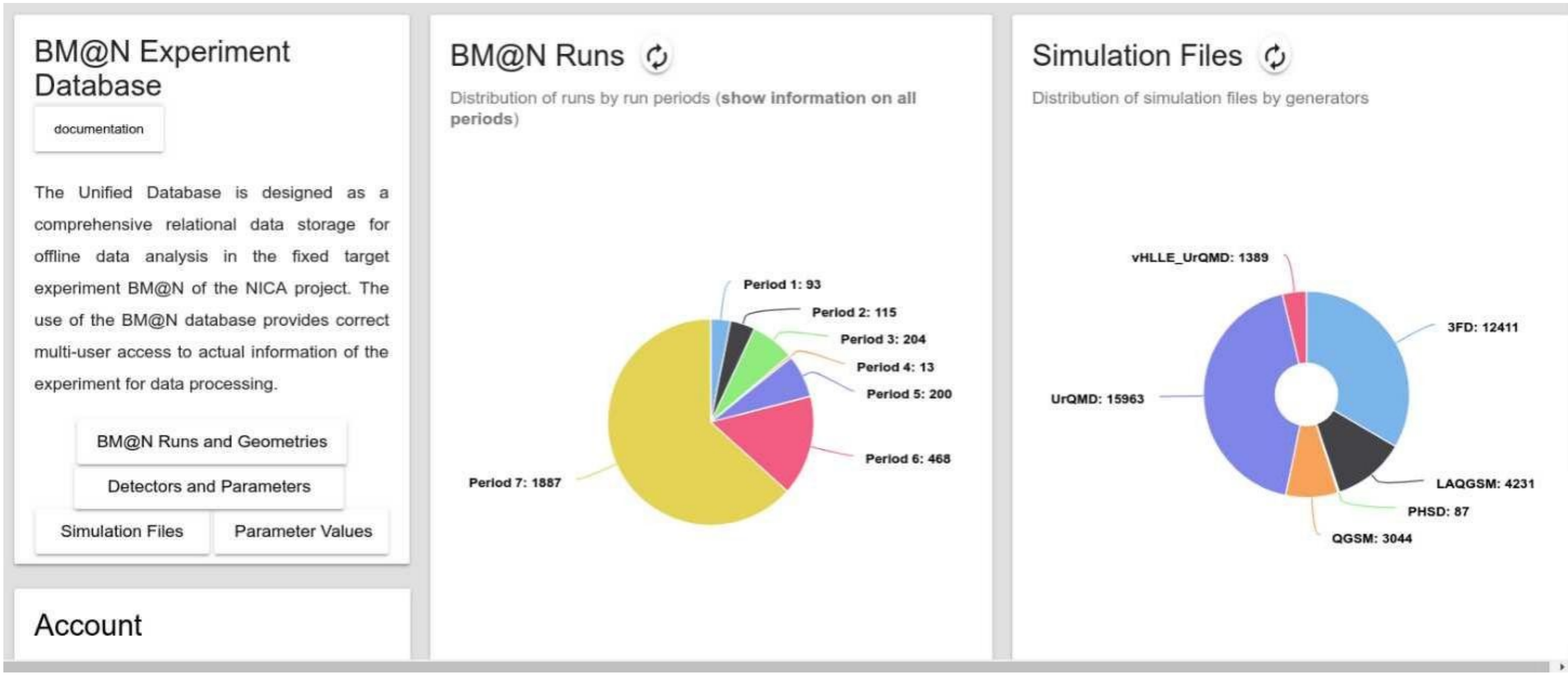
Drawing



GEANT



Simulated + experimental events databases



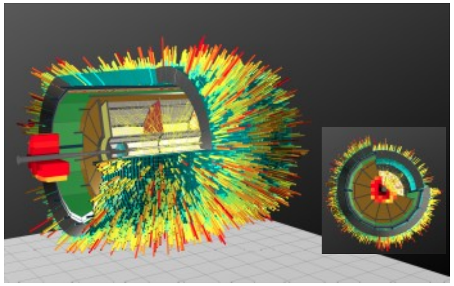
- ✔ UrQMD
- ✔ QGSM
- ✔ PHSD

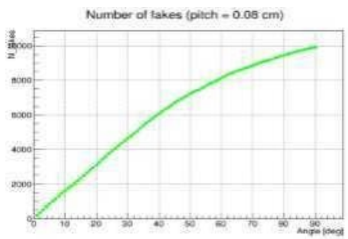
- ✔ Hybrid UrQMD
- ✔ vHLLE_UrQMD
- ✔ 3FD(Theseus)

Exp. data

- d + C,Al, Cu, Pb E = 4 GeV, 3.5 GeV
- C + C, C_2H_4, Al, Cu, Pb E = 4 GeV
- Ar + C, Cu, Sn, Pb E = 3.2 GeV
- Kr + Cu, Sn, Pb E = 2.94

MPD Run Control System

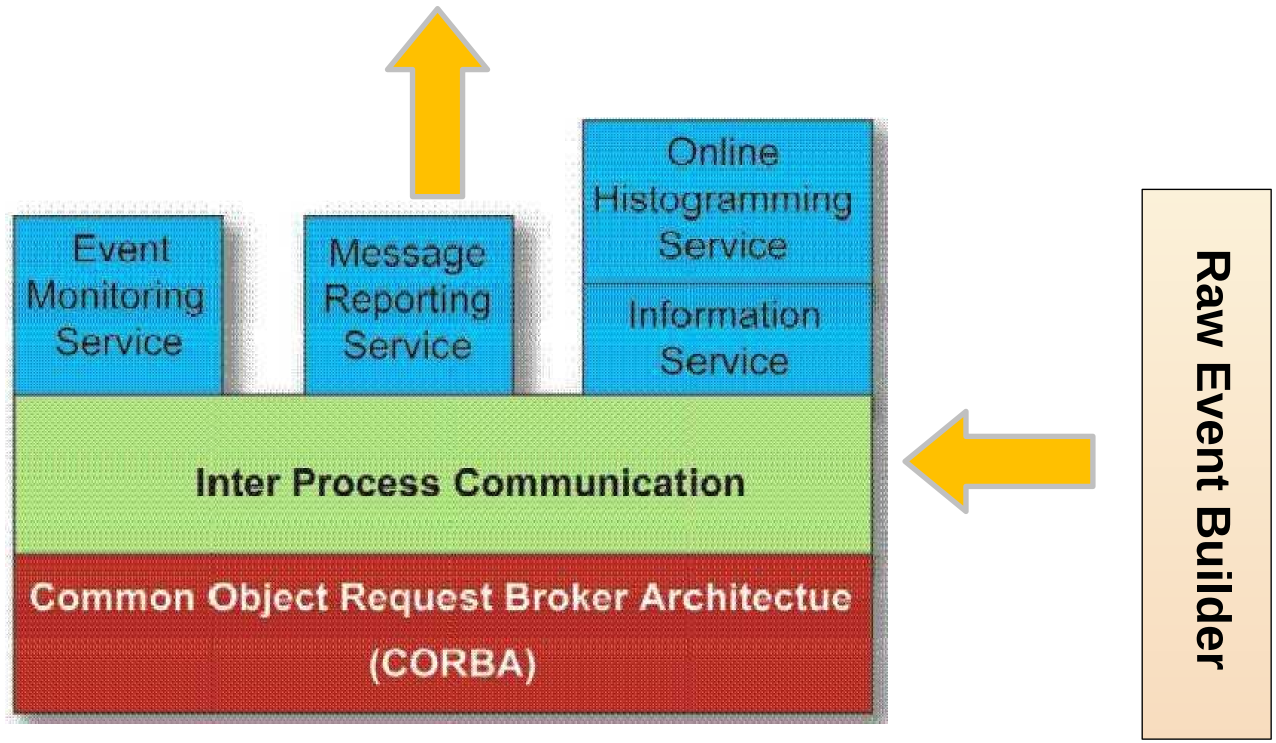


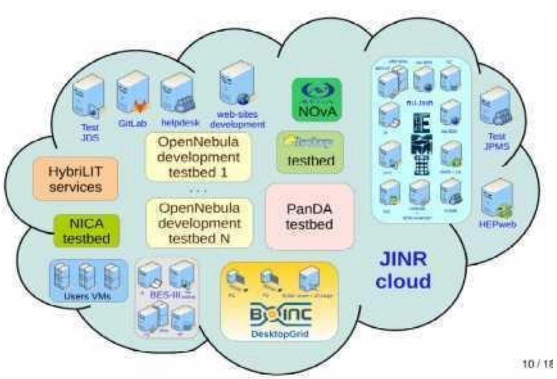


Displays
- Event Display
- Information Monitors
- Histogram Presenter
- Web Monitoring

Analysis
- Data Quality Monitoring

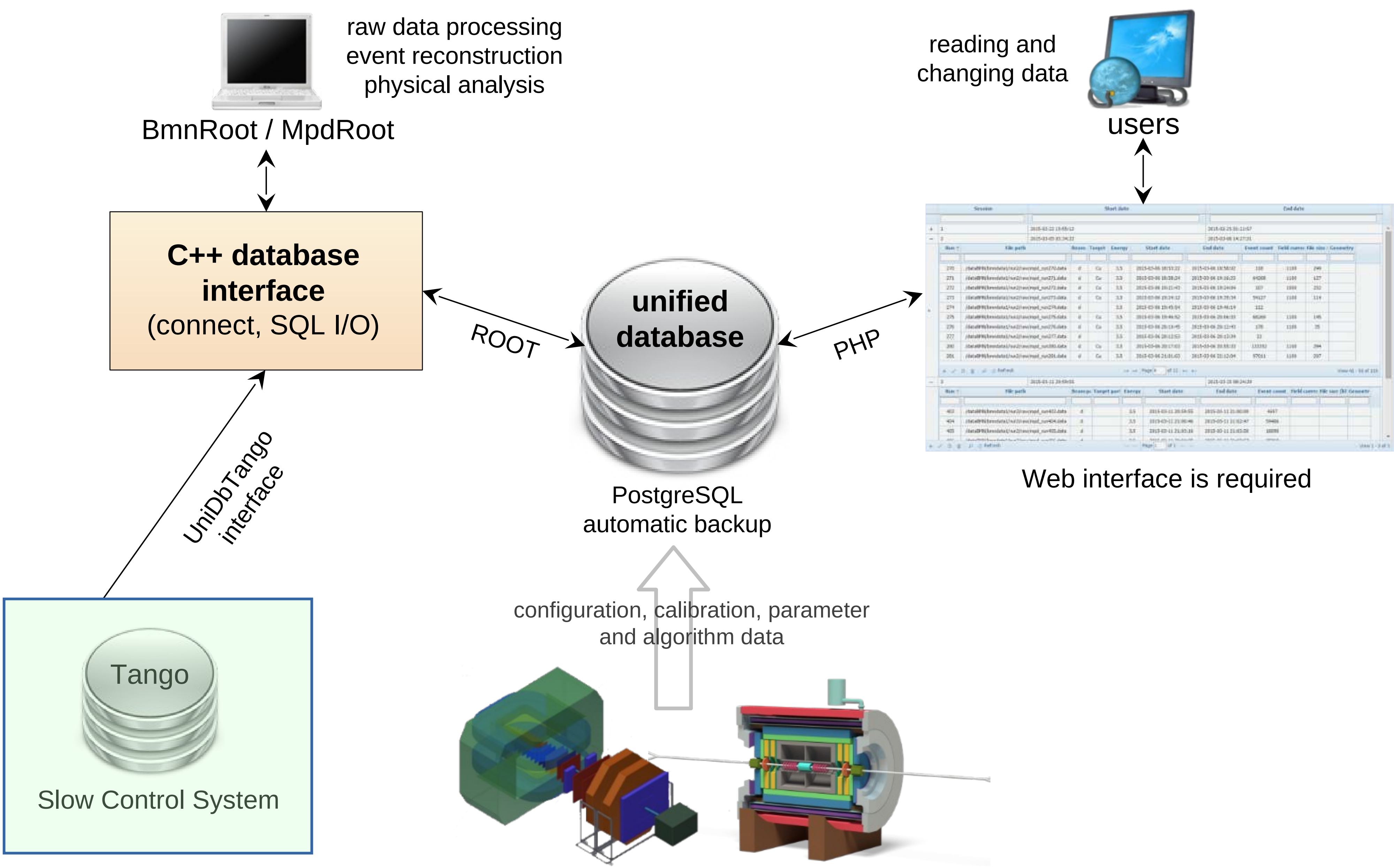
Archiving
- Monitoring Data Archiving
- Archive Browser





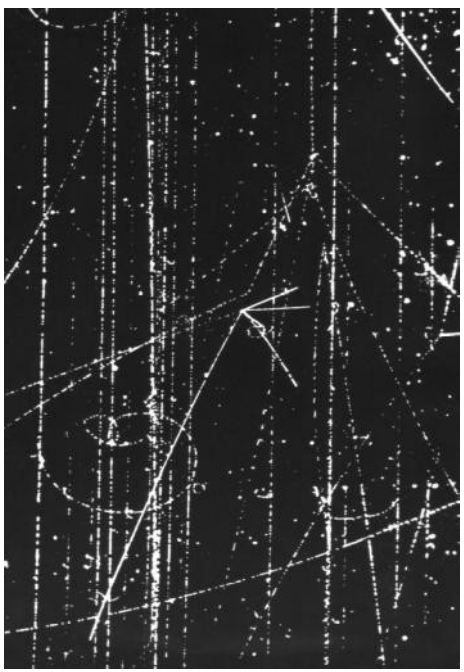
first prototype is developed on LIT Virtual Machines

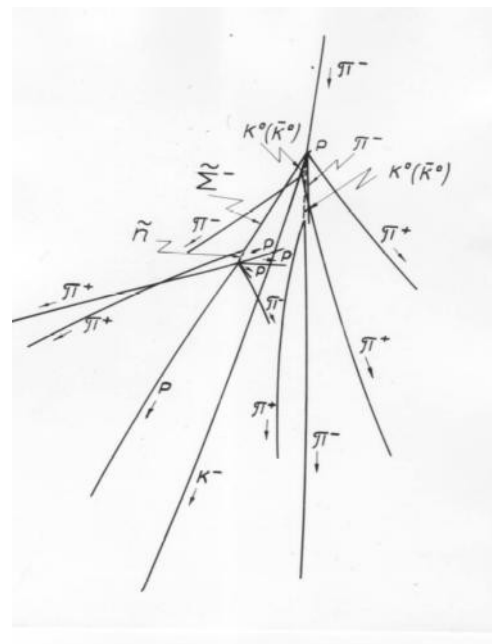
The Unified Database for offline data processing



Anti Sigma-minus hyperon discovery
(Dubna 1960)

A beam of protons with energies of 10 GeV from a synchrophasotron were used to bombard a target and form approximately π^- mesons of high energy. With the help of magnetic lens and focusing magnets a beam of approximately π^- mesons with an energy of 8.3 GeV was separated and directed into a propane bubble chamber at a constant magnetic field tension of 13,700 OE (oersteds). On analyzing 40,000 photographs which recorded tens of thousands of other nuclear interactions, proof of the existence of an unstable antiparticle, the antisigma minus hyperon, was found. It decays in 10^{-10} seconds to approximately π^- and an antineutron.



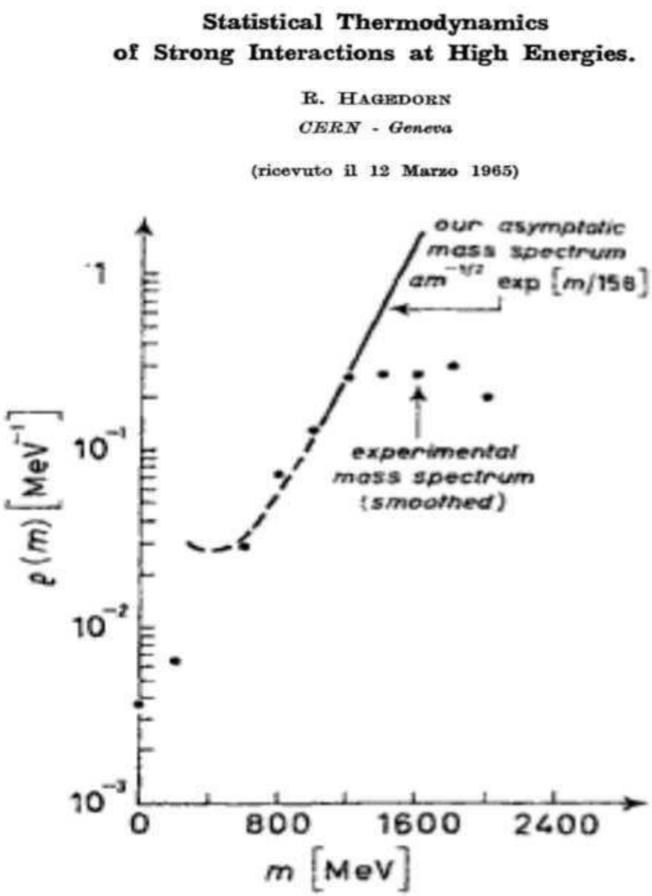


$$\pi^- + C \to \bar{\Sigma}^- + K^0 + \bar{K}^0 + K^- + p^+ + \pi^+ + \pi^- + nucleus\ \ recoil$$

$$\bar{\Sigma}^- \to \bar{n}^0 + \pi^- (1.18 \pm 0.07) \cdot 10^{-10}\ s$$

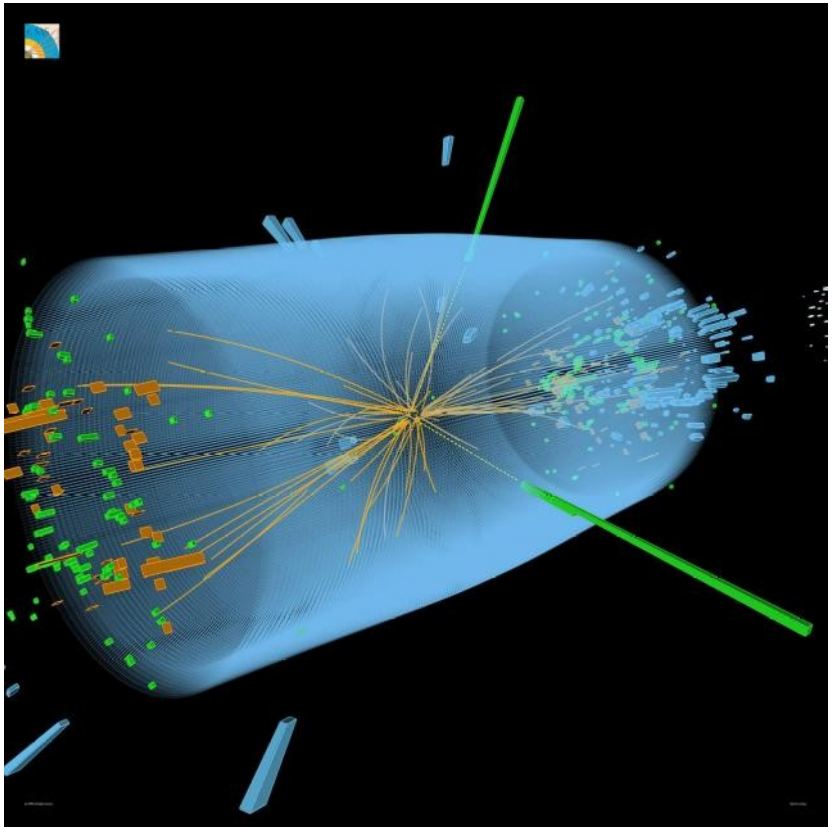
5σ rule

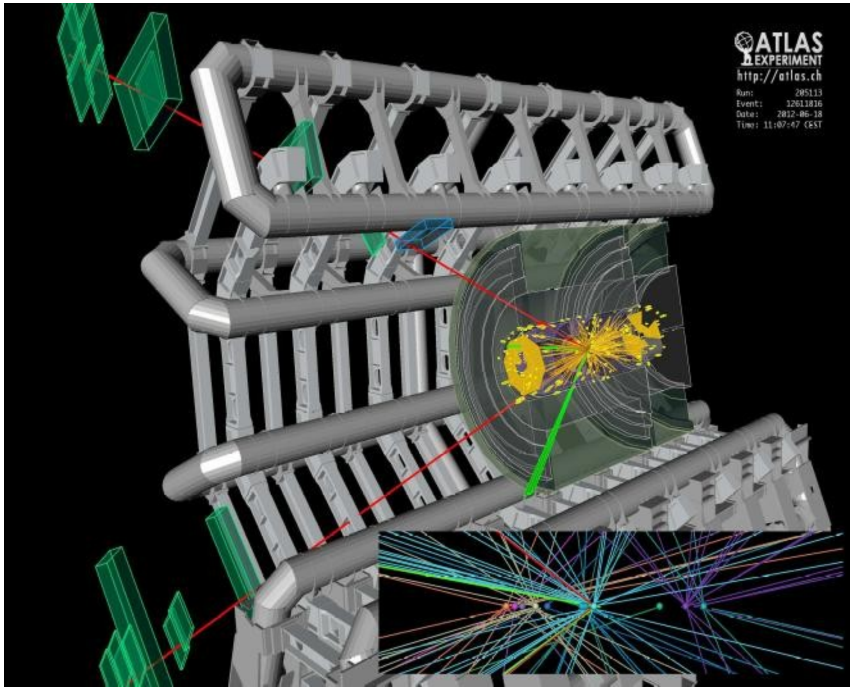
Five-sigma corresponds to a p-value, or probability, of 3×10^{-7}, or about 1 in 3.5 million.

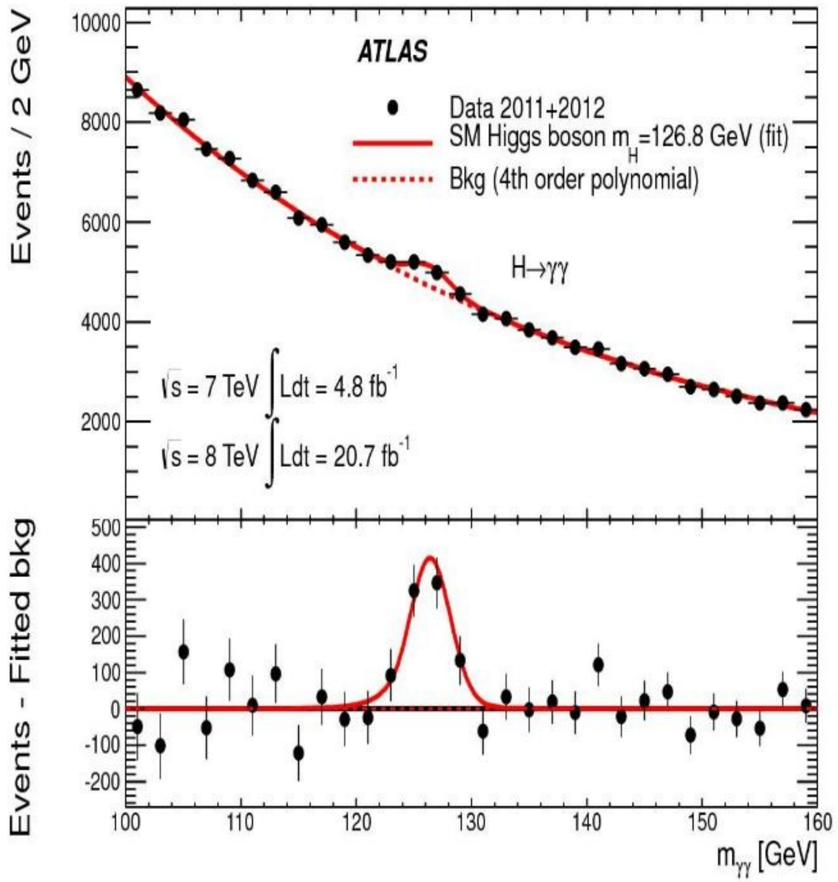


Experimental data:

1432 states known in 1967;
4627 states of mid ’90s.



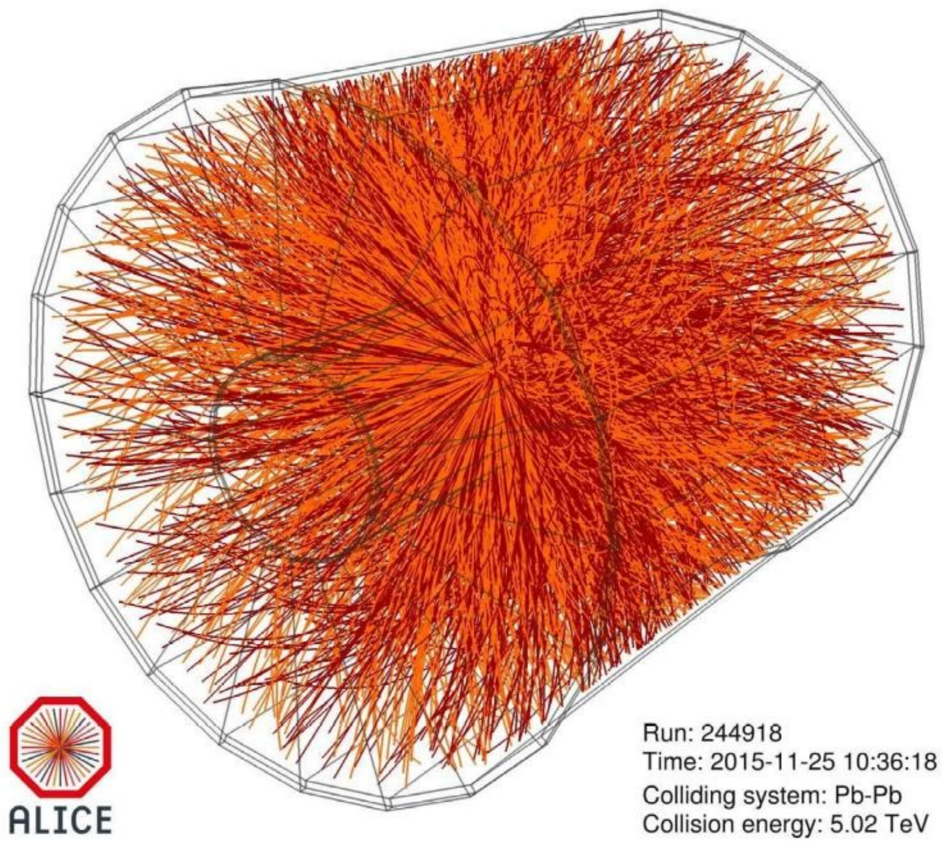




$$1fb^{-1} \approx 10^{12} pp\ events$$

Over a period of time, two streams of particles with a cross-sectional area, measured in femtobarns, are directed to collide. The total number of collisions is directly proportional to the luminosity of the collisions measured over this time.

Find Quark Gluon Plasma



Computing resources used for MPD

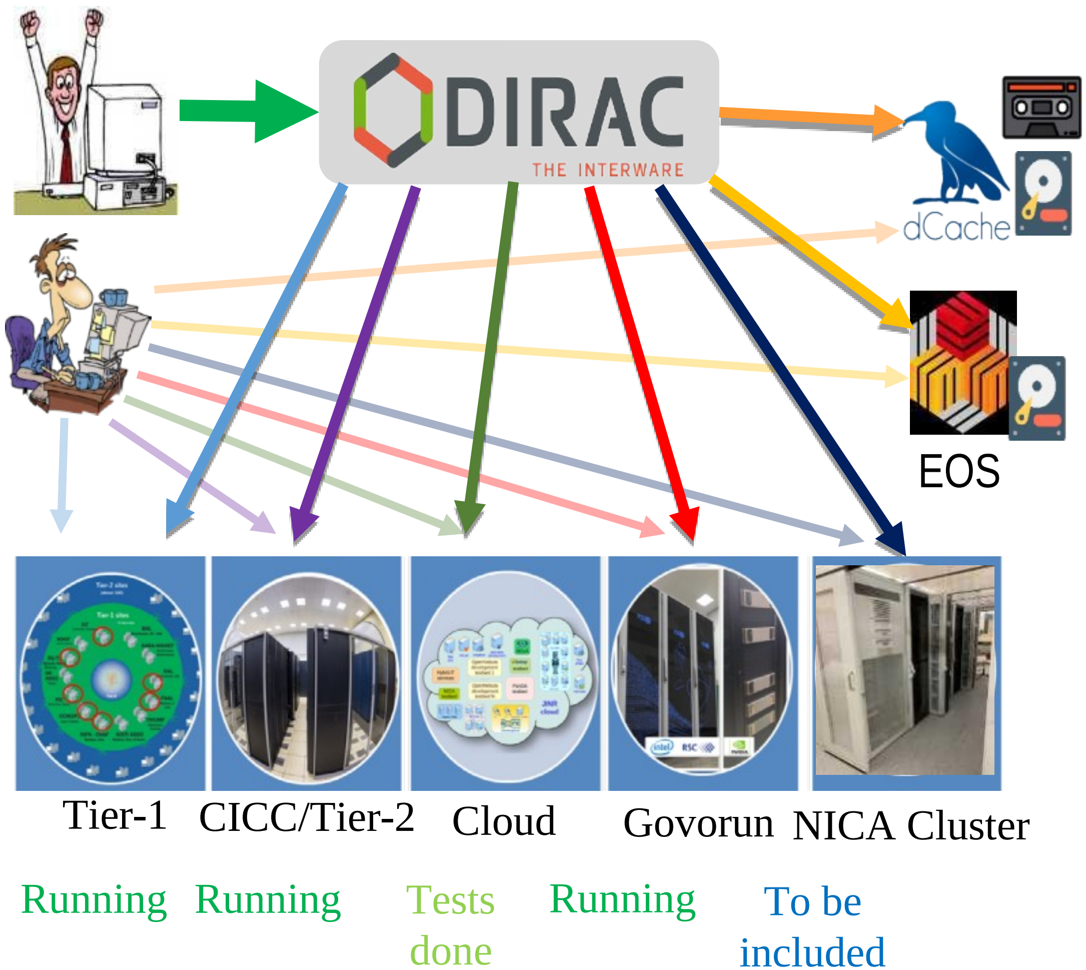
- NICA offline cluster 250 cores (limit for users)
- GOVORUN 818 cores
- Tier1 920 cores
- Tier2 1000 cores
- Clouds 70 cores
- UNAM 100 cores

LHEP

LIT

Mexico

JINR computing resources for MPDintegration



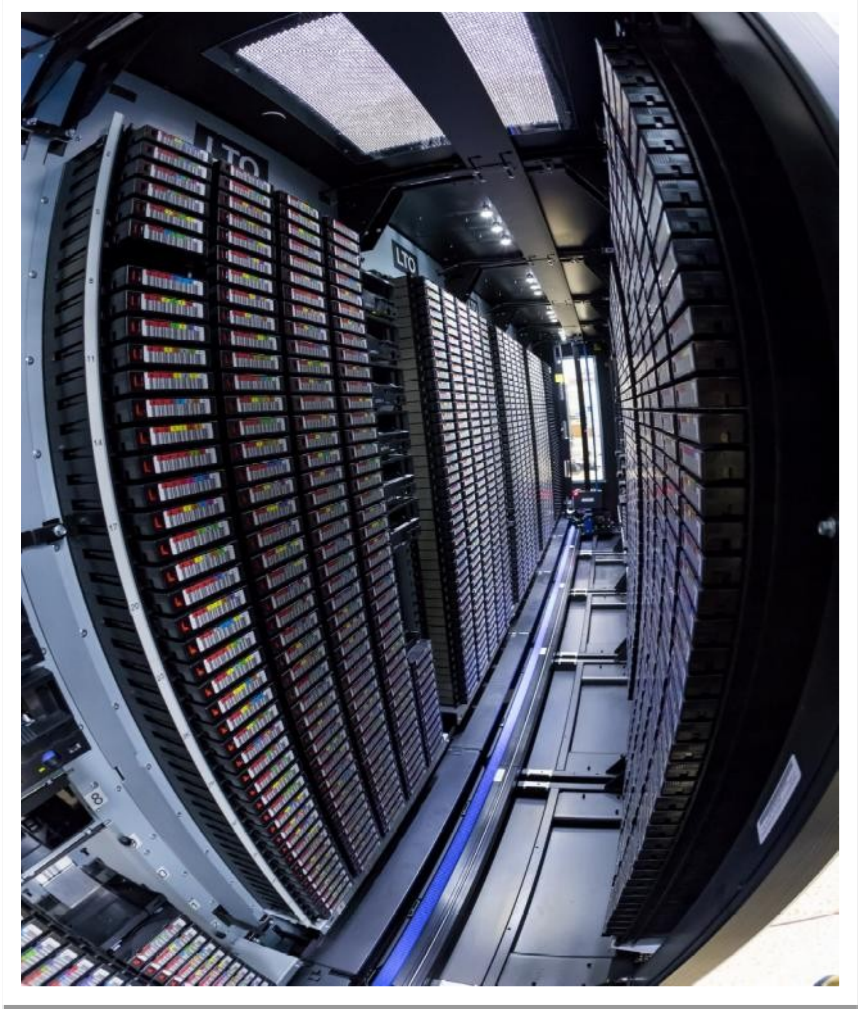
The **DIRAC Interware** is a software which provides various interfaces for the integration of distributed heterogeneous computing and storage resources.

Instead of using all JINR storage and computing resources individually, DIRAC allows processing of large amounts of data through unified single system.

Monte-Carlo mass production for MPD were successfully performed on the integrated system of Tier-1, Tier-2, Govorun and NICA cluster via DIRAC. JINR and Member-States cloud resources have been tested and ready to accept jobs.

Computing resources for NICA @ LIT

CMS TIER1

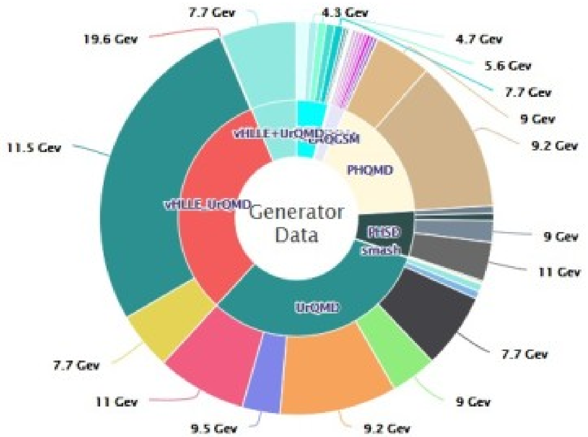


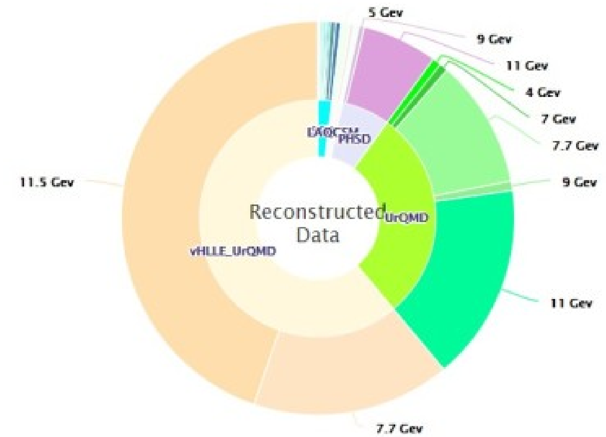
HybriLIT

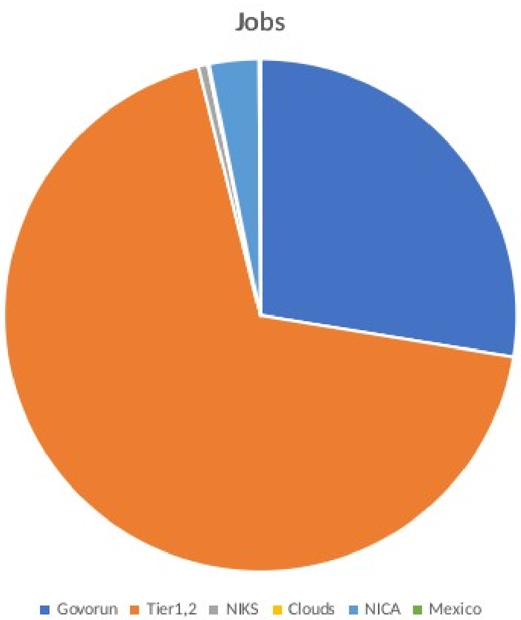
GOVORUN

MPD data mass production

23 mass production requests were done





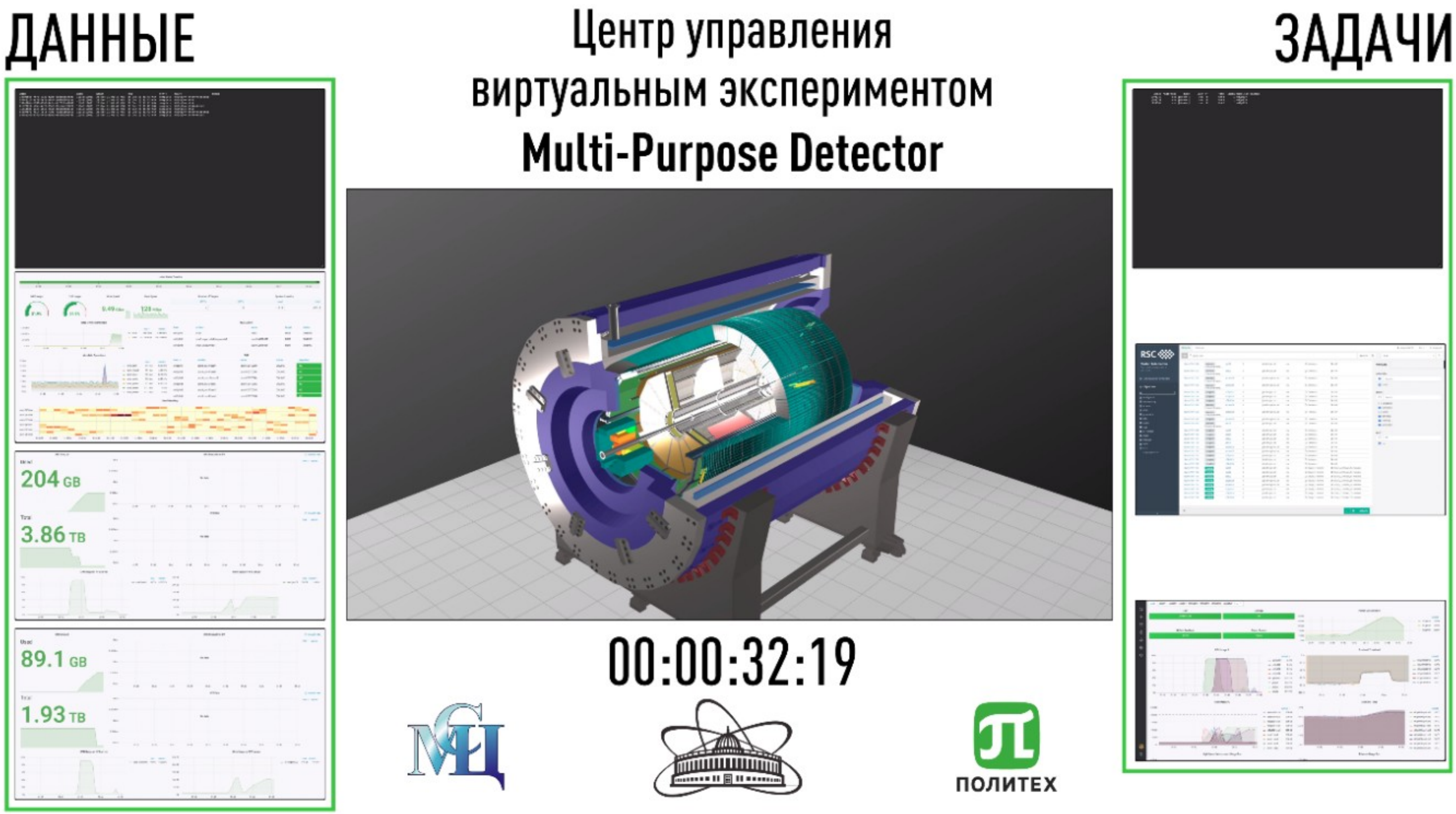


Generator	PWG	Coll.		# of events()	Reco
UrQMD	PWG4	AuAu	11	15	+
		BiBi	9	10	+
			9.46	10	+
			9.2	30	+
	PWG2	AuAu	11	10	+
	PWG3	AuAu	7.7	10	+
		BiBi	7.7	10	+
			9	15	+
		pp	9	10	+
	PWG1	BiBi	9.2	1	+
DCM-SMM	PWG1	BiBi	9.2	1	+
PHQMD	PWG2	BiBi	8.8	15	+
			9.2	40	+
			2.4/3.0/4.5	10/10/2	-
vHLLE-UrQMD	PWG3	BiBi	11.5	15	+
		AuAu	11.5	15	+
		AuAu	7.7	20	+
Smash	PWG1	BiBi	9.46	10	+
		ArAr	4/7/9/11	20/20/20/20	-
		AuAu	4/7/9/11	20/20/20/22	-
		XeXe	4/7/9/11	20/20/20/20	-
		CC	4/7/9/11	20/20/20/20	-
		pp	4/7/9/11	50/50/50/50	-
JAM	PWG3	AuAu	3/3.3/3.5/3.8/4.0/4.2/4.5/5	40/40/40/40/40/40/40/40	
DCM-QGSM-SMM	PWG3	AuAu	4/9.2	5/5	+
		AgAg	4/9.2	5/5	+
		BiBi	4/9.2	5/5	+
PHSD		BiBi	9	10	+
Total				1121	277

MPD at NIKS (The National Research Computer Network of Russia)

http://www.jinr.ru/posts/obedinennaya-superkompyuternaya-infrastruktura-na-baze-niks-zapushhena/

January 2022

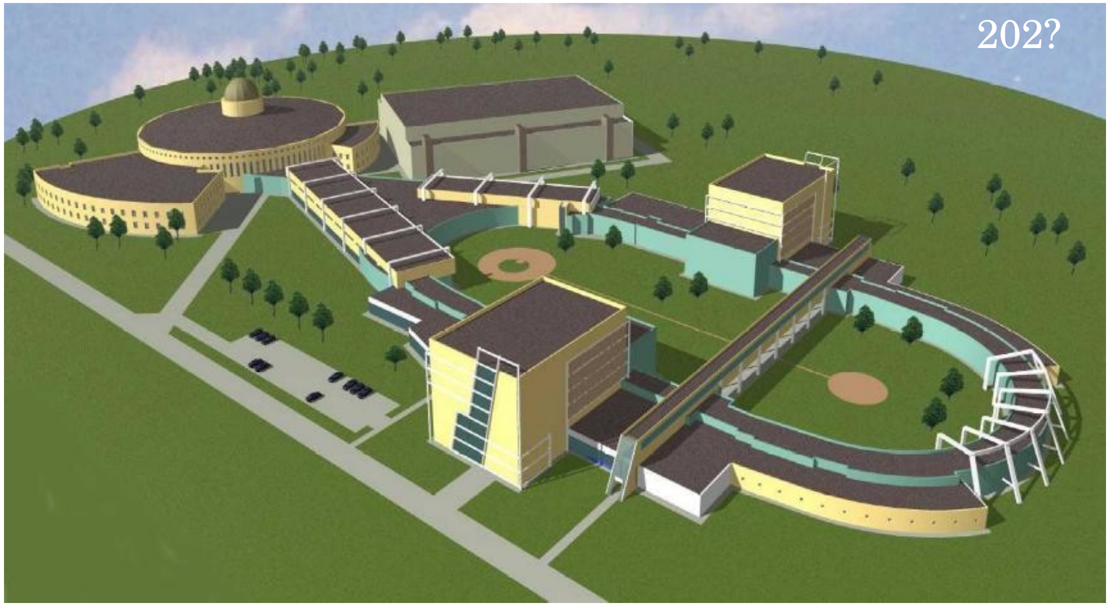


JSC RAS

MLIT JINR

SPbPU

Thank for your attention



Collective phenomena

Volume 157B, number 2,3 PHYSICS LETTERS 11 July 1985

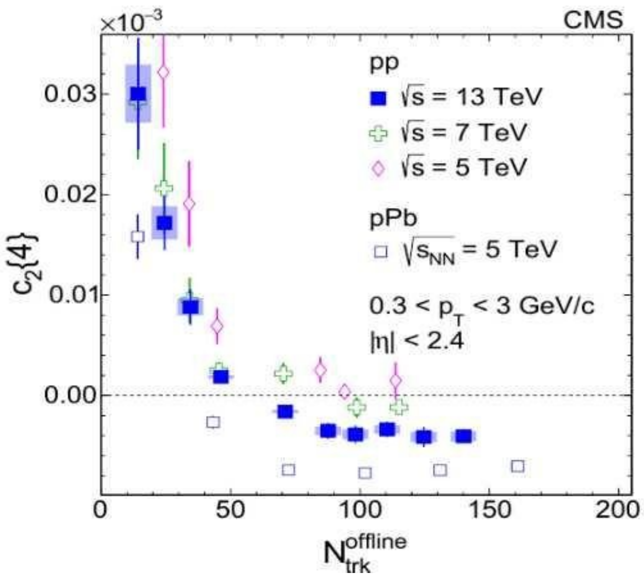
TRANSVERSE MOMENTUM ANALYSIS OF COLLECTIVE MOTION IN RELATIVISTIC NUCLEAR COLLISIONS *

P. DANIELEWICZ [1] and G. ODYNIEC
Nuclear Science Division, Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720, USA

Received 15 March 1985

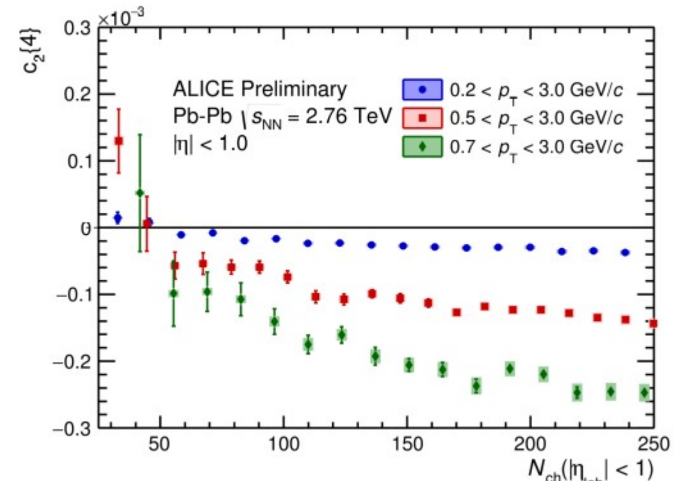
A novel transverse-momentum technique is used to analyse charged-particle exclusive data for collective motion in the Ar + KCl reaction at 1.8 GeV/nucleon. Previous analysis of this reaction, employing the standard sphericity tensor, revealed no significant effect. In the present analysis, collective effects are observed, and they are substantially stronger than in the Cugnon cascade model, but weaker than in the hydrodynamical model.

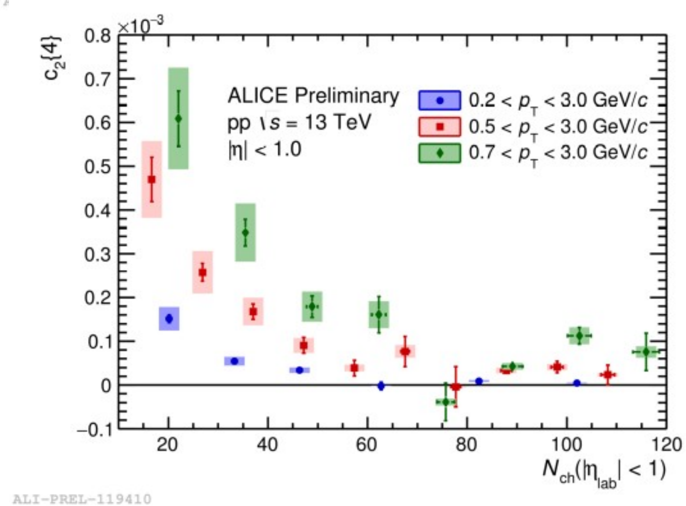
Evidence for collectivity in pp collisions at the LHC
The CMS Collaboration



Katarina Gajdosova ISMD 2017

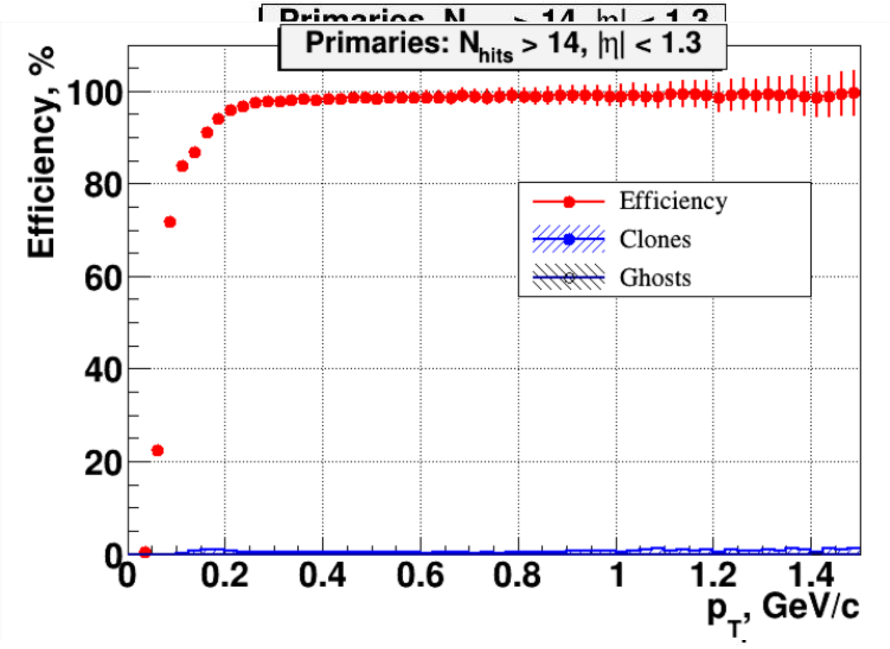
ALICE has not measured a definitive flow-like signature in pp collisions using c 2 {4}





Tracking in MPD TPC

Primaries



efficiency

Transverse momentum resolution