The Quest for the Quark-Gluon Plasma

- some theoretical background
- experiments with (relativistic) nuclei
- the GSI-Marburg-Berkeley collaboration 1974
  experiments with the plastic ball and streamer chamber
- a large scale accelerator proposal for GSI 1977
- heavy ion beams at CERN 1982
- the campaign to build RHIC 1990
- a few selected results from the SPS and RHIC campaigns
- outlook: LHC and FAIR

pbm, on the occasion of Rudolf Bock's 80th birthday
GSI, May 30, 2007

Historical Remarks

- Pomeranchuk 1951: finite hadron size → critical density n_c.
  Dokl. Akad. Nauk. SSSR **78** (1951) 889.
- Hagedorn 1965: mass spectrum of hadronic states $\rho(m) \propto m^{\alpha} \exp{(m/B)}$
  → critical temperature $T_c = B$. Nuovo Cim. Suppl. **3** (1965) 147.
- QCD 1973: asymptotic freedom
  D.J. Gross, F. Wilczek, Phys. Rev. Lett. **30** (1973)1343
  H.D. Politzer, Phys. Rev. Lett. **30** (1973) 1346.
- asymptotic QCD and deconfined quarks and gluons:
  N. Cabibbo, G. Parisi, Phys. Lett. **B59** (1975) 67.
  J.C. Collins, M.J. Perry, Phys. Rev. Lett. **34** (1975) 1353.

The QCD phase diagram – historical version

Quark Gluon Plasma: a consequence of asymptotic freedom

Collins and Perry, Phys. Rev. Lett. 34 (1975) 1353
Cabibbo and Parisi, Phys. Lett. B59 (1975) 67

First schematic phase diagram:
Cabibbo and Parisi,
Phys. Lett. B59 (1975) 67;

First detailed phase diagram:
Gordon Baym, NSAC 1983
Long Range Plan

Volume 59B, number 1 PHYSICS L

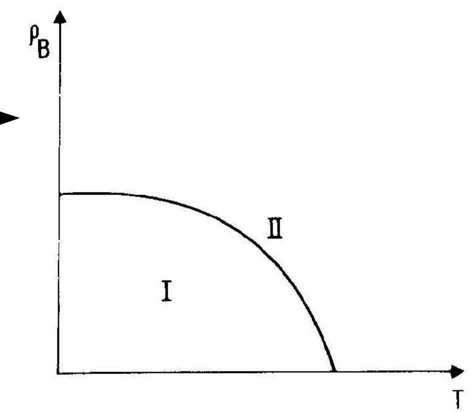
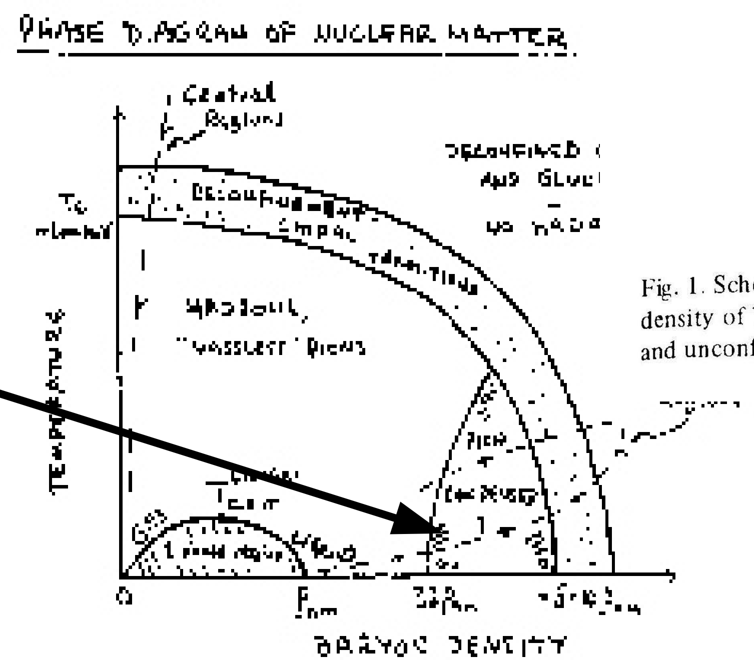
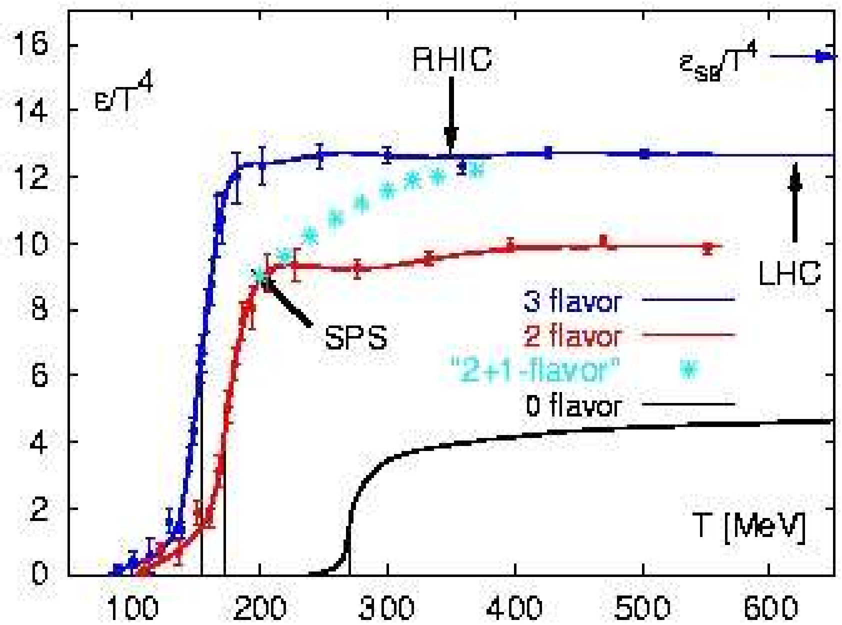


Fig. 1. Schematic phase diagram of hadronic matter. ρ_B is the density of baryonic number. Quarks are confined in phase I and unconfined in phase II.



Critical energy density and critical temperature



Lattice QCD calculations for $\mu_B = 0$
Karsch et al, hep-lat/0305025

$T_c = 170 \pm 20$ MeV

$\varepsilon_c = 700 \pm 200$ MeV/fm^3

for the (2 + 1) flavor case:

the phase transition to the QGP and its parameters are quantitative predictions of QCD.

The order of the transition is not yet definitively determined.

GSI TECHNISCHE UNIVERSITÄT DARMSTADT

Preliminaries: Experiments with Heavy Ions at MPI-K, Heidelberg

1958: PhD (W. Bothe)
1958 – 1962: postdoc with W. Gentner

start of heavy ion physics and build-up of teams and technology for heavy ion research

W. von Oertzen and
R. Bock 1964

World-wide efforts in the 60ties and early 70ties

Berkeley, Yale
Heidelberg, Muenchen
Orsay

mostly focussed on research at energies near
the Coulomb barrier
important development of techniques

... in Germany leading to GSI as a major laboratory

Workshop on BeV Collisions of Heavy Ions: How and Why

Nov 29 - Dec 1 1974

Bear Mountain New York

Introduction and Summary:

The history of physics teaches us that profound revolutions arise from a gradual perception that certain observations can be accommodated only by radical departures from current thinking. The workshop addressed itself to the intriguing question of the possible existence of a nuclear world quite different from the one we have learned to accept as familiar and stable.

Leon Lederman and Joseph Weneser

It would be interesting to explore new phenomena by distributing high energy or high nuclear density over a relatively large volume.

T. D. Lee

from the conclusion ... This leads naturally to the physical picture that the so-called vacuum actually more resembles a medium whose properties can be changed. If this is true, which of course we do not know at present, it must ultimately lead to rather striking physical consequences.

by high energy nucleus-nucleus collisions

PHYSICAL REVIEW D VOLUME 9, NUMBER 8 15 APRIL 1974

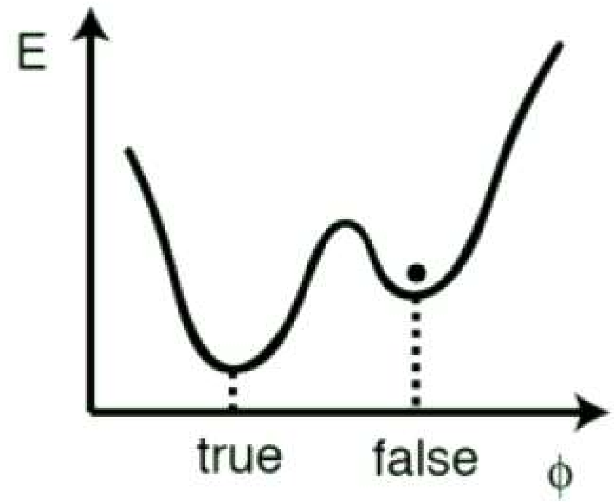
Vacuum stability and vacuum excitation in a spin-0 field theory*

T. D. Lee and G. C. Wick
Columbia University, New York, New York 10027
(Received 17 January 1974)

The theoretical possibility that in a limited domain in space the expectation value $\langle \phi(x) \rangle$ of a neutral spin-0 field may be abnormal (that is to say quite different from its normal vacuum expectation value) is investigated. It is shown that if the ϕ^3 coupling is sufficiently large, then such a configuration can be metastable, and its physical size may become substantially greater than the usual microscopic dimension in particle physics. Furthermore, independent of the strength of the ϕ^3 coupling, if $\phi(x)$ has sufficiently strong scalar interaction with the nucleon field, the state that has an abnormal $\langle \phi(x) \rangle$ inside a very heavy nucleus can become the minimum-energy state, at least within the tree approximation; in such a state, the "effective" nucleon mass inside the nucleus may be much lower than the normal value. Both possibilities may lead to physical systems that have not yet been observed.

Lee Wick Matter

Is our vacuum stable?



can the true vacuum be reached in nucleus-nucleus collisions at high energy?

Z. Physik A 273, 359 – 371 (1975)

Early and influential emulsion experiments and theoretical steps

Shock Waves and Mach Cones in Fast Nucleus-Nucleus Collisions*

H.G. Baumgardt, J.U. Schott, Y. Sakamoto**, and E. Schopper

Institut für Kernphysik, Johann Wolfgang Goethe-Universität, Frankfurt am Main, Germany

H. Stöcker, J. Hofmann, W. Scheid, and W. Greiner

Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, Frankfurt am Main, Germany

Received April 1, accepted April 4, 1975

Abstract. Mach shock waves and head shock waves occur during the interpenetration of a light high energetic nucleus with a heavy one. Collisions of ^{16}O, ^{12}C and ^{4}He ions at energies between 0.25 and 2.1 GeV/N with Ag and Cl nuclei have been investigated. The theoretical concepts and the experiment are presented and interpreted. From that a velocity of first sound in nuclear matter $c_s \approx 0.19c$, a Mach shock velocity $v_s \approx 0.58c$ and a nuclear compression constant $K = 300$ MeV are deduced.

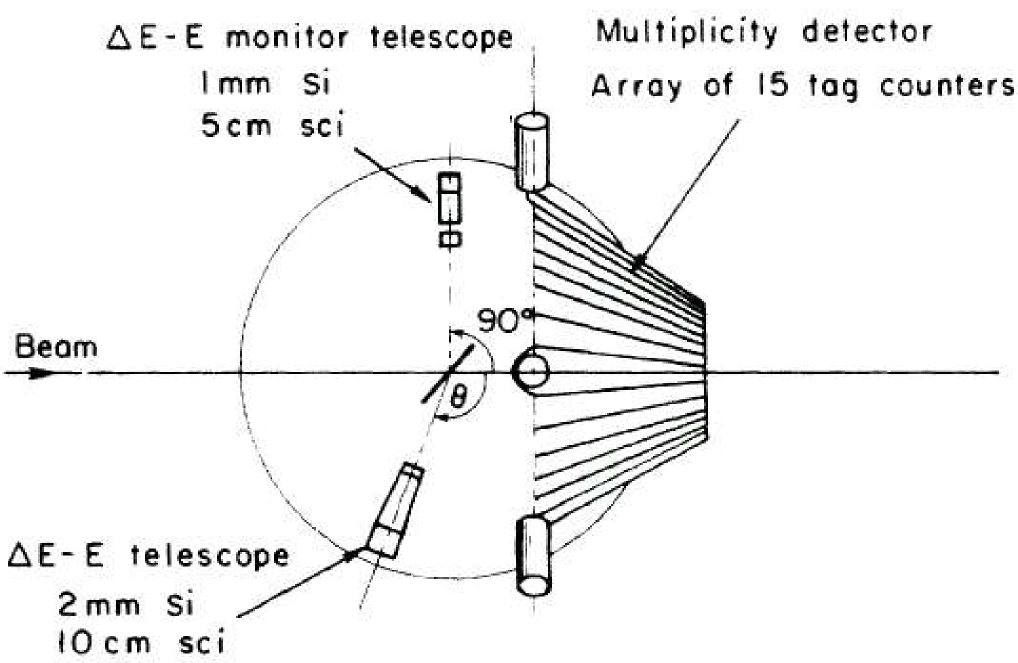
an interesting remark at the end of the paper

Note Added in Proof. The position of this peak has been confirmed by recent results from an electronic $\Delta E - E$-type experiment by Gutbrod, Jandoval and Stock (Marburg); and Poskanzer, Sextro and Zebelmann, at the LBL Berkeley: The reaction $^4He + ^{238}U \rightarrow ^3He$ at $E(^4He) = 0.7$ GeV/N and 1.05 GeV/N shows (broadened) forward peaks in the angular distribution $d\sigma/d\theta$ at $40 \pm 3°$ (1.05 GeV/N) and $38 \pm 5°$ (0.7 GeV/N) for ^3He-particles with $60 < E < 100$ MeV/N (private communication by R. Stock).

First steps: the GSI-Marburg-Berkeley collaboration

1974: R. Bock, Reinhard Stock, Hans Gutbrod et al.
first experiments at Bevatron/Bevalac accelerator
$E_{kin}/A \approx 1$ GeV

particle telescopes in a scattering chamber



techniques developed by Rudolf Bock's group at HD and GSI

The first paper: fireball emits heavy fragments...
no Mach cones ...
but Mach cone concept important to date

PHYSICAL REVIEW C VOLUME 16, NUMBER 2 AUGUST 1977

Central collisions of relativistic heavy ions*

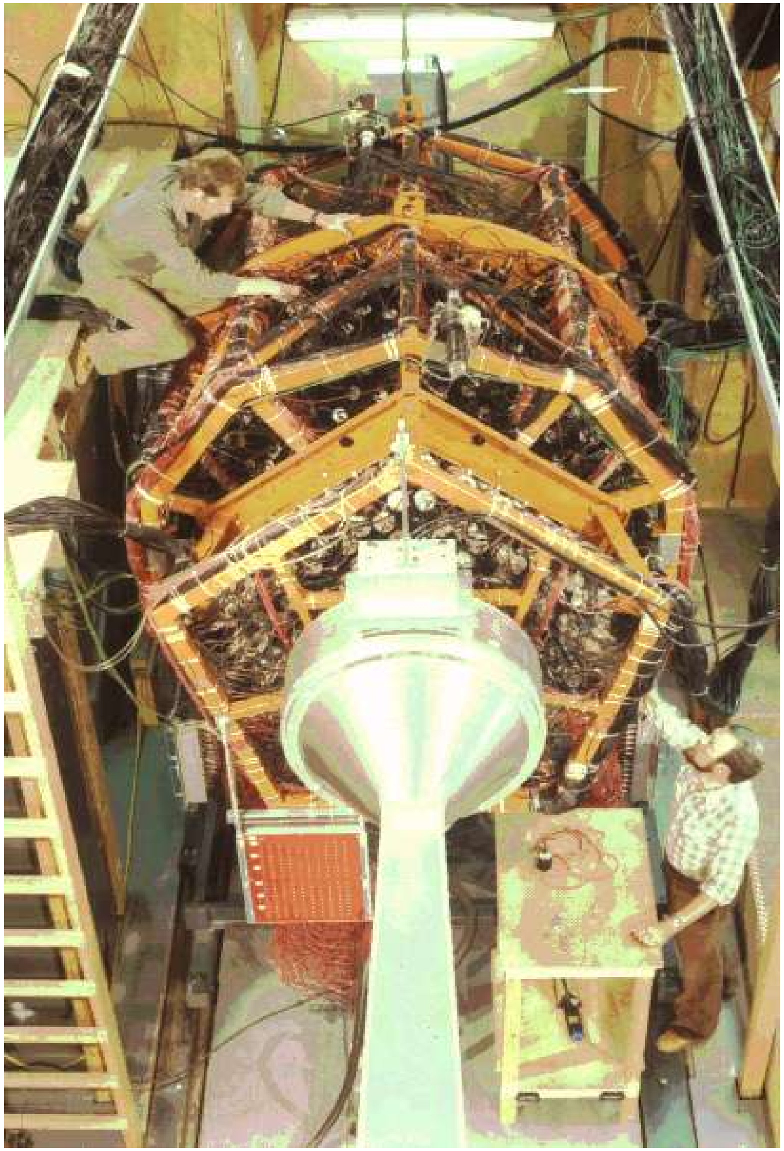
J. Gosset,[†] H. H. Gutbrod, W. G. Meyer, A. M. Poskanzer, A. Sandoval, R. Stock, and G. D. Westfall

Lawrence Berkeley Laboratory, Berkeley, California 94720,
Gesellschaft für Schwerionenforschung, Darmstadt, Germany,
and Fachbereich Physik, Universität Marburg, Marburg, Germany

(Received 13 May 1977)

The energy spectra of protons and light nuclei produced by the interaction of ^{4}He and ^{20}Ne projectiles with Al and U targets have been investigated at incident energies ranging from 0.25 to 2.1 GeV per nucleon. Single fragment inclusive spectra have been obtained at angles between 25° and 150°, in the energy range from 30 to 150 MeV/nucleon. The multiplicity of intermediate and high energy charged particles was determined in coincidence with the measured fragments. In a separate study, fragment spectra were obtained in the evaporation energy range from ^{12}C and ^{20}Ne bombardment of uranium. We observe structureless, exponentially decaying spectra throughout the range of studied fragment masses. There is evidence for two major classes of fragments; one with emission at intermediate temperature from a system moving slowly in the lab frame, and the other with high temperature emission from a system propagating at a velocity intermediate between target and projectile. The high energy proton spectra are fairly well reproduced by a nuclear fireball model based on simple geometrical, kinematical, and statistical assumptions. Light cluster emission is also discussed in the framework of statistical models.

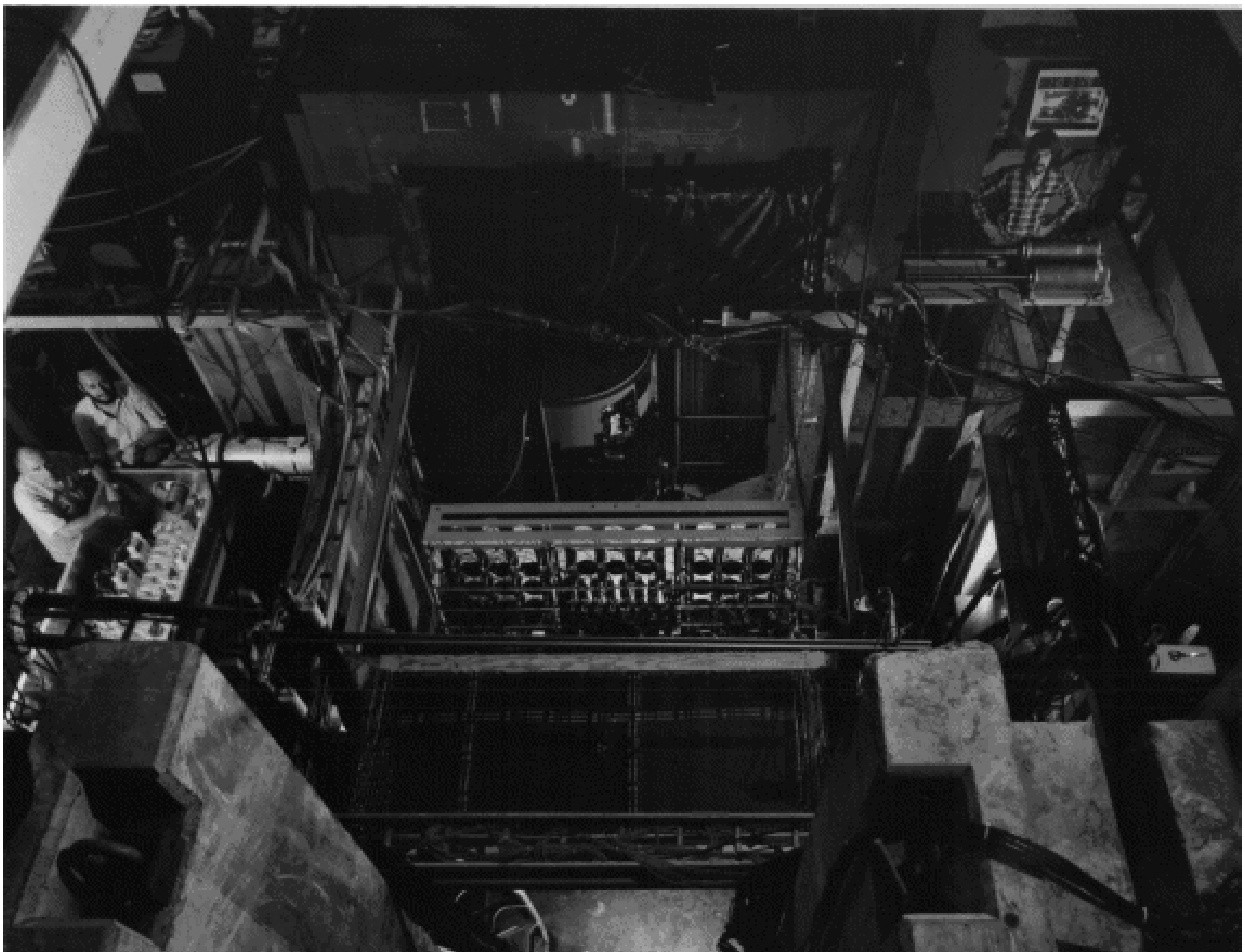
The first large scale experiments: plastic ball and streamer chamber



plastic ball with 815 modules of subdetectors built by GSI/LBL

The Streamer Chamber

refurbished and made fit for AA collision studies by GSI/LBL



Meanwhile, much bigger plans were contemplated at GSI

GSI-P-2-77
JANUAR 1977

ÜBERLEGUNGEN
ZUR PHYSIK DER KERNMATERIE
UNTER EXTREMEN BEDINGUNGEN
UND
ZU EINEM BESCHLEUNIGER
FÜR RELATIVISTISCHE SCHWERE IONEN

GSI - BERICHT P-2-77

GESELLSCHAFT FÜR SCHWERIONENFORSCHUNG MBH, DARMSTADT

An dieser Studie wirkten mit:
K. Blasche, R. Bock, B. Franzke, W. Greiner,
H.H. Gutbrod, B. Povh, Ch. Schmelzer und R. Stock

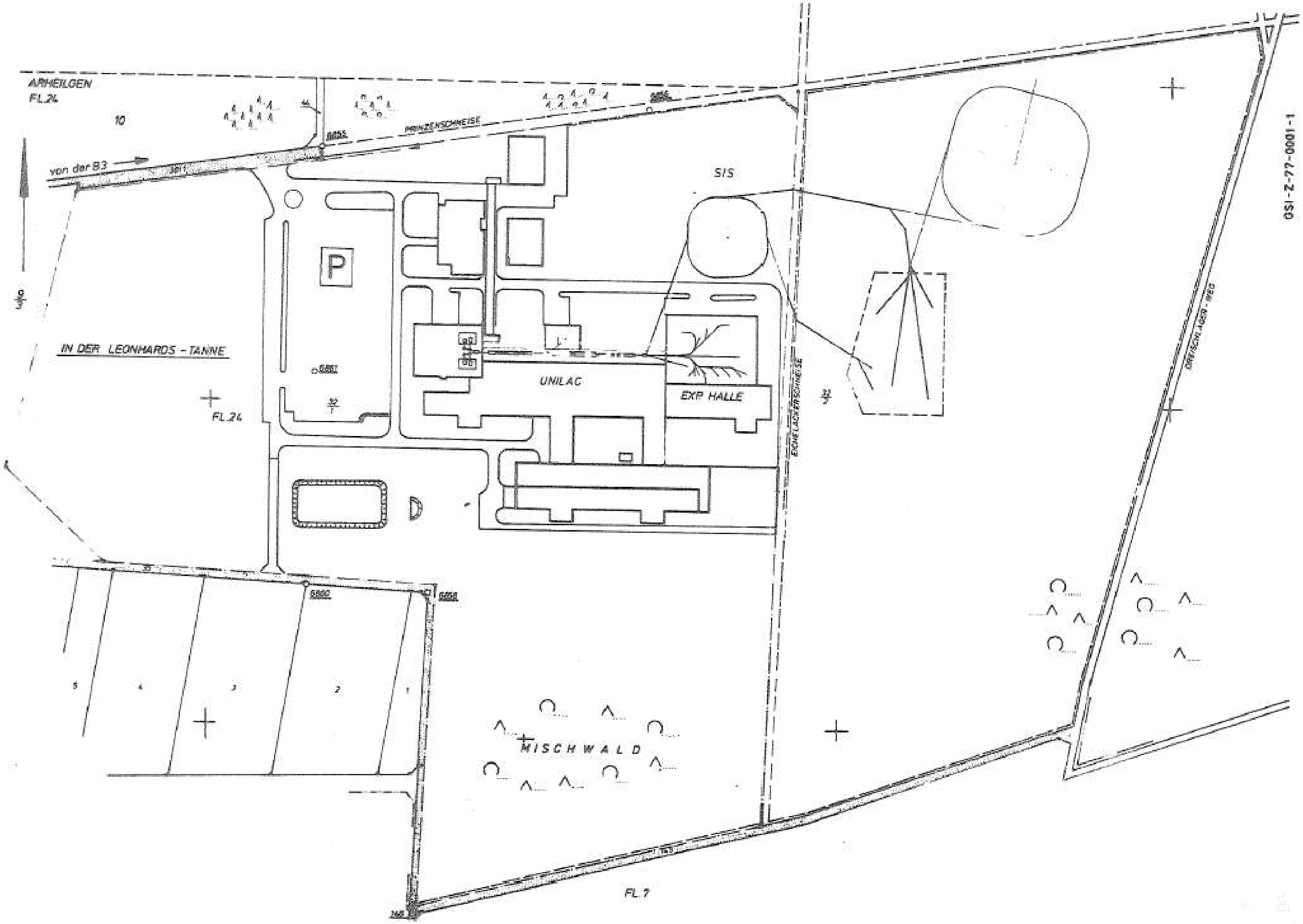
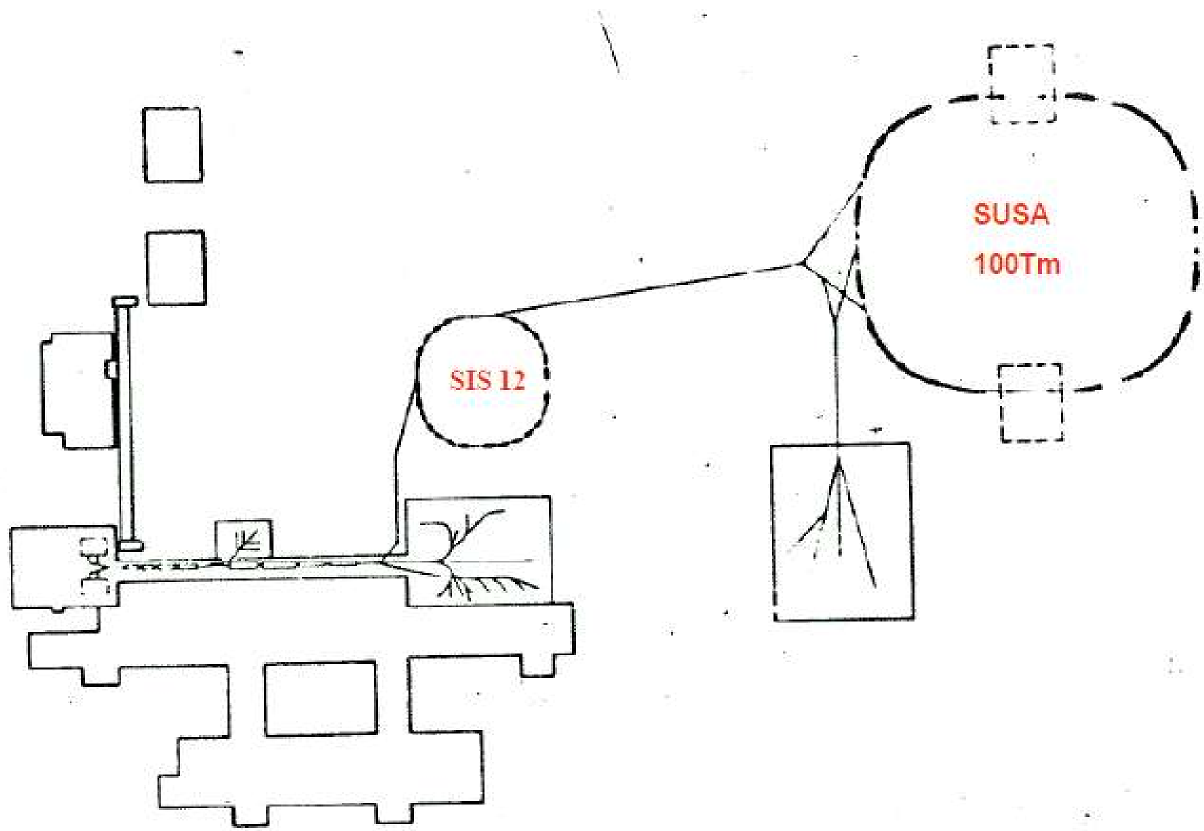


Abb. 12: Übersichtsplan zur Anordnung einer Nachbeschleuniger-Anla auf dem GSI-Gelände.



16.10.1978
SIS 12 plus Superconducting Storage Ring (SUSA) with possibility for a collider mode

RHIC at GSI?

the nuclear physics community as well as GSI were not ripe for such far reaching plans in 1977

ambitious plans were pursued elsewhere:

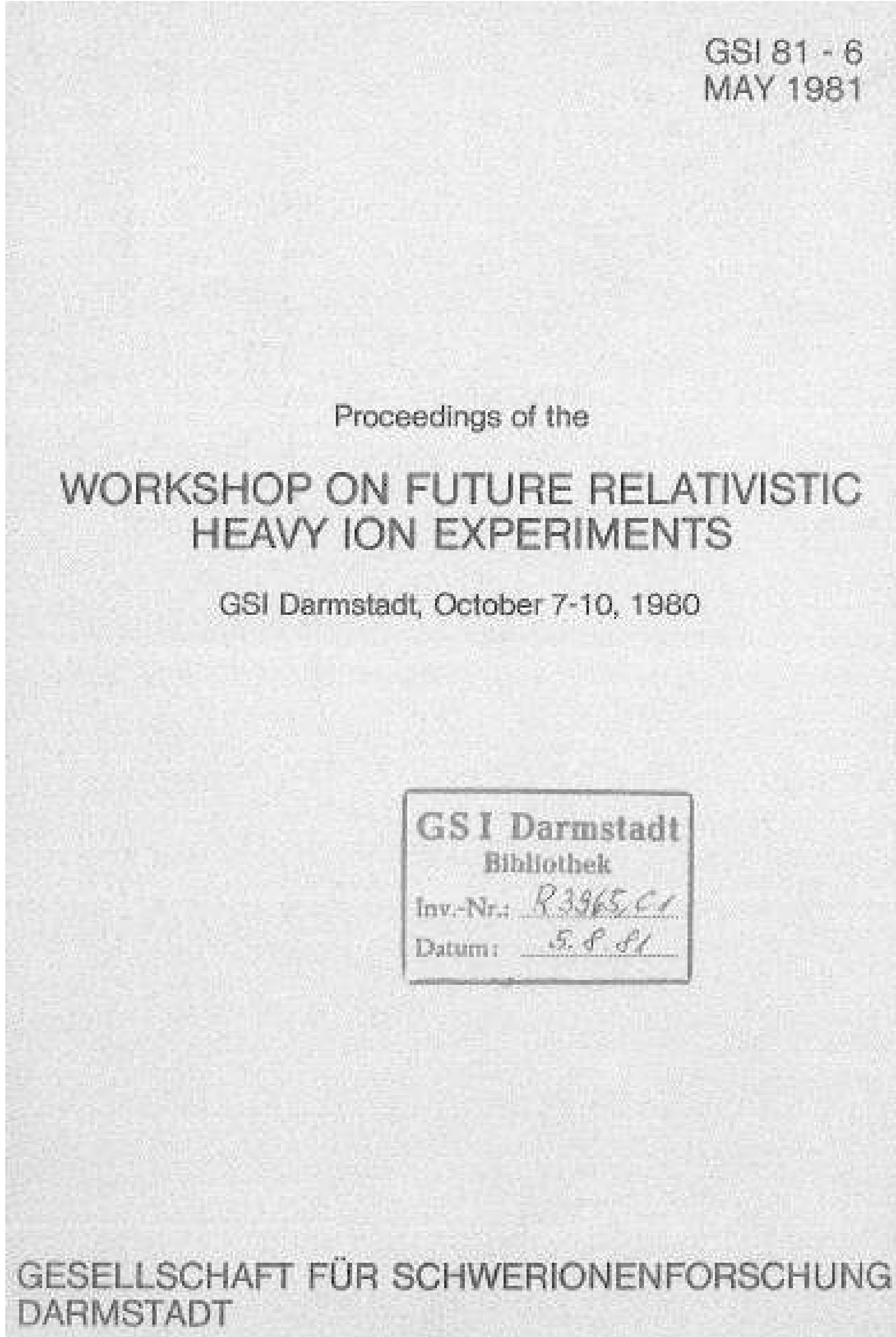
VENUS@LBL

ISABELLE@BNL

Si and Au beams at BNL AGS

S and Pb beams at CERN SPS

RHIC -- a dedicated collider at BNL


GSI 81 - 6
MAY 1981

Proceedings of the

WORKSHOP ON FUTURE RELATIVISTIC HEAVY ION EXPERIMENTS

GSI Darmstadt, October 7-10, 1980

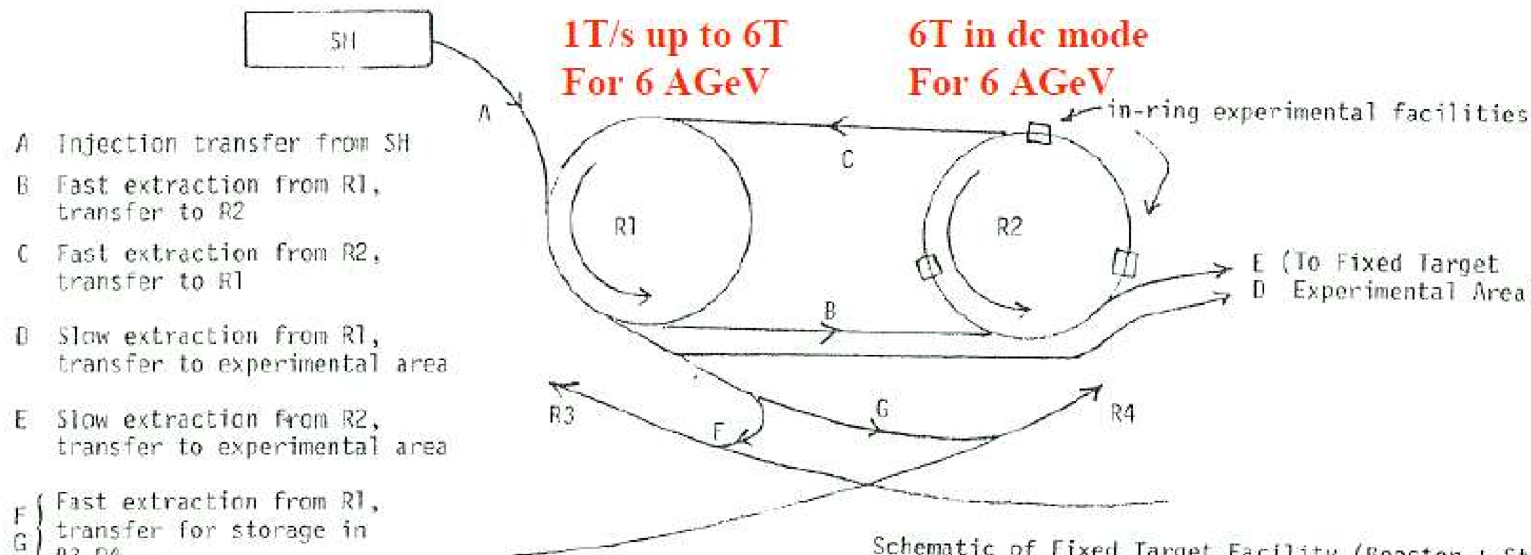
GESELLSCHAFT FÜR SCHWERIONENFORSCHUNG
DARMSTADT

and the physics was developed further ....

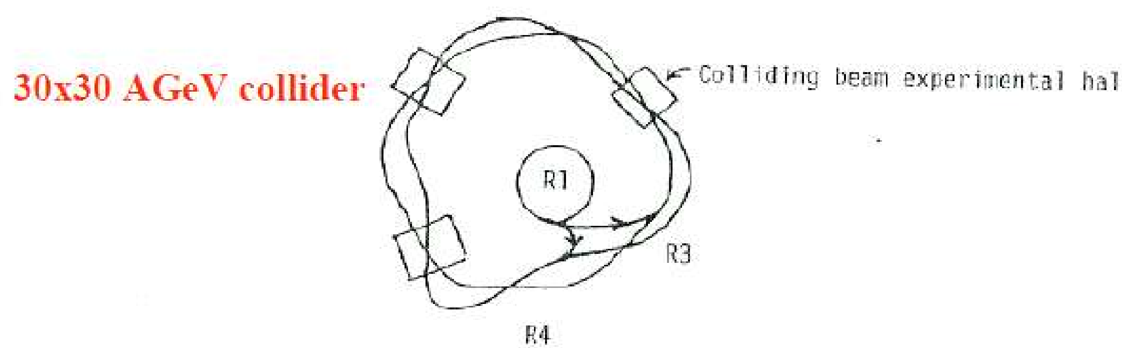
R. Bock and R. Stock

VENUS at Berkeley

15.07.1982



Schematic of Fixed Target Facility (Booster + Stretcher Rings)



Schematic of Colliding Beam Facility

7th HIGH ENERGY HEAVY ION STUDY

GSI Darmstadt, October 8-12, 1984

PROCEEDINGS

R. Bock, H.H. Gutbrod, R. Stock
Editors

HEAVY NUCLEAR BEAMS AT CERN

R. STOCK , FACHBEREICH PHYSIK , UNIV. FRANKFURT

R. BOCK , GSI DARMSTADT.

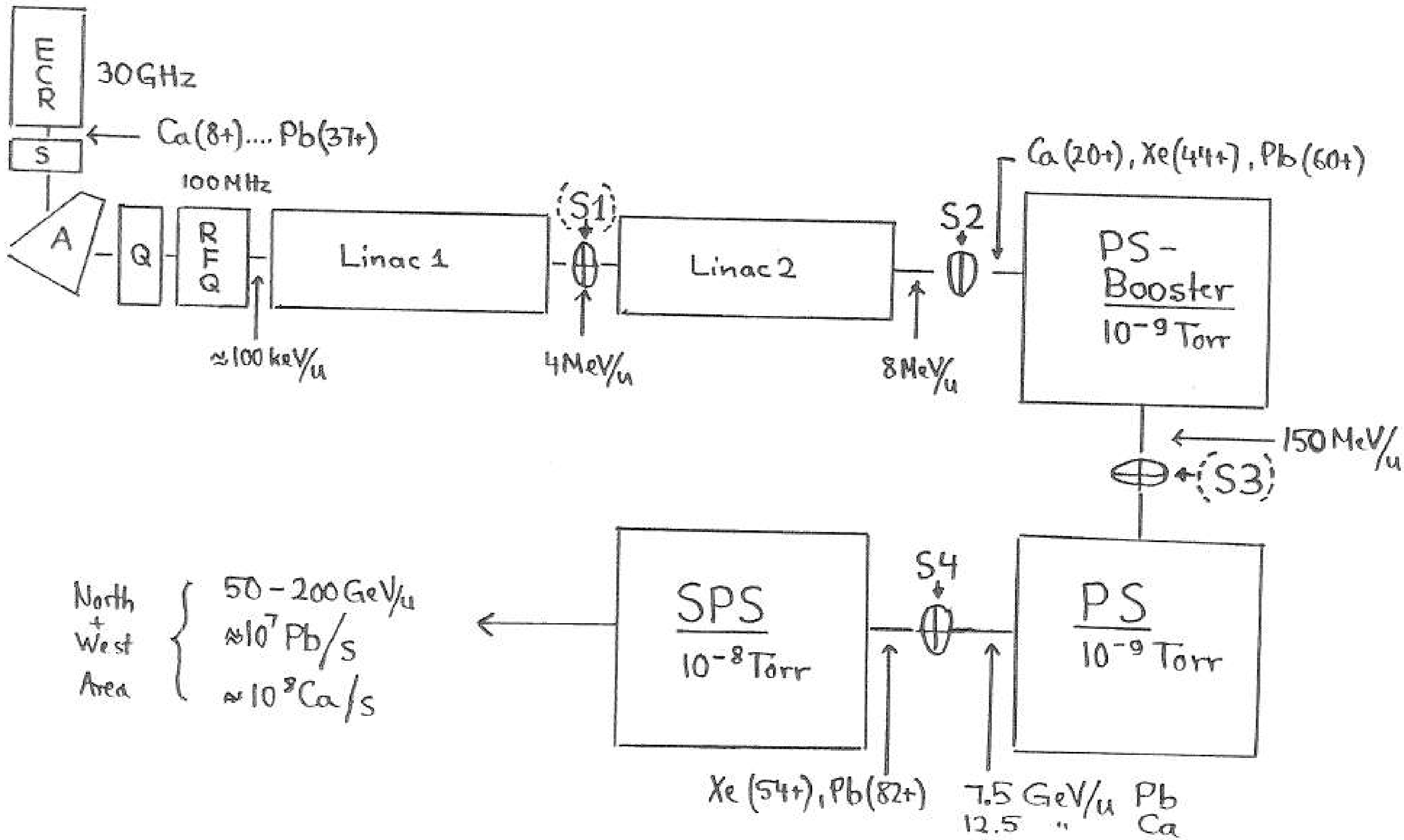

ECR
30GHz
S
Ca(8+)....Pb(37+)
A
Q
100MHz
RFQ
Linac 1
S1
Linac2
S2
Ca(20+), Xe(44+), Pb(60+)
PS-Booster
10^-9 Torr
≈100 keV/u
4MeV/u
8MeV/u
150MeV/u
S3
SPS
10^-8 Torr
S4
PS
10^-9 Torr
North + West Area
50 - 200 GeV/u
≈10^7 Pb/s
≈10^8 Ca/s
Xe (54+), Pb(82+)
7.5 GeV/u Pb
12.5 " Ca

FIG.2

INSTITUT FÜR KERNPHYSIK

DER JOHANN WOLFGANG GOETHE-UNIVERSITÄT FRANKFURT AM MAIN

D-6000 FRANKFURT (M) 90
AUGUST-EULER-STRASSE 6
TELEFON (069) 798-4240
ODER (069) 798-4238

Prof. Dr. H. Schopper
Prof. Dr. R. Klapisch
C.E.R.N.
1211 GENEVA 23

September 1st, 1986

Dear Professor Schopper and Professor Klapisch,

Enclosed please find a draft paper with thoughts on a possible future extension of the heavy ion SPS program to the acceleration of all nuclei up to lead. It briefly discusses the physics arguments in favour of heavy nuclear projectiles as part of a long-term CERN nuclear beam program. It also outlines the required accelerator construction, chiefly a new ECR source, an RFQ and a Linac at the site of the old Linac 1.

A preliminary version of the paper has been widely discussed among accelerator groups at CERN, GSI and Grenoble. The conclusion is that the proposed scheme should be close enough to any final solution in order to serve as a trigger and guideline for an initial discussion. A first presentation within the CERN "heavy ion community", convened on 1 August 1986 by N. McCubbin and G. London at the initiative of the SPSC, has received enthusiastic support of such plans by all experimental groups. It was decided to further discuss future experiments and to work out a more detailed accelerator design. This is expected to lead to a more formal proposal early next year, to be submitted by a wider and more international group. The experiences made in the first heavy ion runs will, of course, also guide the further approach. However, we consider it justified already now to point out to CERN the possibilities to further develop this attractive field of basic research.

The purpose of this letter is to bring these thoughts to your attention at the occasion of the first internal CERN discussion, taking place on September 2 in the joint SPSC/PSCC meeting. We would very much appreciate if you could support this idea, introduce it into the discussion and decision-making process, and, if possible, give an early indication of CERN's basic backing and support for an extended nuclear beam program.

Yours sincerely,

R. Bock (GSI)
W. Geist (LBL)
H.H. Gutbrod (GSI)
L. Kluberg (Ec.Poly.Palaiseau)
F. Pühlhofer (U. Marburg)
R. Santo (U. Münster)
N. Schmitz (MPI München)
H.J. Specht (U. Heidelberg)
R. Stock (U. Frankfurt)

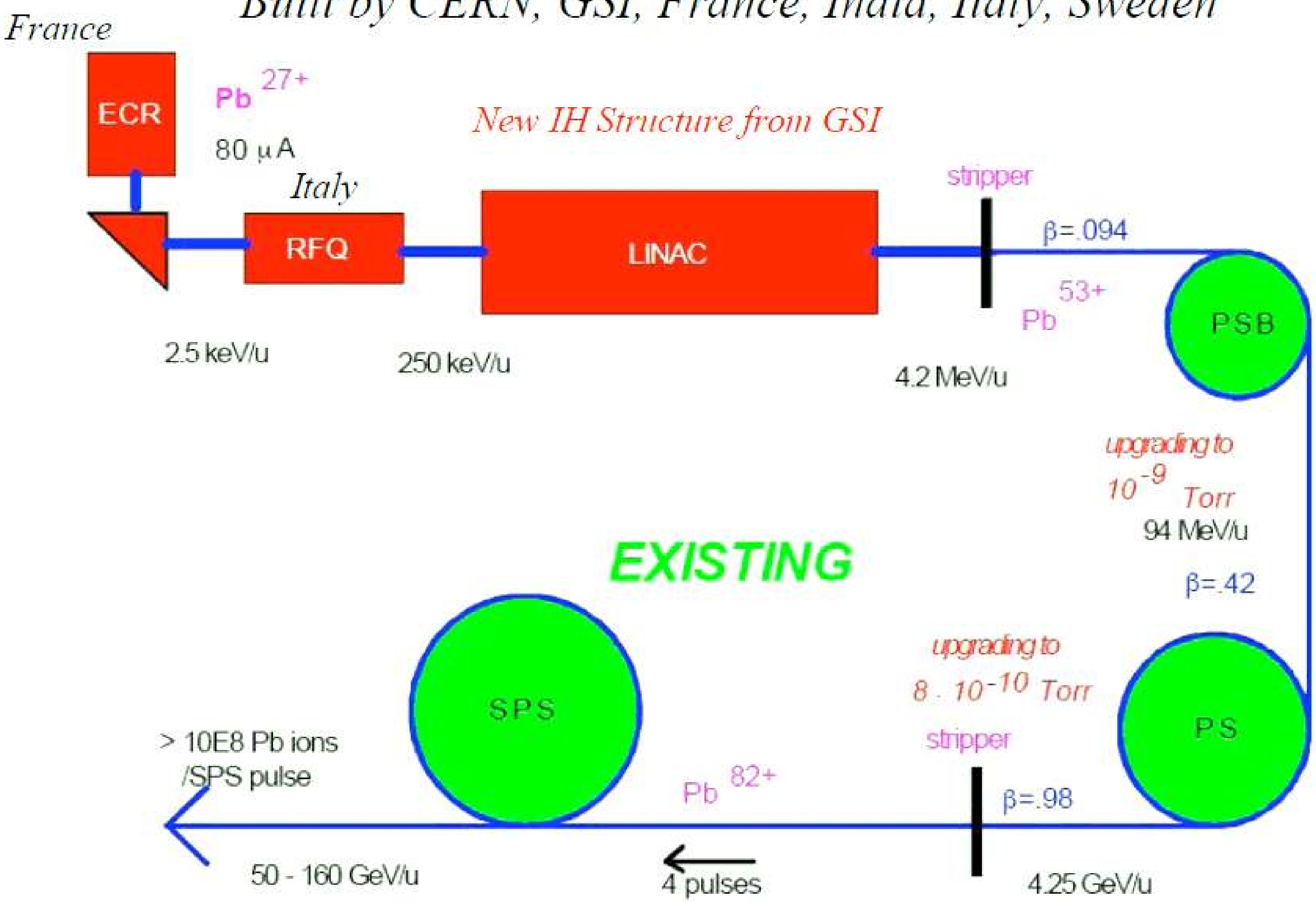
c.c Prof. L. Foà,
Prof. G. Brianti,
Dr. N. McCubbin,
Dr. G. W. London

begin of the program
with ultra-relativistic nuclear
beams at CERN

first SPS S and Pb beams
soon Pb beams at LHC

The new CERN Lead Injector

Built by CERN, GSI, France, India, Italy, Sweden



Two major experiments with GSI leadership at the CERN SPS

NA35: spokesperson Reinhard Stock

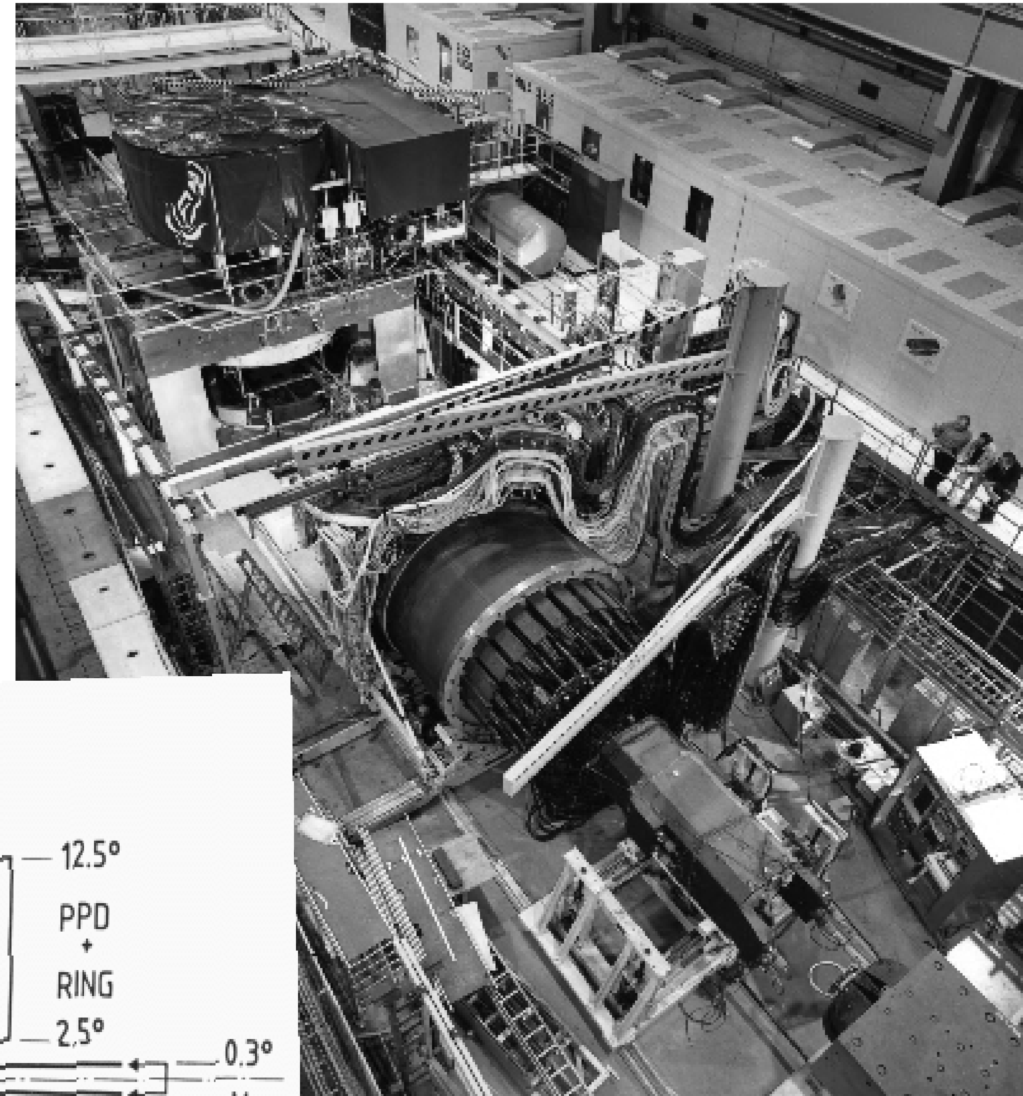
WA80: spokesperson Hans Gutbrod

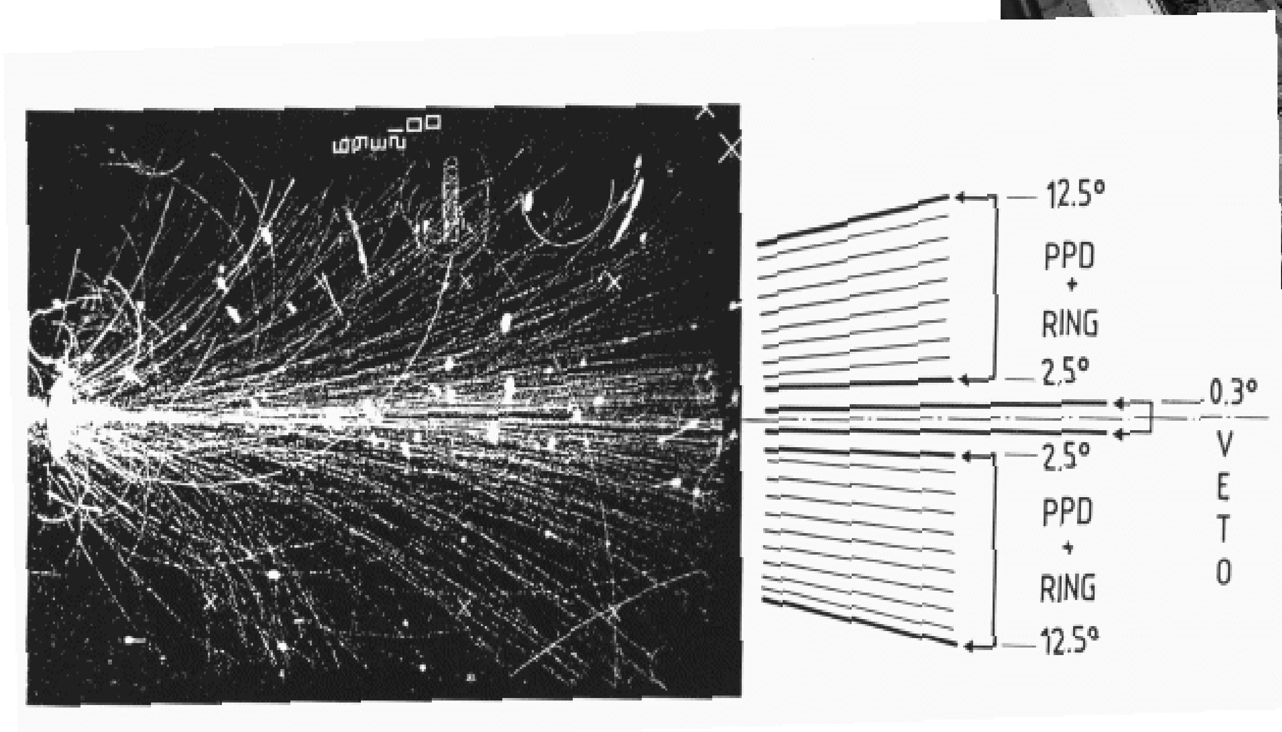
O^{16} beams at CERN in 1986 O^{16} ***ECR source (GSI), RFQ (LBL)***

S^{32} beams at CERN in 1987/8 S^{32} ***ECR source (GSI)***

Pb^{208} beams at CERN in 1994 Pb^{208} France, Germany, India, Italy, Sweden

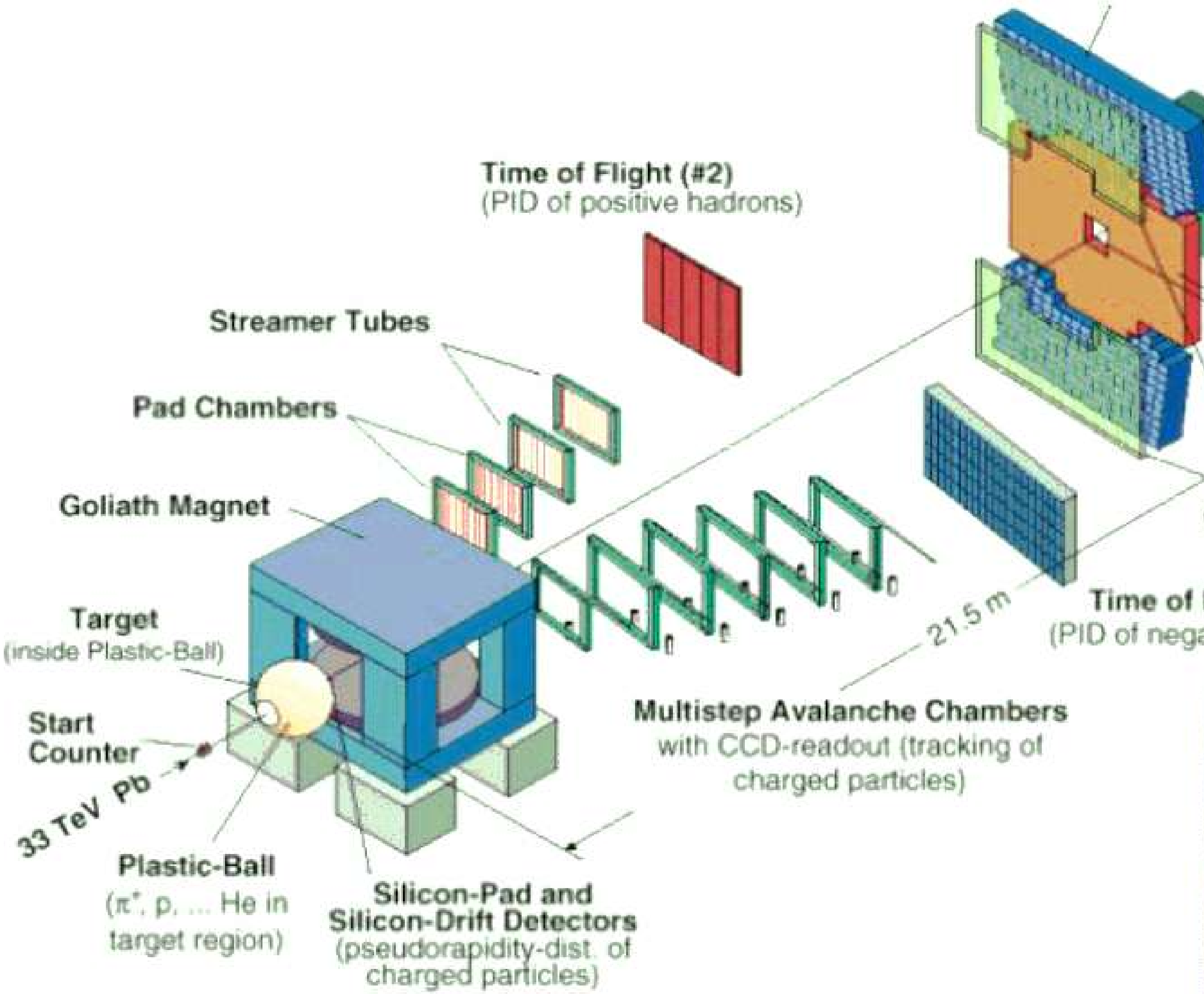
NA35



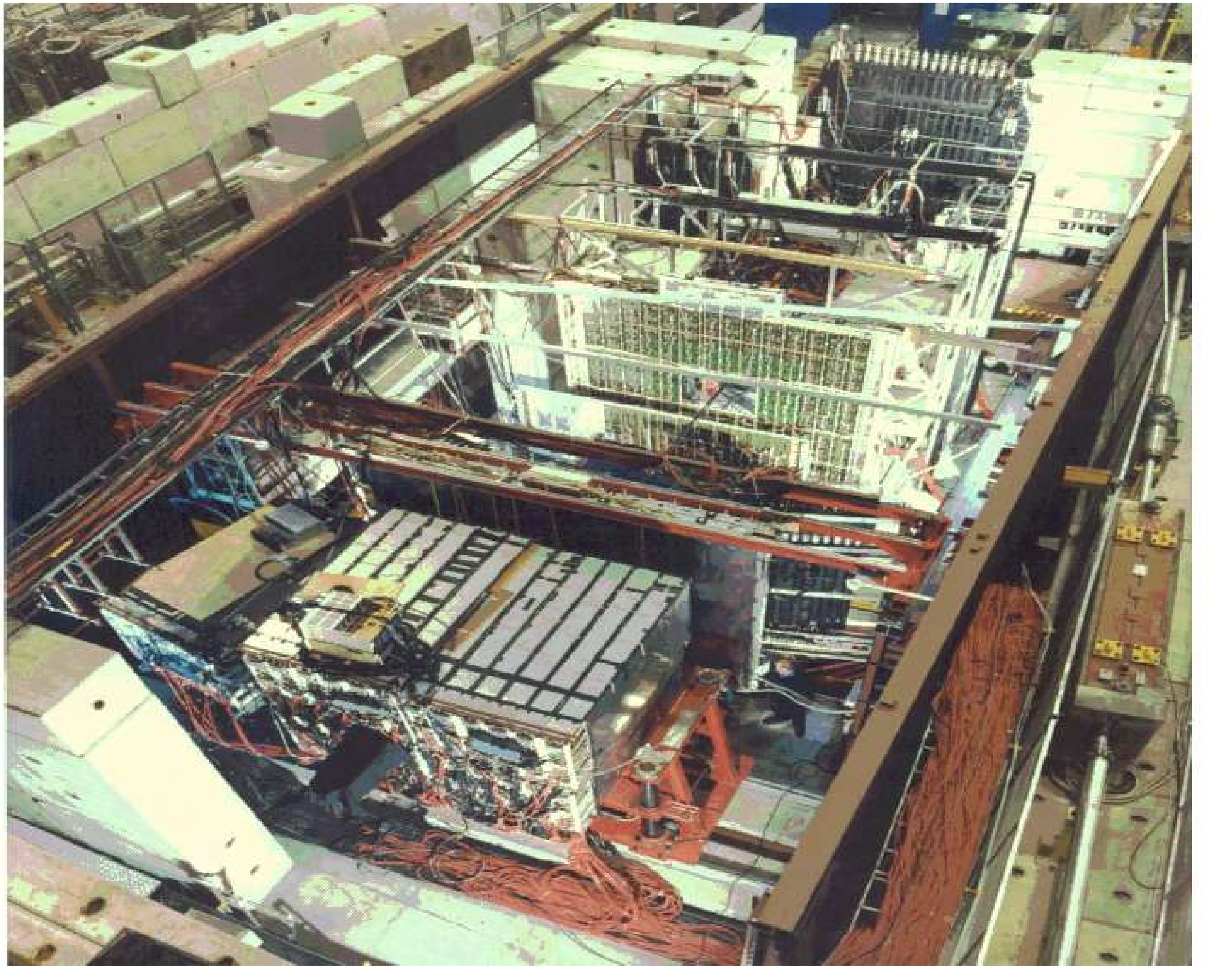


The NA35 Collaboration in 1990

WA 80/93/98 CERN SPS 1985-96



WA80 Experiment

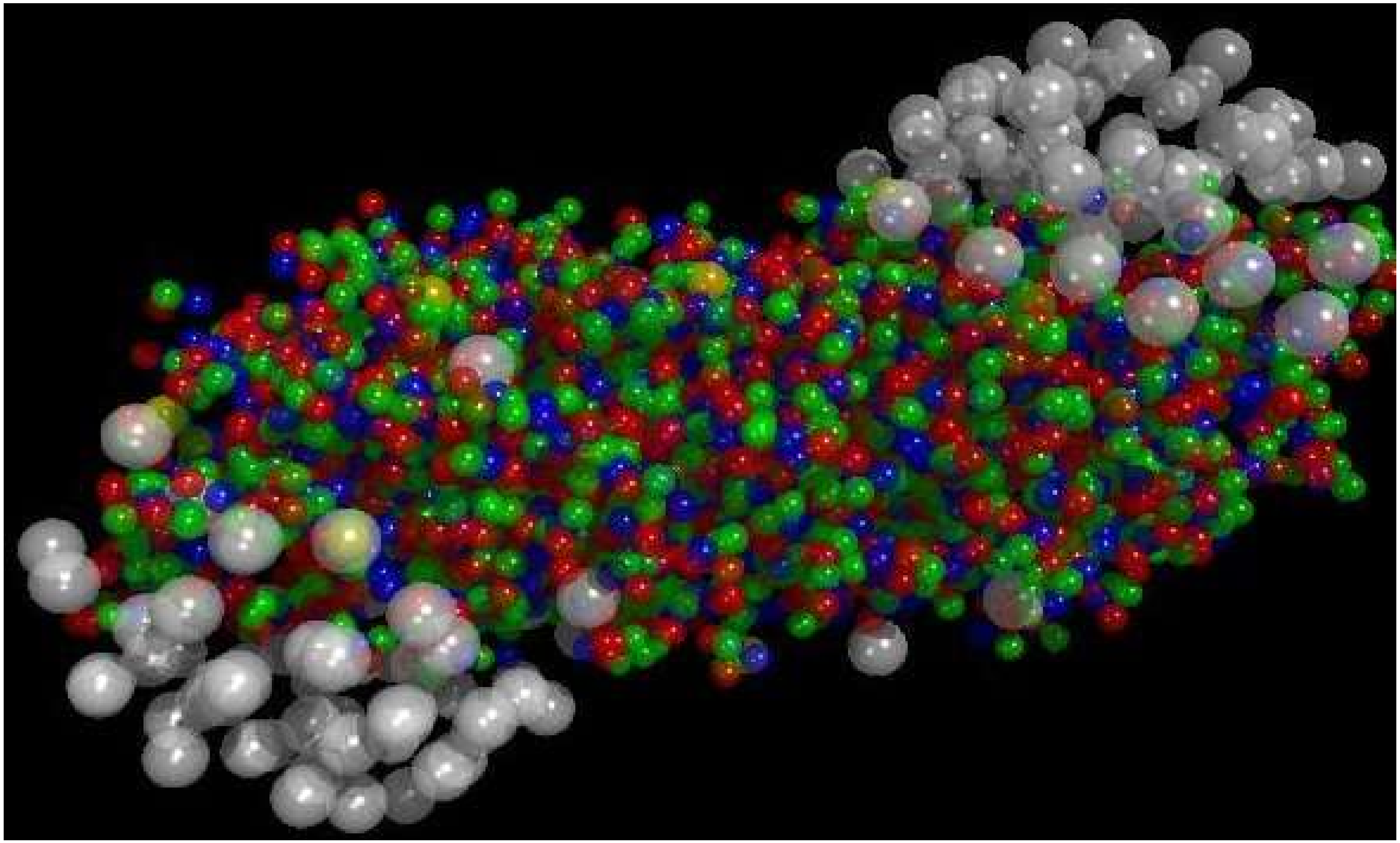


WA80

Peter Braun-Munzinger

TECHNISCHE UNIVERSITÄT DARMSTADT

Press Release Feb. 2000: New State of Matter created at CERN



At a special seminar on 10 February, spokespersons from the experiments on CERN* 's Heavy Ion programme presented compelling evidence for the existence of a new state of matter in which quarks, instead of being bound up into more complex particles such as protons and neutrons, are liberated to roam freely.

And what about RHIC?

a brief history of the RHIC project

RHIC and the decisive year 1983

- ISABELLE cancelled
- VENUS cancelled
- Quark Matter 1983 conference at Brookhaven
  Harvey Wegner and Tom Ludlam – organizers

  led to major push for new experimental initiatives

- AGS heavy ion program in the USA
- SPS heavy ion program in Europe
- first serious plans for a collider (RHIC)

The world-wide community unites to support RHIC

Our increasing understanding of the underlying structure of nuclei and of the strong interaction between hadrons has developed into a new scientific opportunity of fundamental importance – the chance to find and to explore an entirely new phase of nuclear matter. In the interaction of very energetic colliding beams of heavy atomic nuclei, extreme conditions of energy density will occur, conditions which hitherto have prevailed only in the very early instants of the creation of the universe. We expect many qualitatively new

....

community of science and on the world at large. The facility necessary to achieve this scientific breakthrough is now technically feasible and within our grasp; it is an accelerator that can provide colliding beams of very heavy nuclei and with energies of about 30 GeV per nucleon. Its cost can be estimated at this time only very roughly as about 150-200 million dollars. *It is the opinion of this Committee that such a facility should be built by the United States expeditiously, and we see it as the highest priority new scientific opportunity within the purview of our science.*

1983 US long range plan: RHIC is highest priority!

Timeline for completion of RHIC: 1990

1983 International RHIC task force:

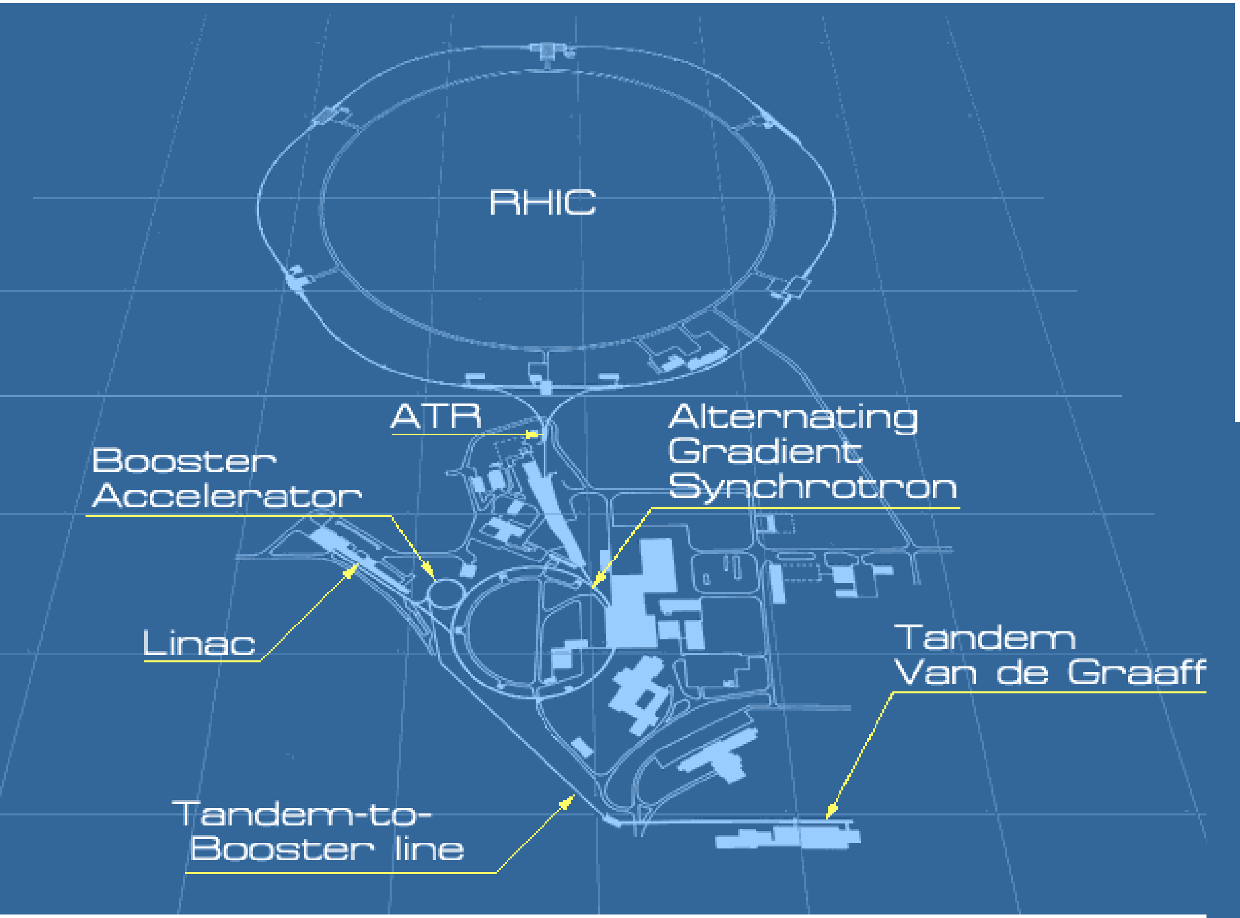
B. Baym, J. Bjorken, C.K. Gelbke, H.H. Gutbrod, A. Kerman, C. Leeman, L. Madansky, A. Mueller, I. Otterlund, A. Ruggiero, L. Schroeder, G. Young, W.I. Willis

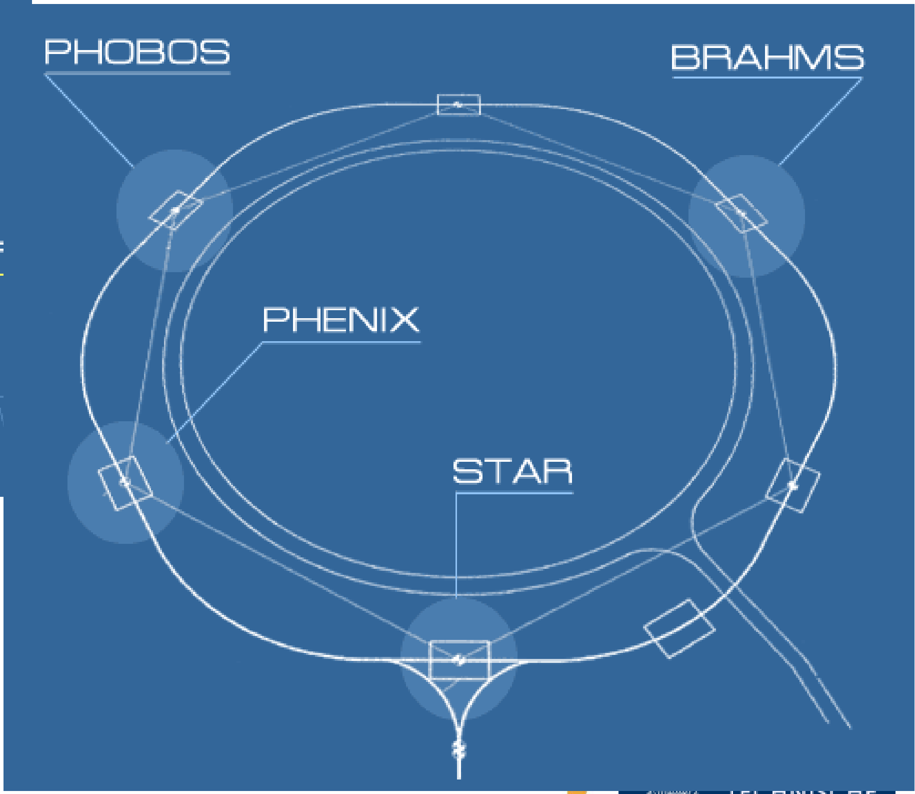
Report of Task Force for relativistic heavy ion physics, Nucl. Phys. **A418** (1984) 657c. As the plans for RHIC came more into focus, the Task Force was succeeded by an *ad hoc* panel which met in December 1983, the RHIC Technical Committee, chaired by Bill Willis, which met in April 1984, the RHIC Review Board, chaired by Allan Bromley, which met in May 1984, and eventually by the RHIC Policy Committee, chaired by Herman Feshbach, which met regularly from 1991 through 1995.

In 1995, timeline for completion of RHIC shifted to 1999
first RHIC run in 2000

RHIC Advisory Committee

heavy ion collider RHIC – dedicated machine

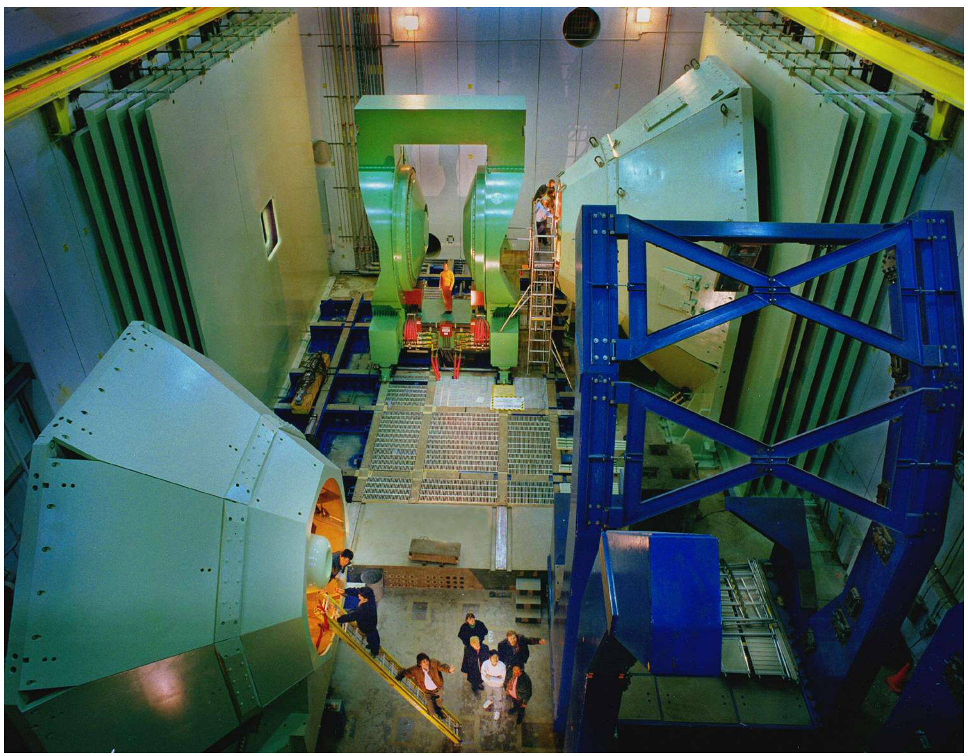




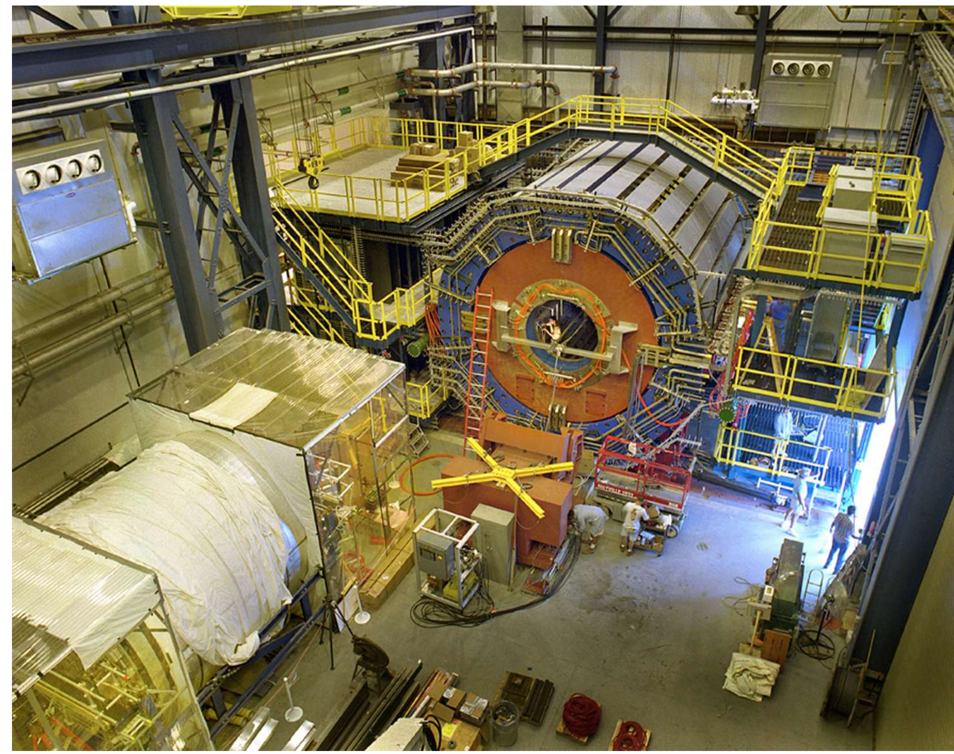
RHIC: the Relativistic Heavy Ion Collider

RHIC experiments: 2 large and 2 small

PHENIX: central 2 arm spectrometer plus forward/backward muon arms



STAR: large TPC at central rapidity

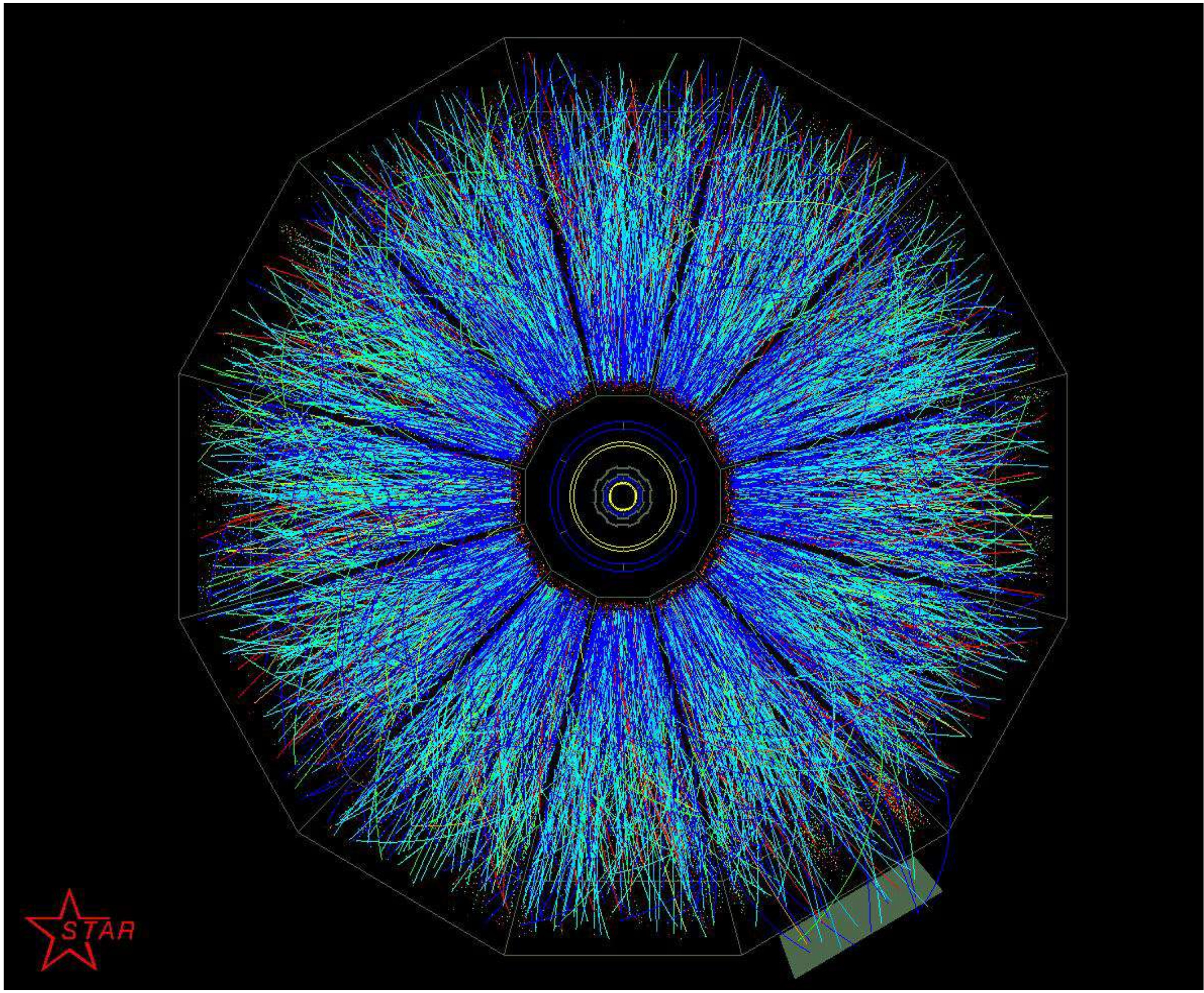


as well as PHOBOS and BRAHMS

STAR event display

in central AuAu collsions
at RHIC √s = 200 GeV
about 7500 hadrons
produced

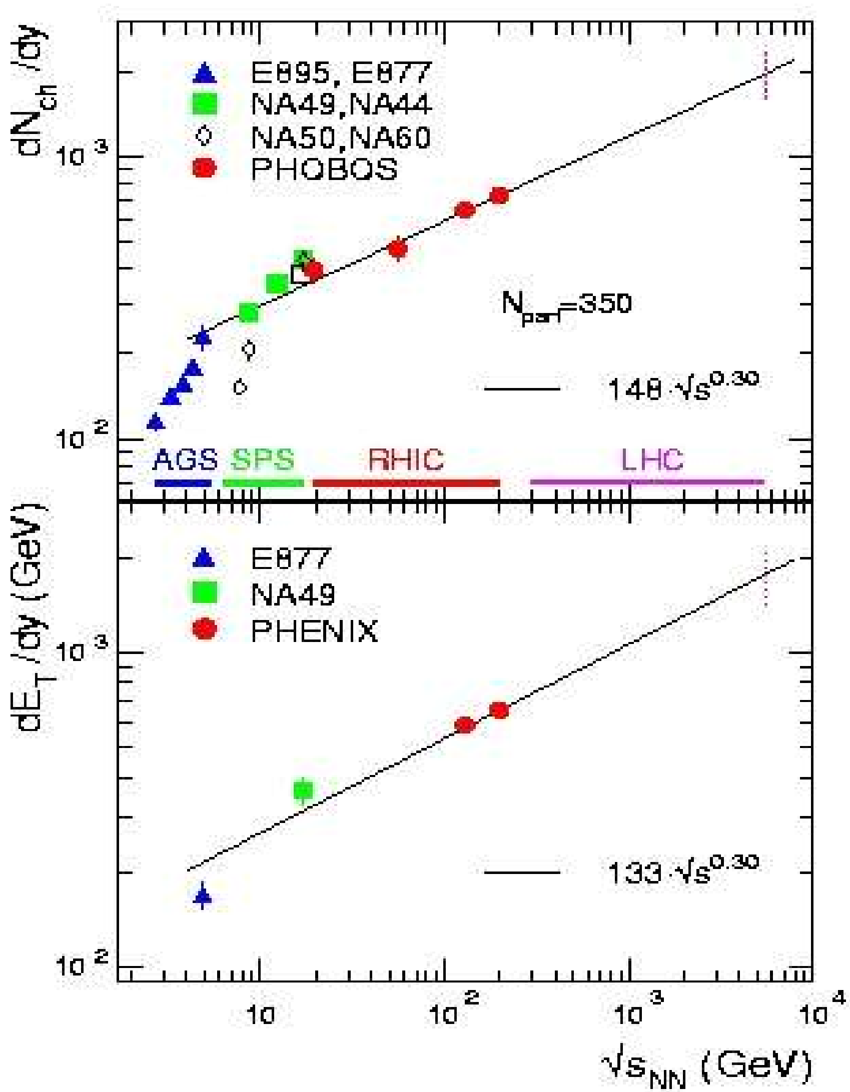
about three times as
much as at CERN SPS



Accelerators where ultra-relativistic nuclei collide

	fixed target		collider	
	AGS	SPS	RHIC	LHC
	1987-2000		since 2000	from 2008
beam momentum	29 ·Z GeV/c	450 ·Z GeV/c	ea250 ·Z GeV/c	ea7000 ·Z GeV/c
projectile	p...Au	p...Pb	p...Au	p...Pb
energy available in c.m. system	Au+Au 600 GeV	Pb+Pb 3200 GeV	Au+Au 40 TeV	Pb+Pb 1150 TeV
hadrons produced per collision	900	2400	7500	40000?

Energy dependence of global observables



Mid-rapidity data for central Au-Au collisions.

Energy density from Bjorken estimate:

$\varepsilon = dE_T/dy \; 1/(\pi R^2) 1/\tau$

$\pi R^2 = 150 \text{ fm}^2$

= 1, 0.3, 0.1 fm

SPS RHIC LHC

ε = 2.5, 14, (120) GeV/fm^3

$\varepsilon \gg \varepsilon_c$ for all energies

Impressive experimental data base

- Fixed target data from AGS (2 – 14.6 A GeV) and SPS (20 – 200 A GeV)
- Collider data from RHIC ($\sqrt{s_{nn}}$ = 20 – 200 GeV)
- At all energies, yields have been measured for (nearly) all stable or weakly decaying hadrons over a substantial part of the available phase space.

Most important physics results

- The fireball produces particles near T_c in chem. equilibrium
- Strong collective expansion flowing like a liquid is observed
- Jet suppression: the fireball is opaque to fast partons
- Low mass lepton pairs
- Anomalous charmonium production

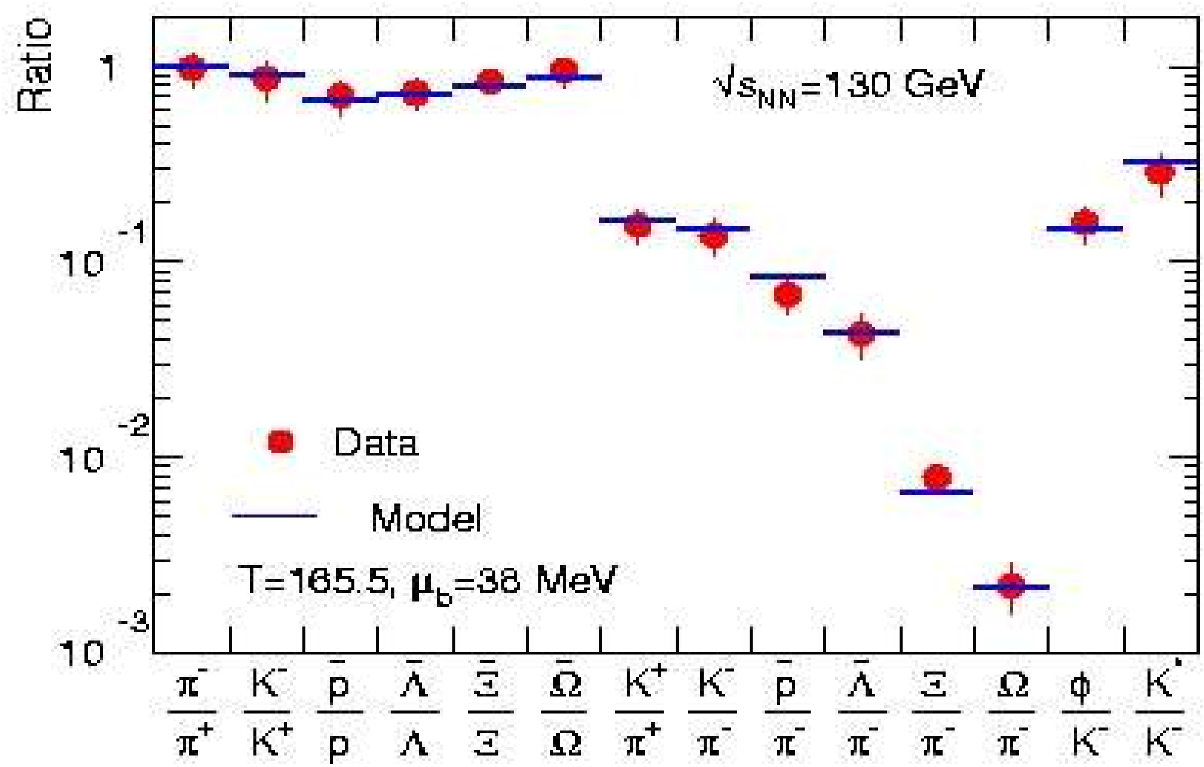
Hadro-chemistry at RHIC -- weakly decaying particles

All data in excellent agreement with thermal model predictions

chemical freeze-out at: T = 165 ± 8 MeV

fit uses vacuum masses

most recent analysis: A. Andronic, pbm, J. Stachel, nucl-th/0511071 Nucl. Phys. A772 (2006) 167



pbm, d. magestro, j. stachel, k. redlich, Phys. Lett. B518 (2001) 41; see also Xu et al., Nucl. Phys. A698(2002) 306; Becattini, J. Phys. G28 (2002) 1553; Broniowski et al., nucl-th/0212052.

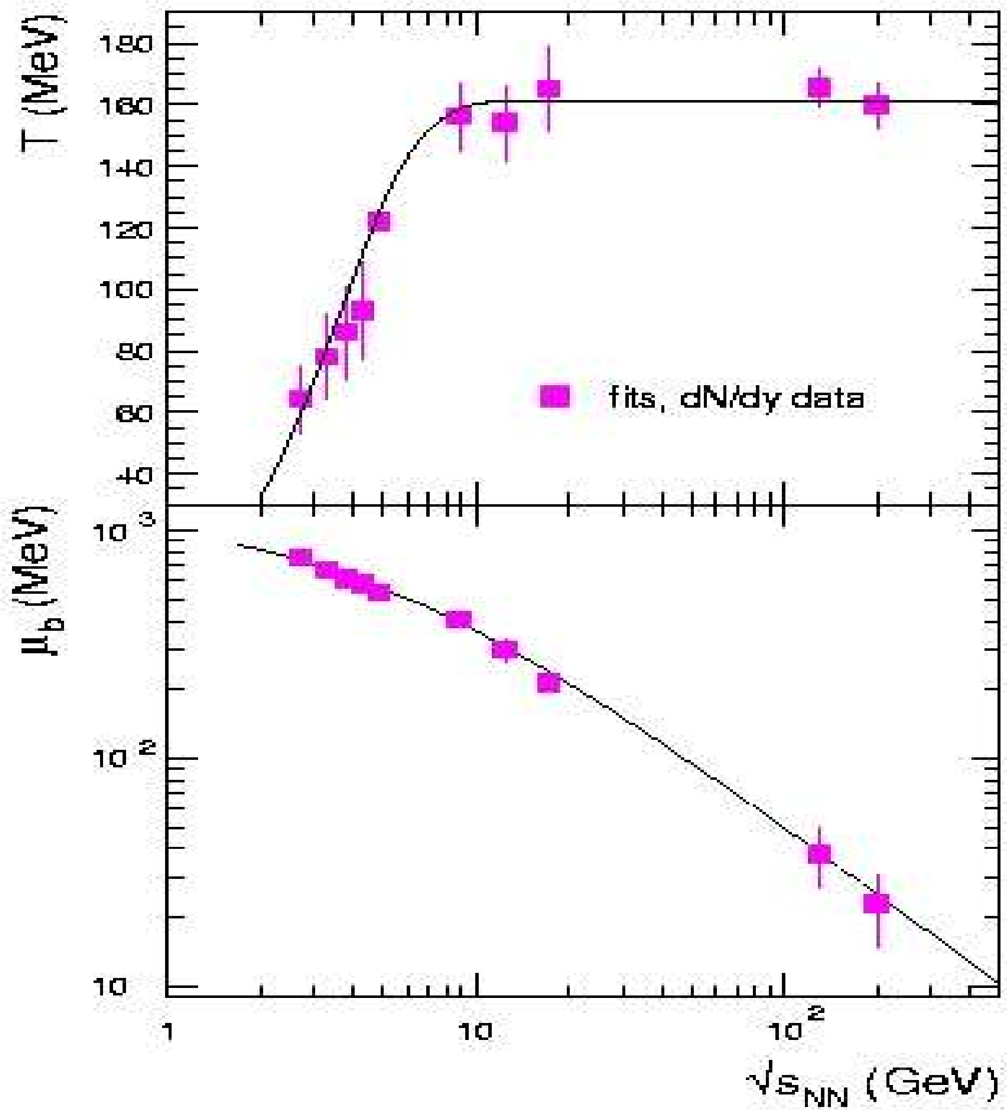
The limiting temperature is T_c

T_{lim} = 160 MeV

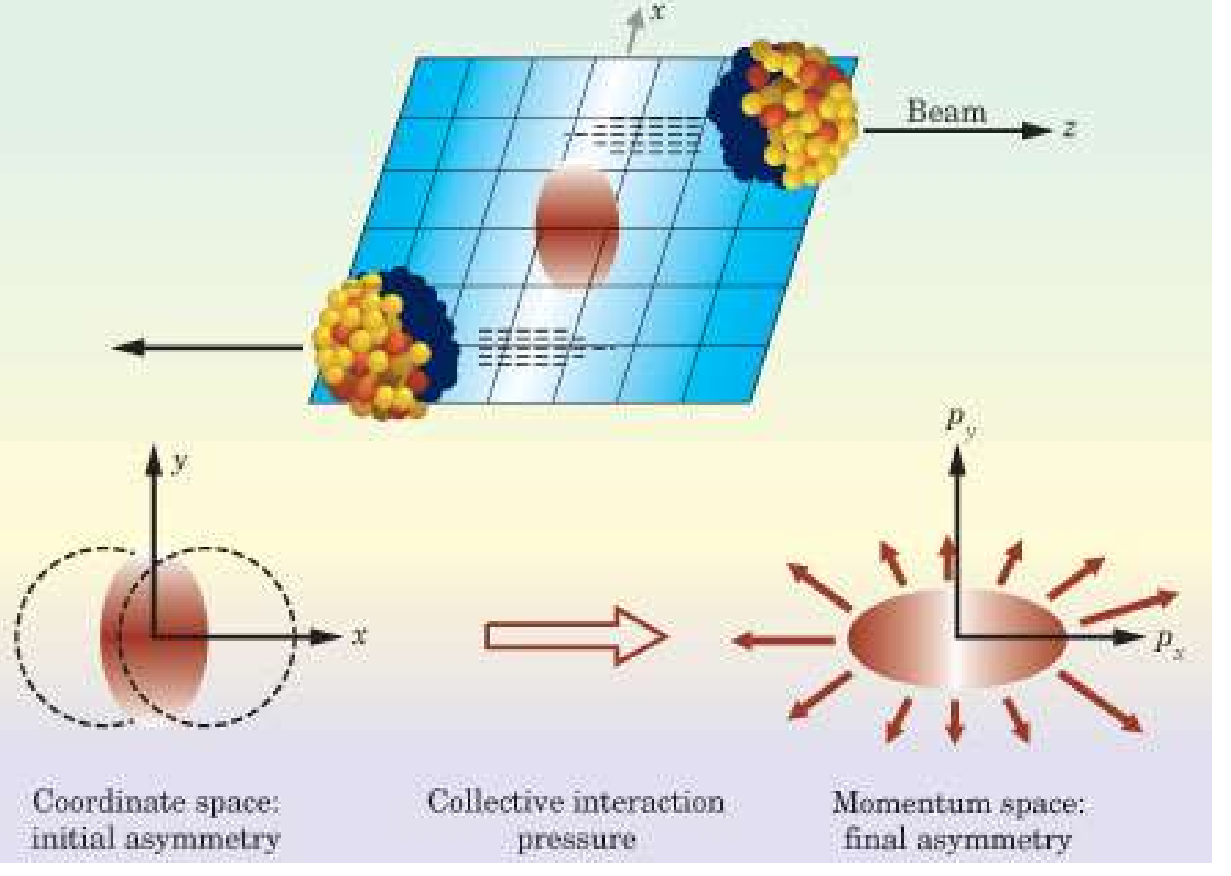
T_c = 160 (+12 -16) MeV

estimated systematic errors

A. Andronic, pbm, J. Stachel,
Nucl. Phys. A772 (2006) 167
nucl-th/0511071



Fireball Flow and the Azimuthal Anisotropy Parameter v_2

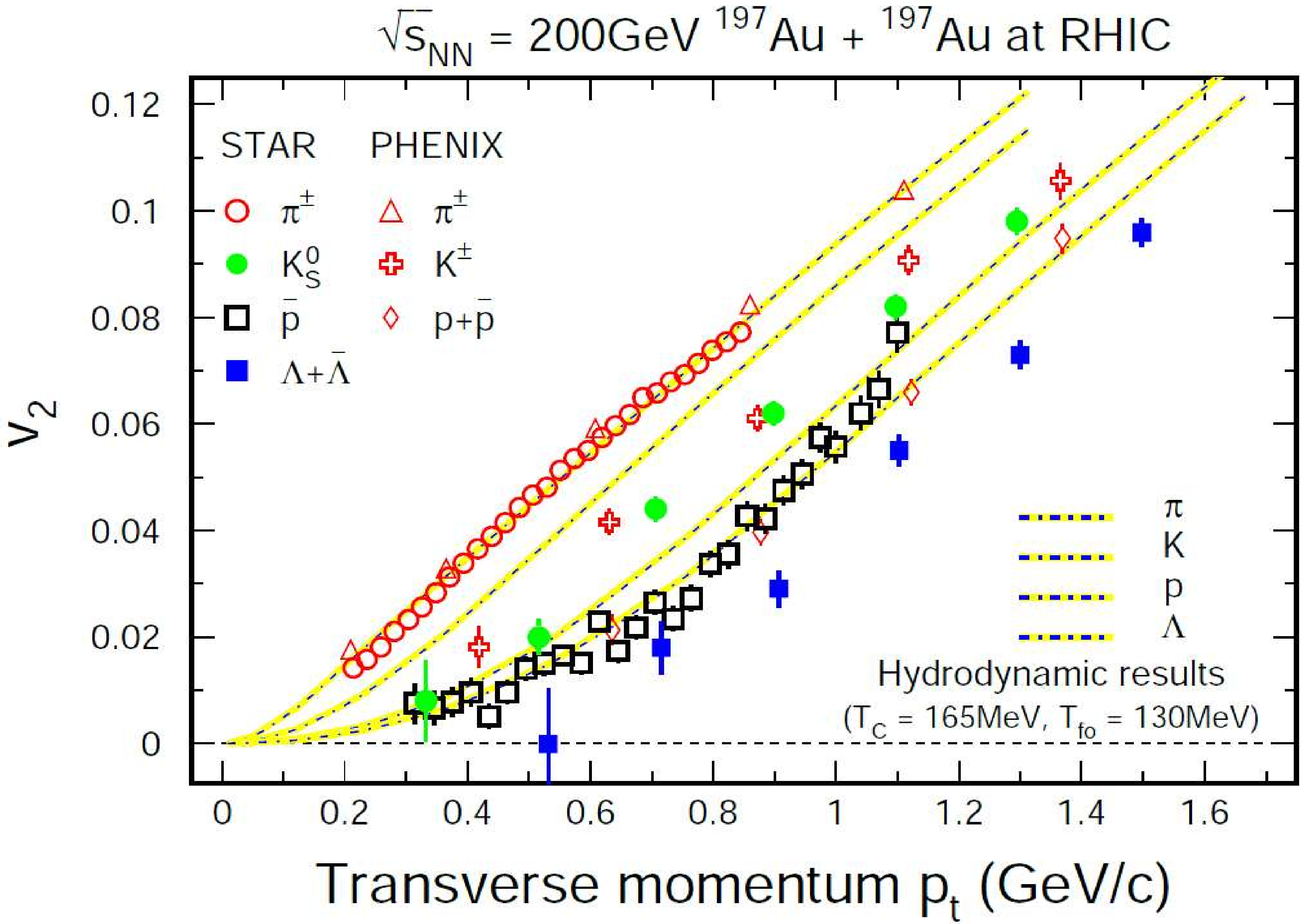


Fourier decomposition of momentum distributions rel. to reaction plane:

$$\frac{dN}{dp_t\, dy\, d\phi} = N_0 \cdot \left[1 + \sum_{i=1} 2 v_i \left(y, p_t \right) \cos\left(i \phi \right) \right]$$

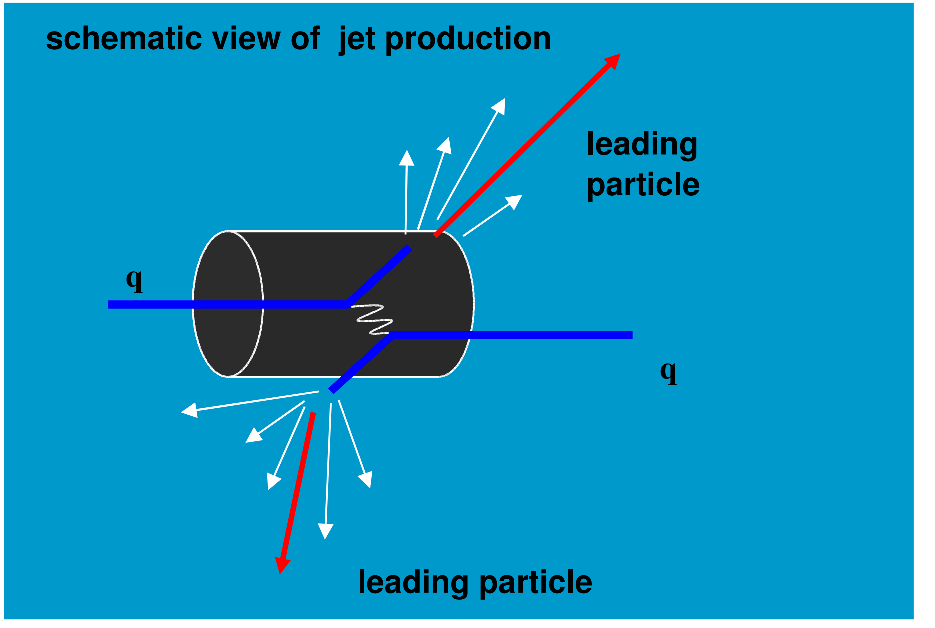
quadrupole component v_2
"elliptic flow"

the fireball flows like an ideal fluid



Jet quenching

- Hard parton scattering observed via leading particles
- Expect strong $\Delta\phi=\pi$ azimuthal correlations



However, the scattered partons may loose energy (~ several GeV/fm) in the colored medium

$\longrightarrow$ momentum reduction (fewer high p_T particles in jet)

$\longrightarrow$ no jet partner on other side

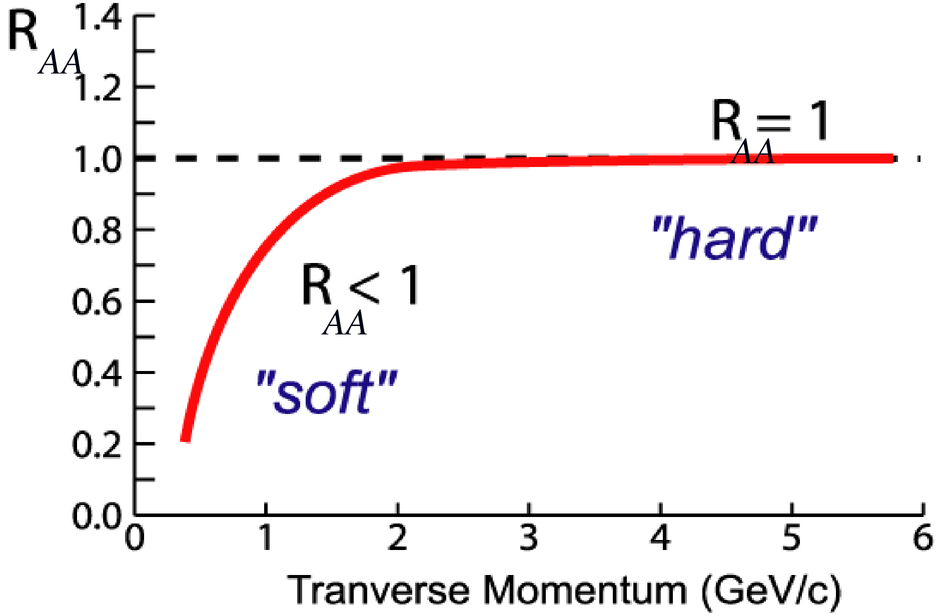
Jet Quenching

Definition of R_{AA}

R_{AA} = medium/vacuum

$$R_{AA}(p_T) = \frac{d^2N^{AA}/dp_T d\eta}{T_{AA} d^2\sigma^{NN}/dp_T d\eta}$$

$\langle N_{binary} \rangle / \sigma_{inel}^{p+p}$



no medium effects:

$R_{AA} < 1$ in regime of soft physics

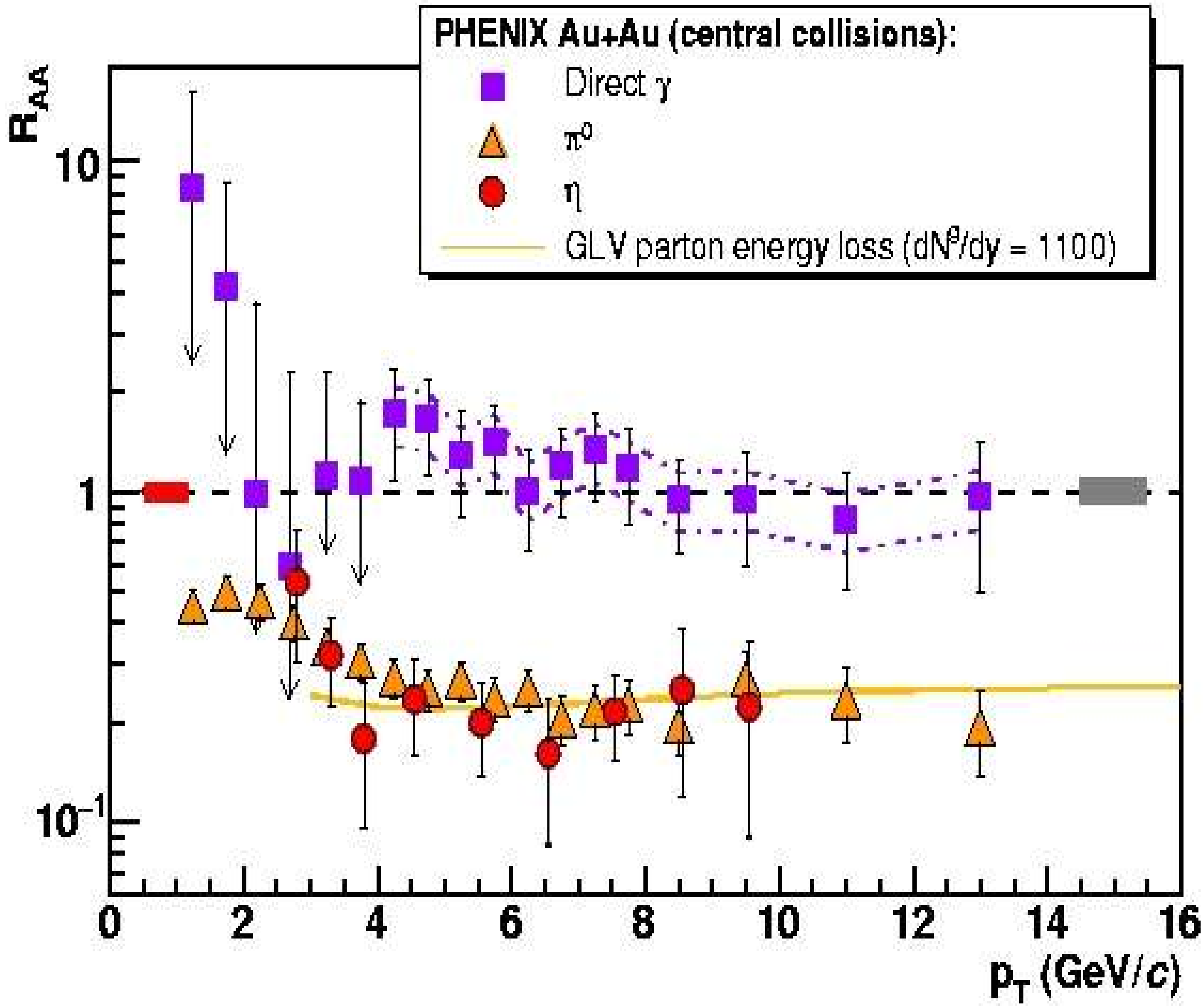
$R_{AA} = 1$ at high-p_T where hard scattering dominates

Suppression:

$R_{AA} \ll 1$ at high-p_T

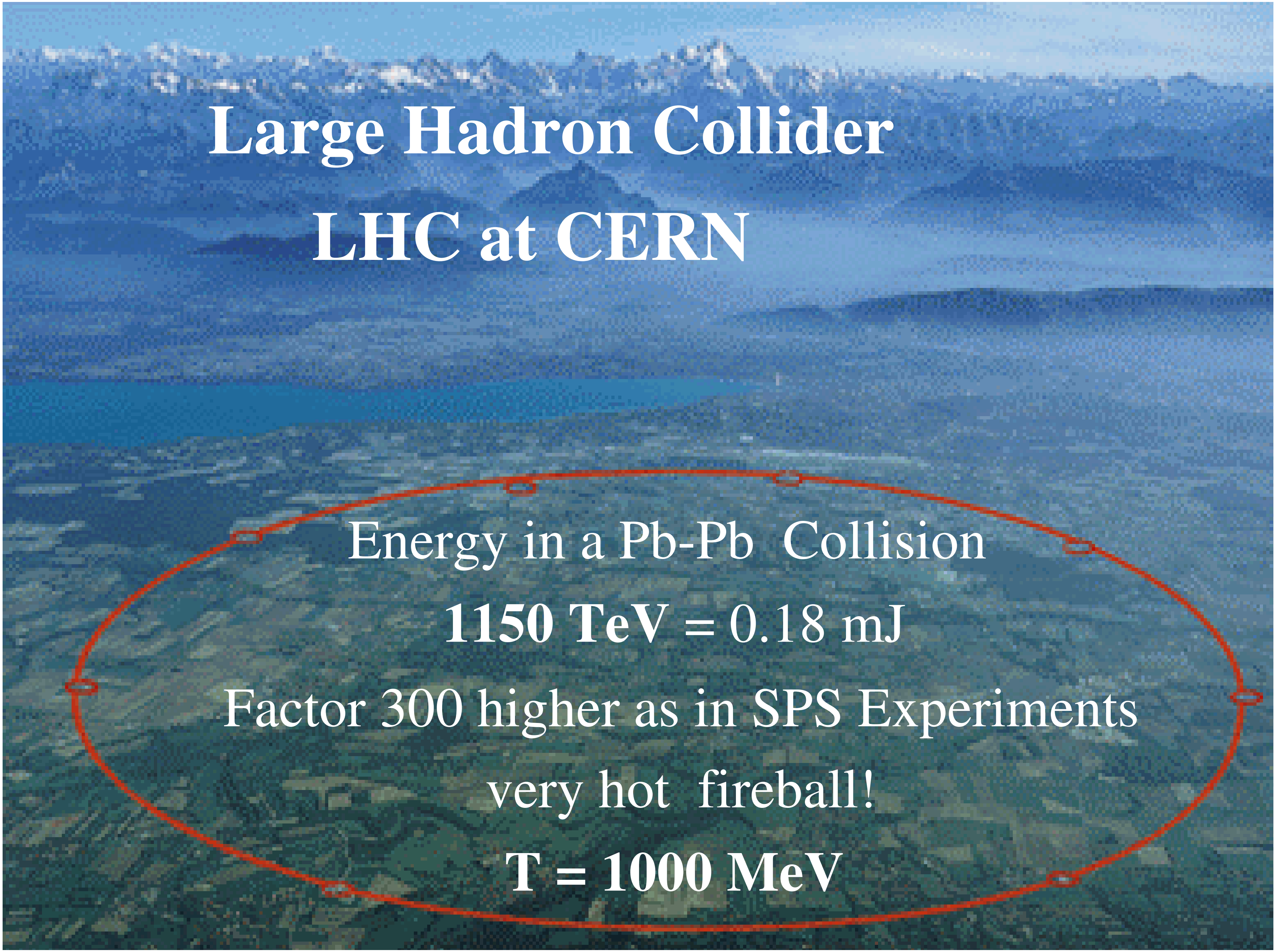
the fireball is opaque to fast partons

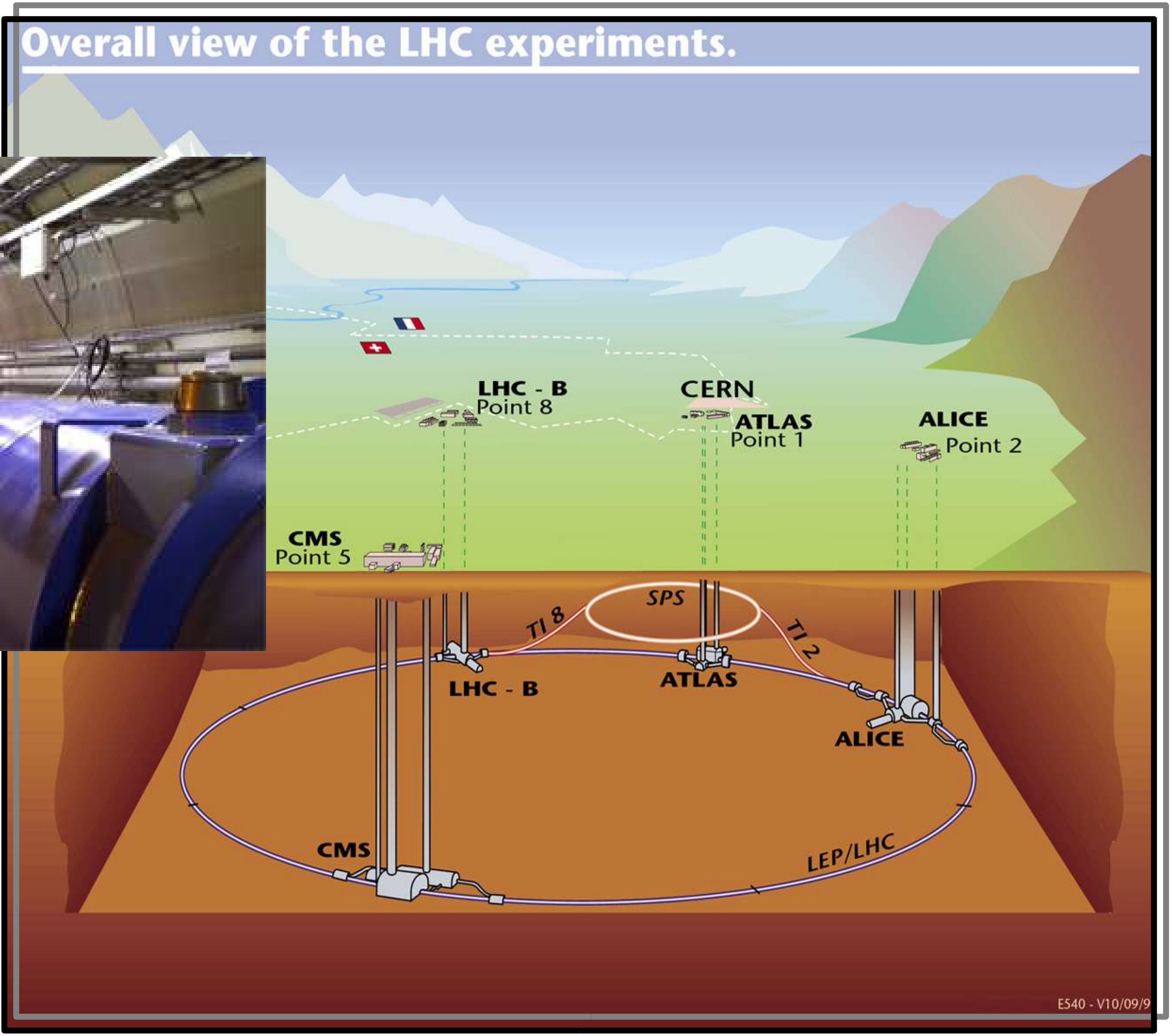
R_{AA} = medium/vacuum



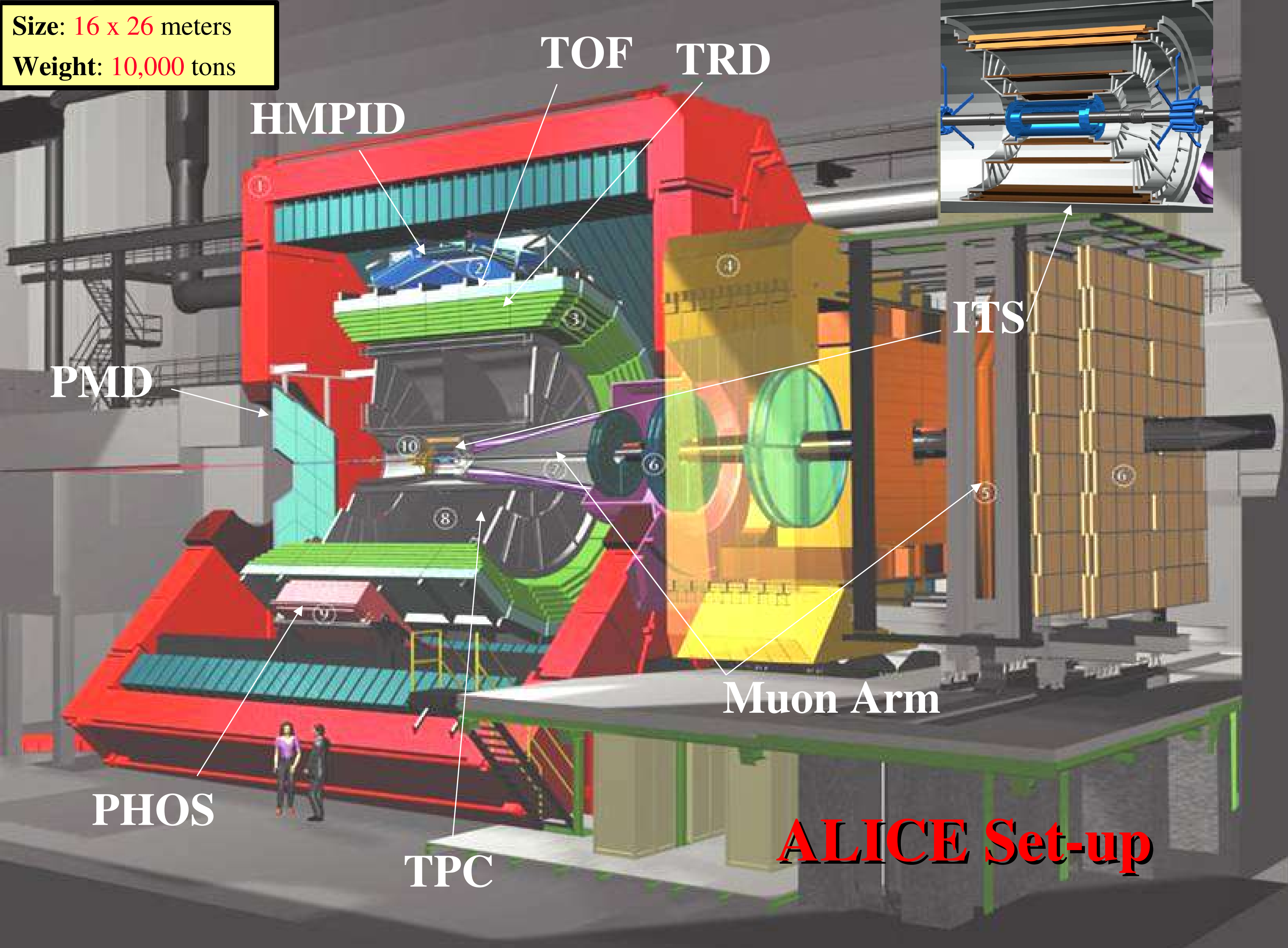
The future: ALICE at LHC : start April 2008

CBM at FAIR : start 2015 ?


Large Hadron Collider
LHC at CERN
Energy in a Pb-Pb Collision
1150 TeV = 0.18 mJ
Factor 300 higher as in SPS Experiments
very hot fireball!
T = 1000 MeV



all 1700 magnets installed



Size: 16 x 26 meters
Weight: 10,000 tons
TOF
TRD
HMPID
PMD
ITS
Muon Arm
PHOS
TPC
ALICE Set-up

The charm and challenge of modern detectors: a fisheye's view into the ALICE TPC

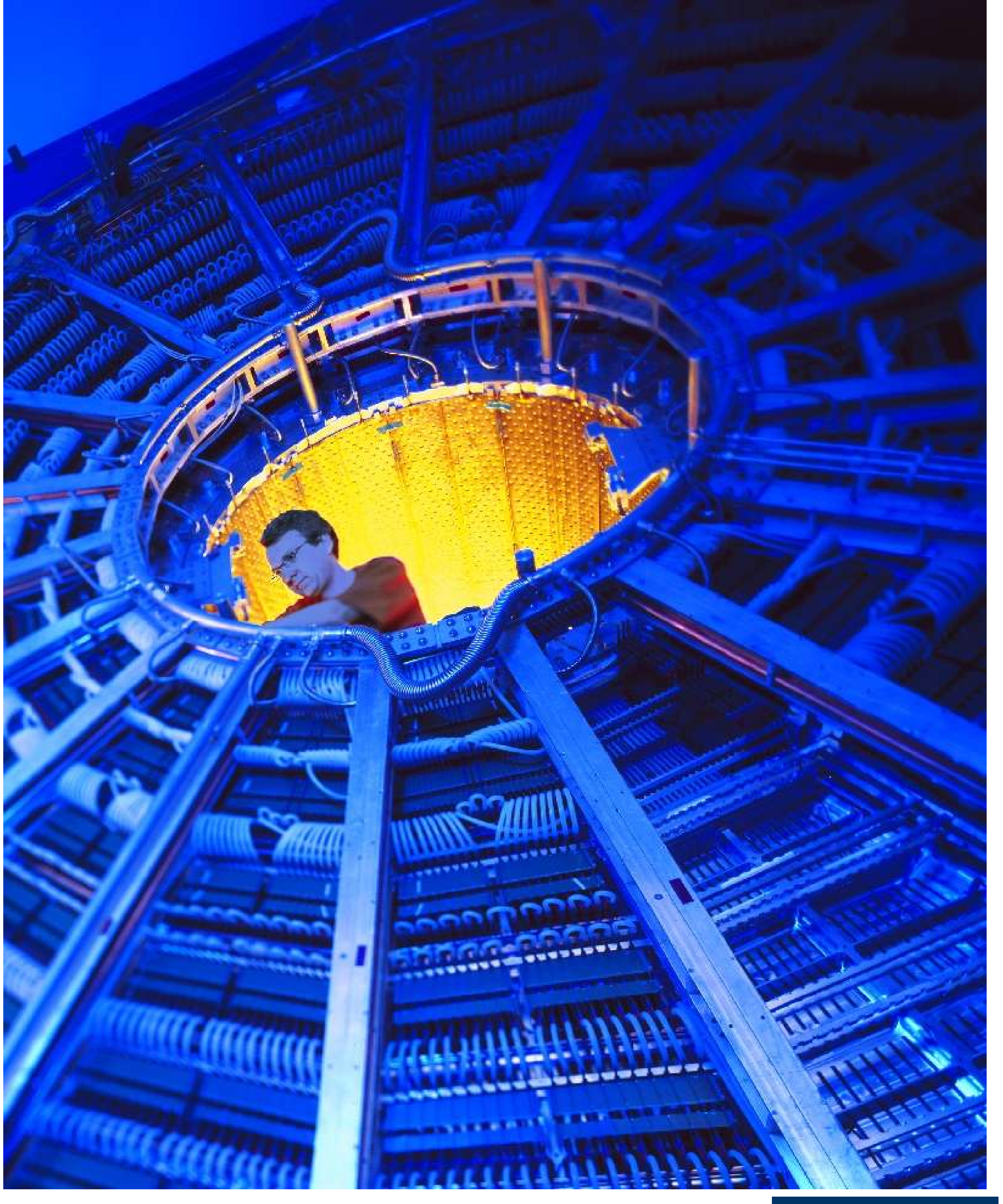
bmb+f - Förderschwerpunkt

ALICE

Großgeräte der physikalischen Grundlagenforschung

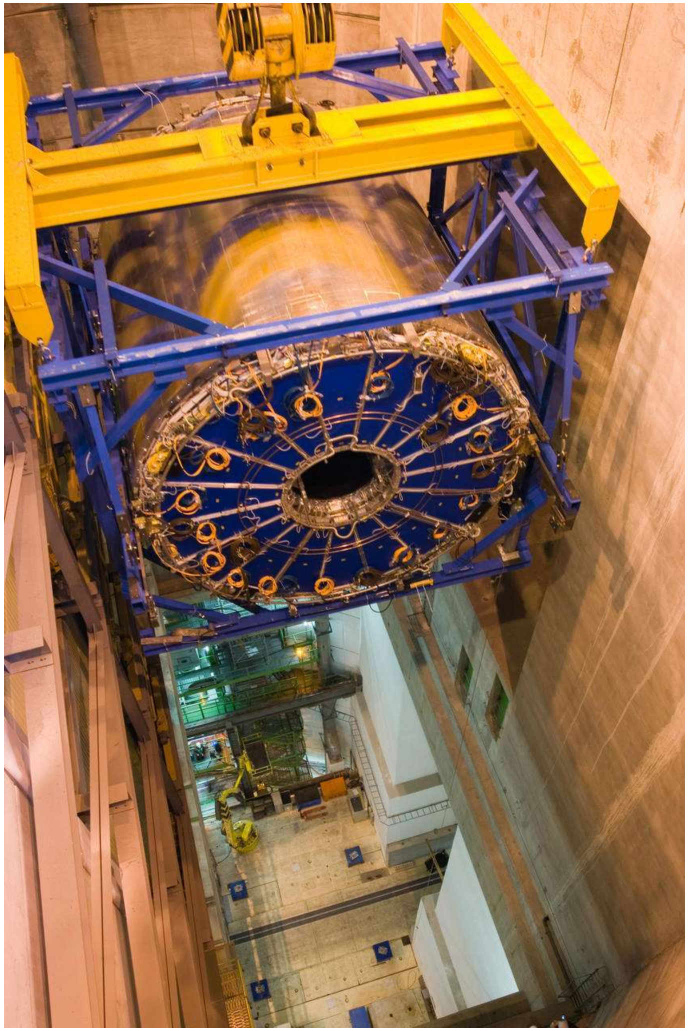
ALICE@LHC

the ALICE TPC has been installed in the experiment,

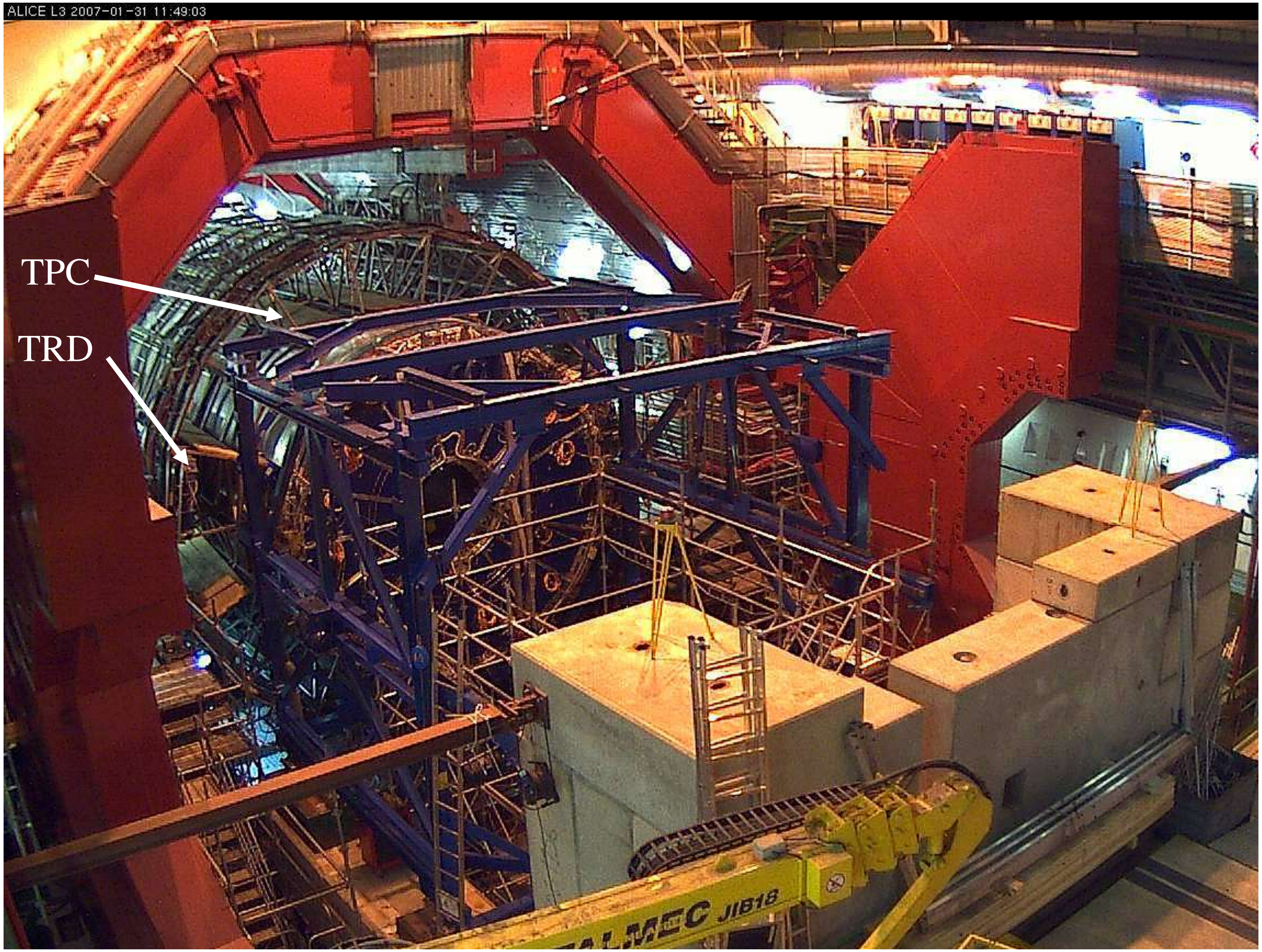


TPC::Transport

transport of TPC on from assembly hall to
underground location



TPC::Parking Position



The ALICE Experiment

Transition Radiation Detector (TRD)

Purpose:

Electron-ID & trigger

Quarkonia $\rightarrow e^+e^-$
Heavy flavour

Some numbers:

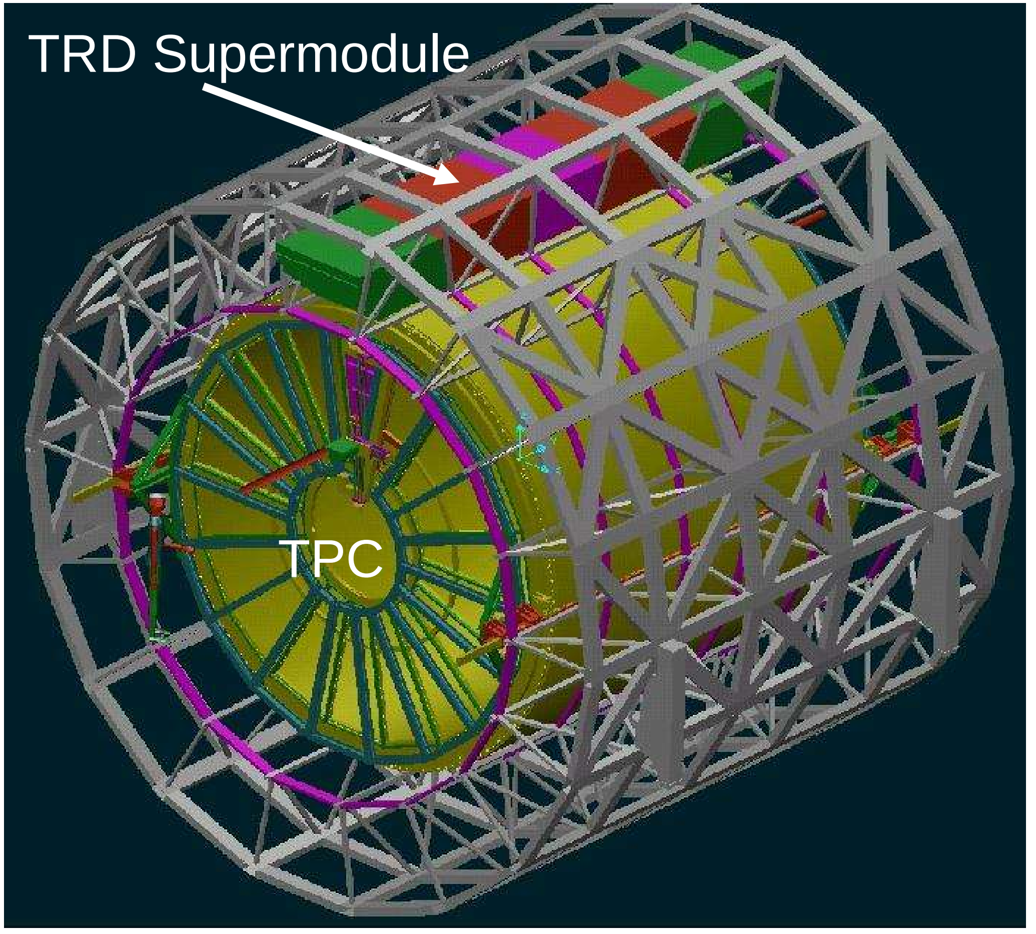
540 chambers

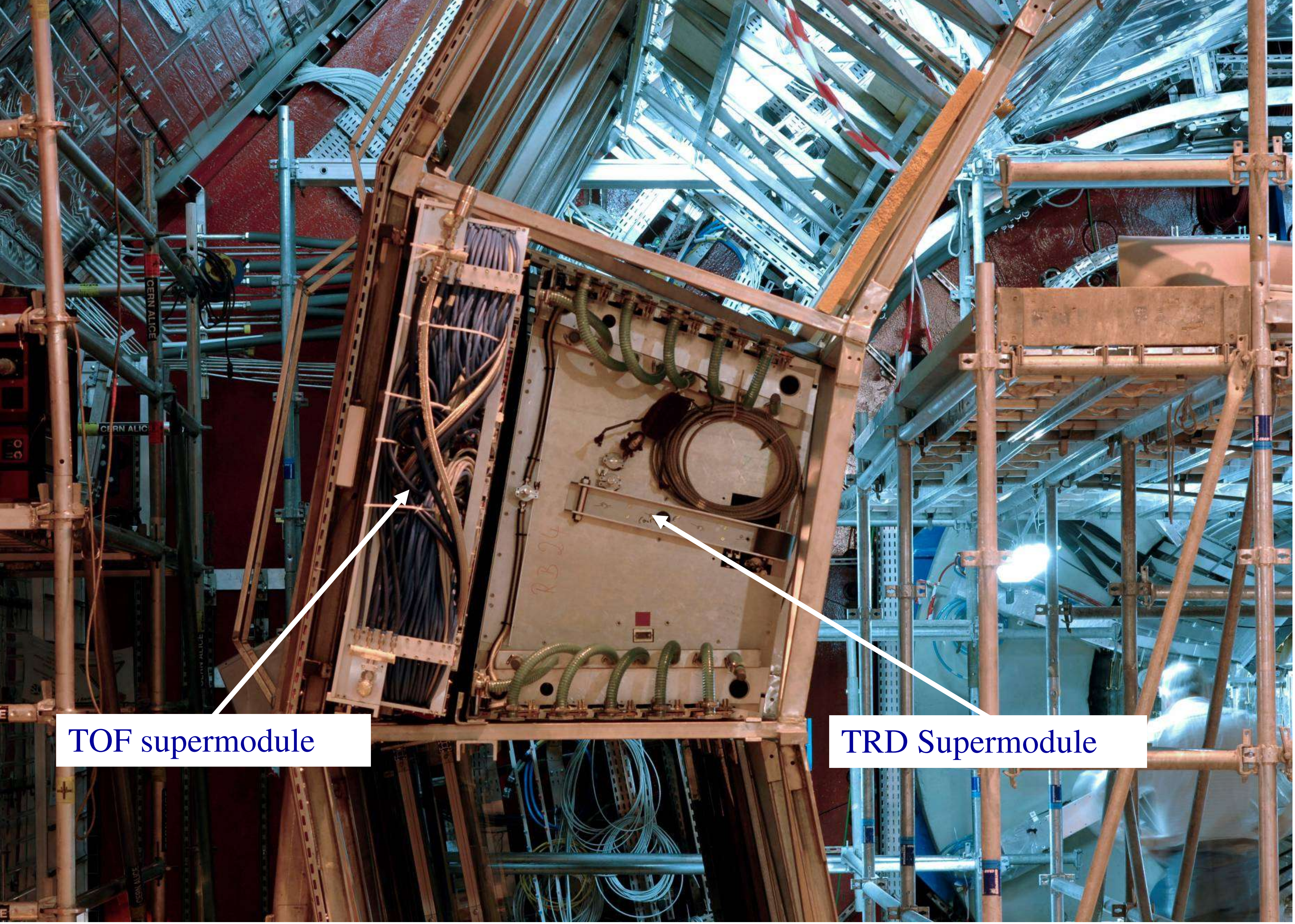
Total area: 736 m^2
(3 tennis courts)

Gas volume: 27.2 m^3

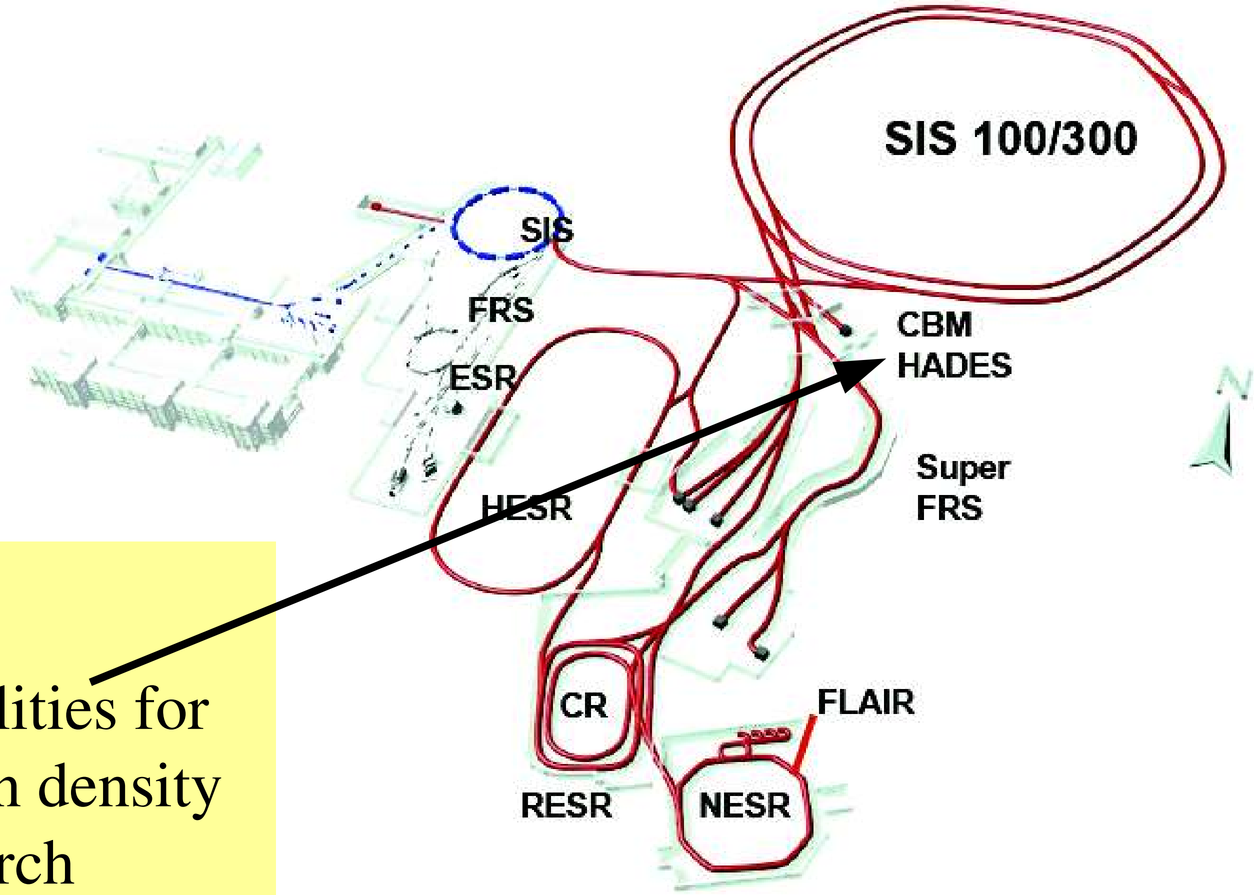
Resolution
($r\varphi$) 400 μm

Number of read out channels: 1.2×10^6




TOF supermodule
TRD Supermodule

The FAIR Project in 2007



future facilities for high baryon density research

The CBM experiment

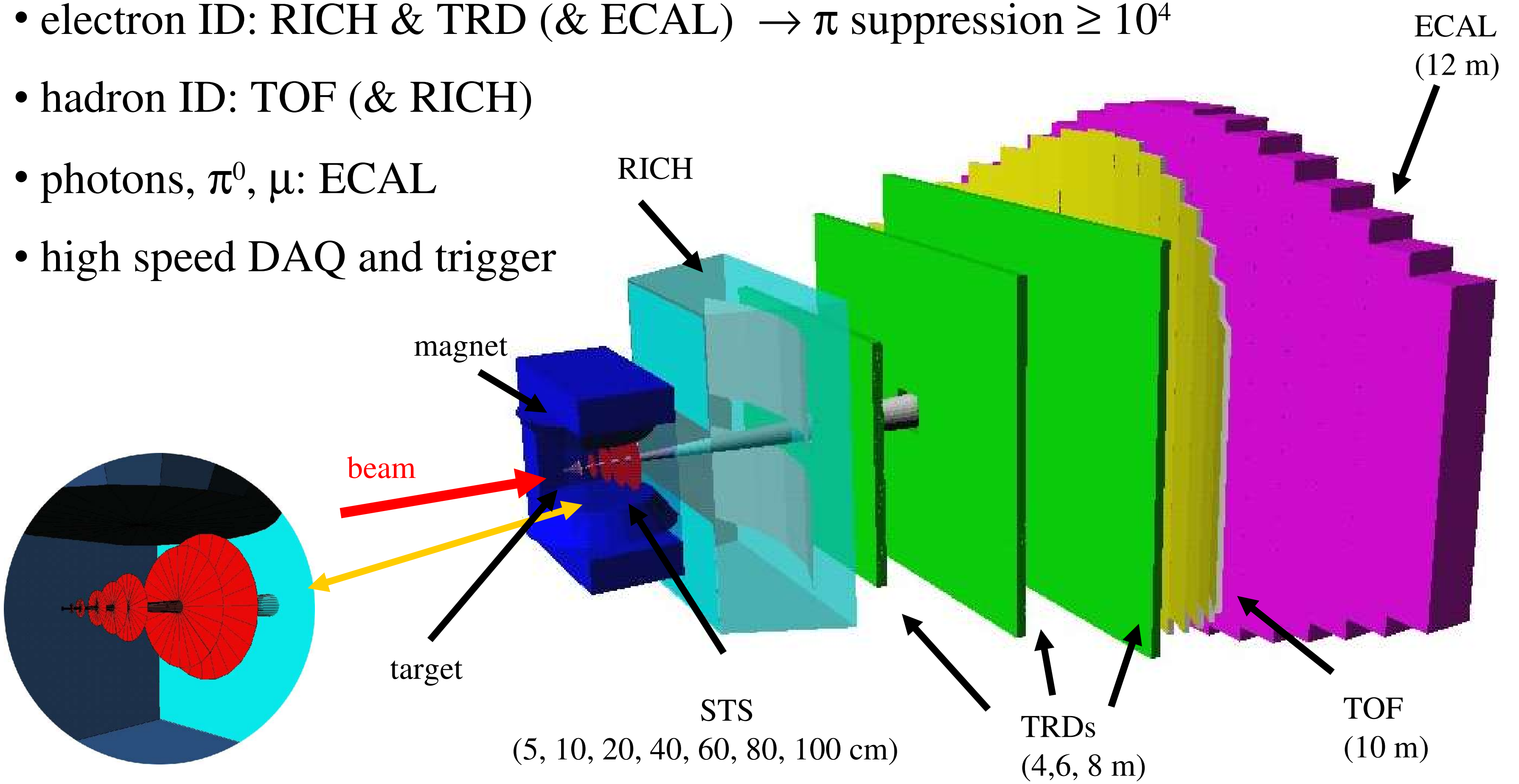
• tracking, momentum determination, vertex reconstruction: radiation hard silicon pixel/strip detectors (STS) in a magnetic dipole field

• electron ID: RICH & TRD (& ECAL) $\rightarrow \pi$ suppression $\geq 10^4$

• hadron ID: TOF (& RICH)

• photons, π^0, μ: ECAL

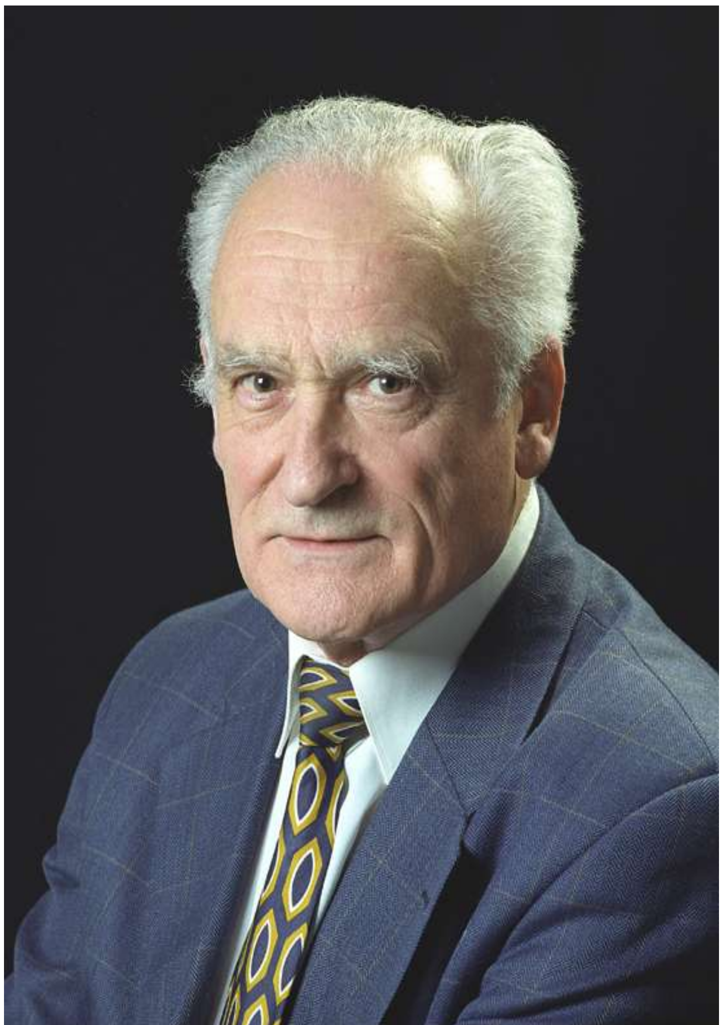
• high speed DAQ and trigger



pushing the frontier at high intensities

Epilogue:

the important results of the past 15 years were made possible by far-sighted developments and decisions in the years 1970 – 1995. Rudolf Bock had a major and for some programs decisive part in them.



Thank you and Happy Birthday