Heavy Ion Physics and Experiments at FAIR@GSI

Peter Braun-Munzinger

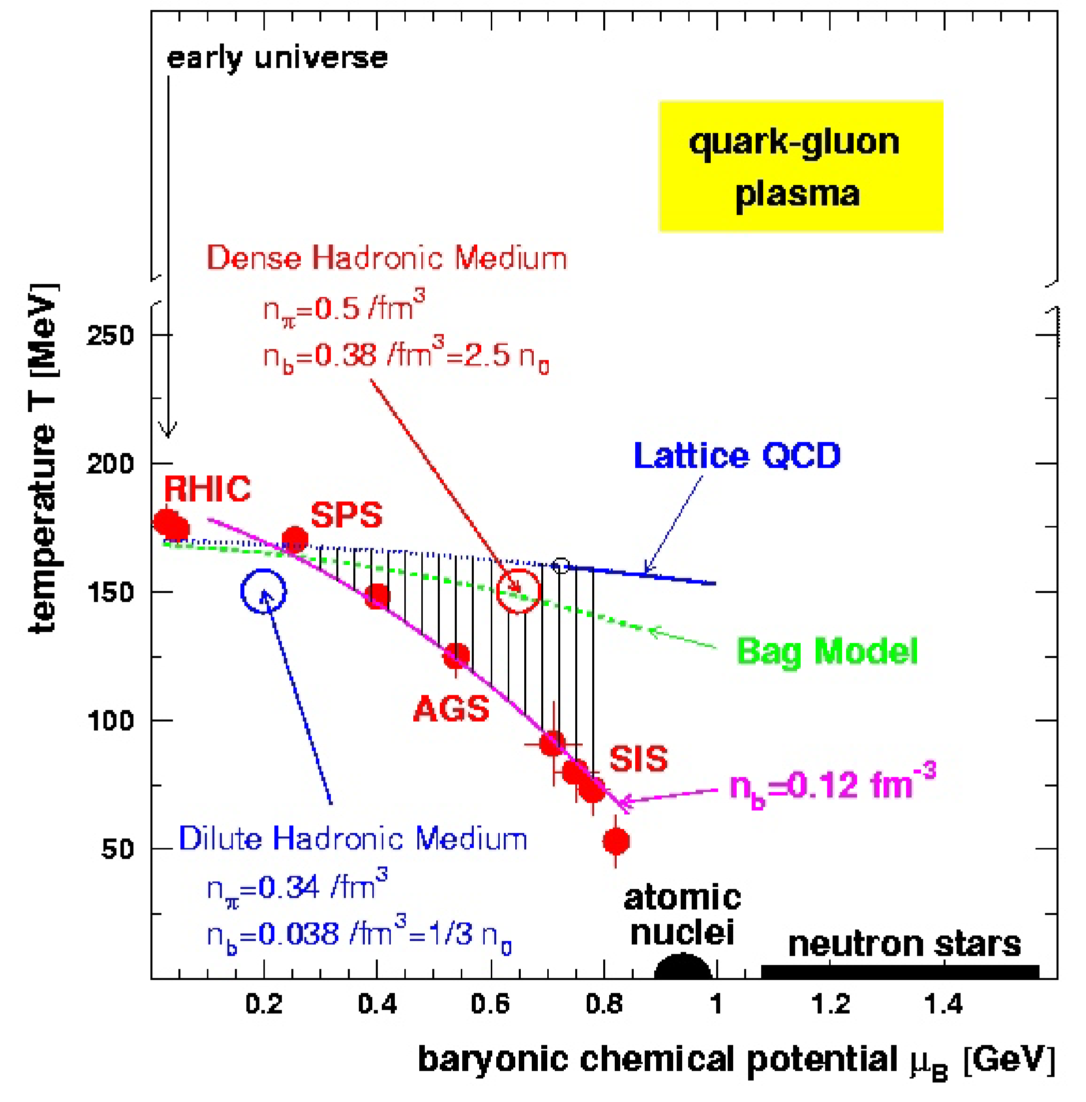
NSAC Subcommittee Meeting on
Heavy Ion Physics
June 2 – 6, 2004
BNL

Outline

- Some further thoughts on physics
- The FAIR project and relativistic nucleus-nucleus collisions
- The CBM experiment: the high intensity frontier in heavy ion physics

The QCD Phase Diagram and Chemical Freeze-out Points

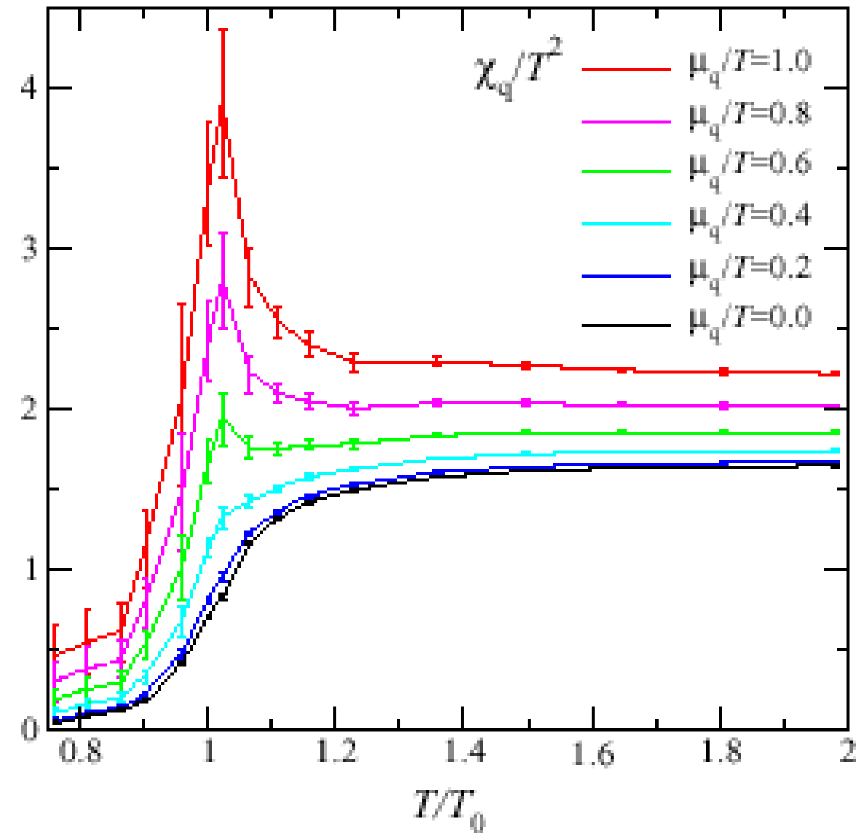
- At SPS and RHIC: freeze-out very near phase boundary via multiple hadron-hadron collisions (pbm, stachel, wetterich, nucl-th/0311005, Phys. Lett. B(in print)
- Critical Point: somewhere between $0 < \mu_B < 700$ MeV
- Where is the phase boundary for large chemical potential ?



P. Braun-Munzinger, J. Stachel, J. Phys. G. 28 (2002) 1971

Baryon Number Susceptibility

C. R. Allton et al, hep-lat 0305007

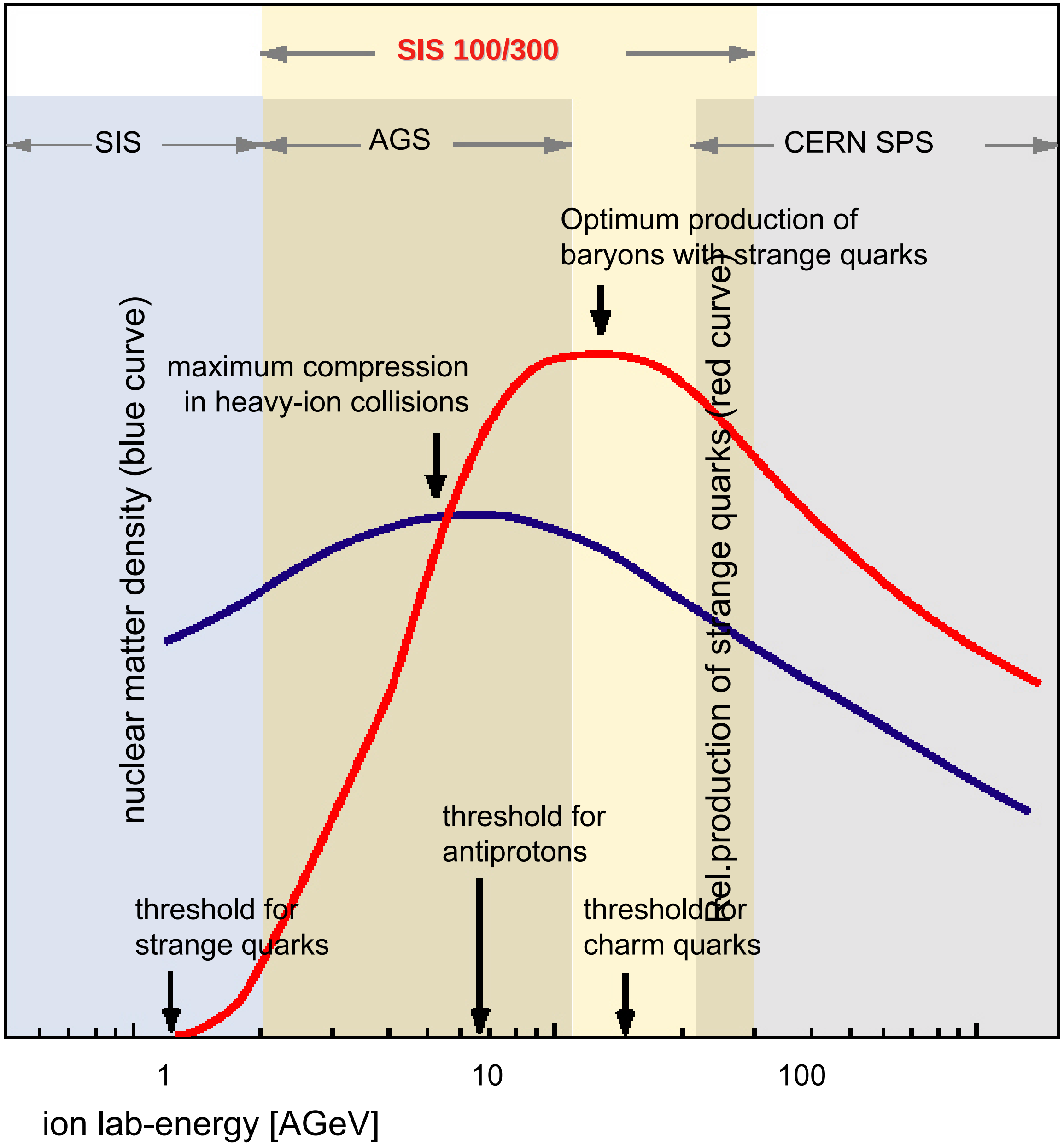


Lattice QCD :

maximal baryon number density fluctuations at T_C for μq=Tc

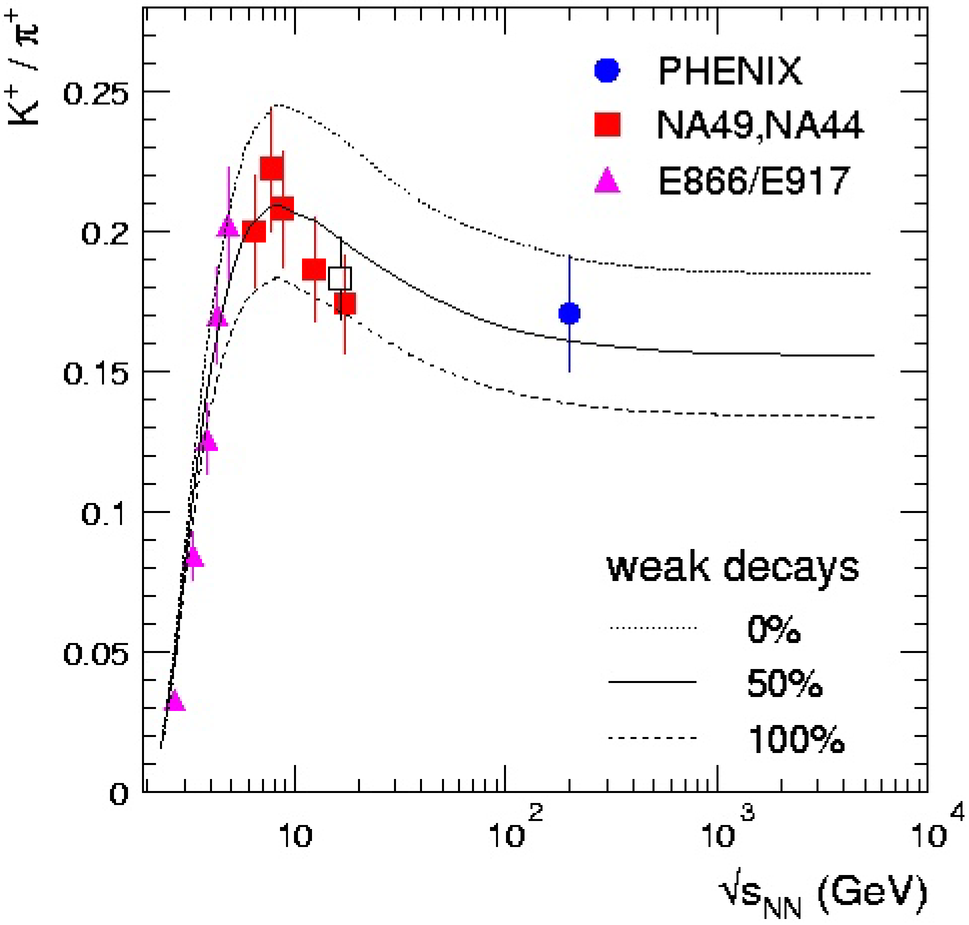
(μ_B = 480 MeV)

Further motivation for AA collisions at 2-40



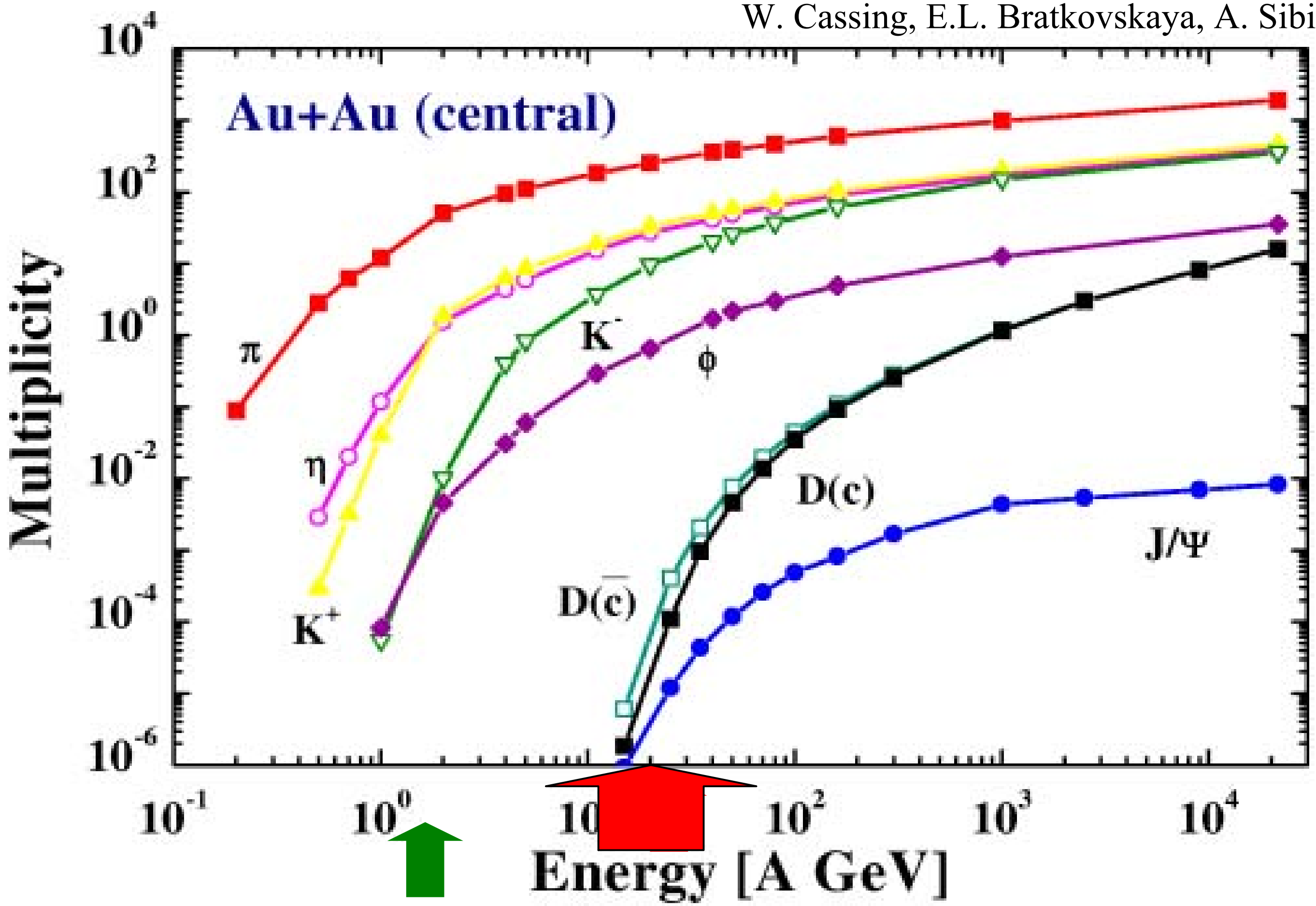
Energy Dependence of Strangeness Production

- Strangeness maximum near 30 A GeV.
- Trend reproduced well by evolution of T and m.
- Anomalous sharp structure?
- Need independent confirmation.



Meson production in central Au+Au collisions

W. Cassing, E.L. Bratkovskaya, A. Sibirtsev



Theory

SIS300

Charm production near threshold may probe the D-meson mass change in the baryon-rich fireball

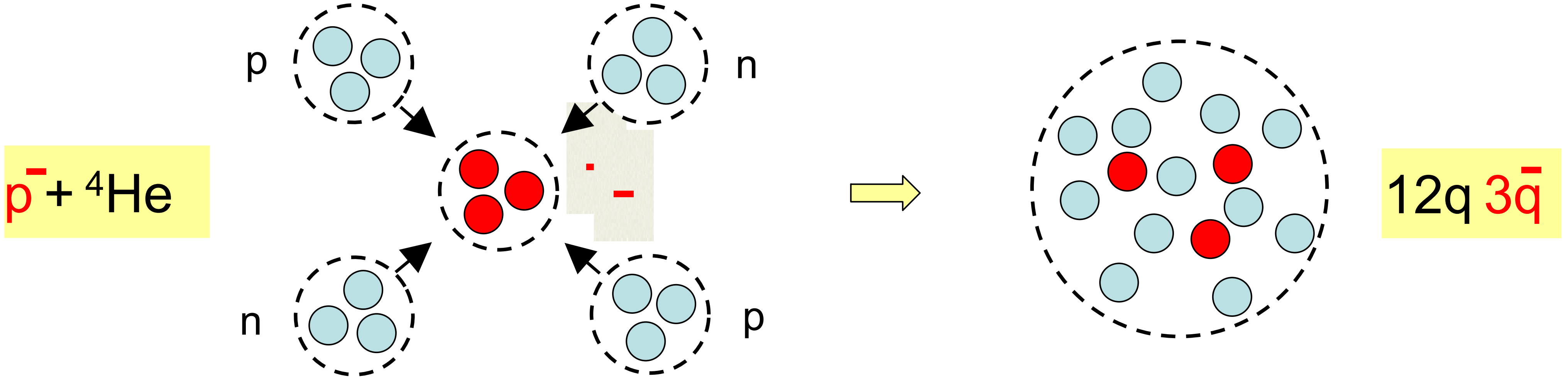
Multi-quark-antiquark clusters

I.N.Mishustin et al.

An antibaryon (n_bar, anti-lambda) acts as a strong attractor for surrounding Nucleons forcing them move towards the center

High density cloud containing b_bar and few nucleons is in fact a relatively cold peace of quark-gluon plasma

E.g. the whole ^{4}He nucleus could be transformed into deconfined phase by a deeply bound p_bar

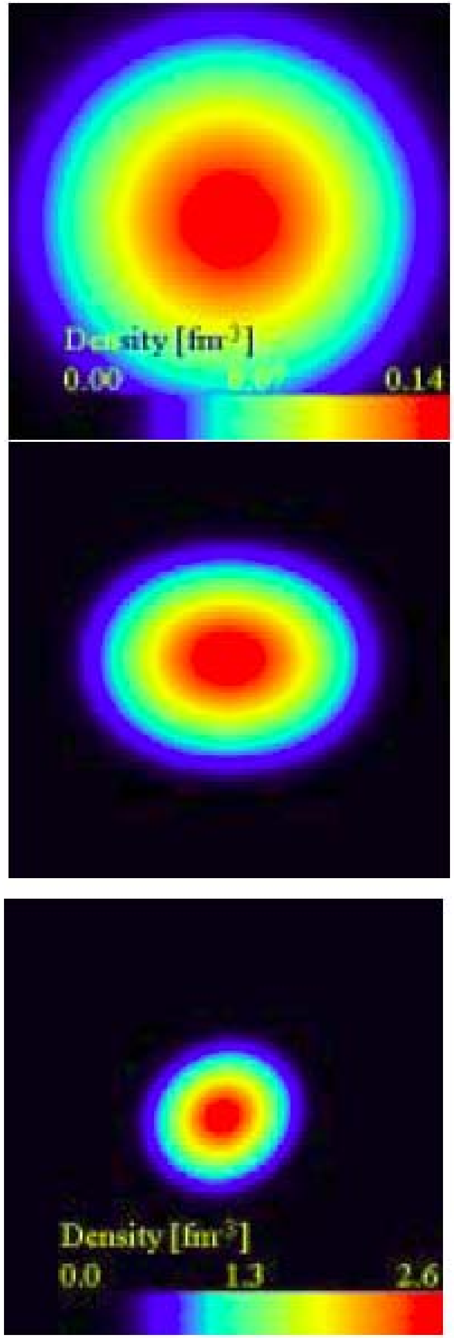


$\bar{p} + {}^4He$

$12q\ 3\bar{q}$

High Density nuclear systems with Isovector deformation

Dote, Horiuchi, Akaishi, Yamazaki, Prog. Theo. Phys. Suppl. 149(2003)221



ppn

0.14 fm^{-3}

ppnK$^-$

ppnK$^-$K$^-$

2.6 fm^{-3}

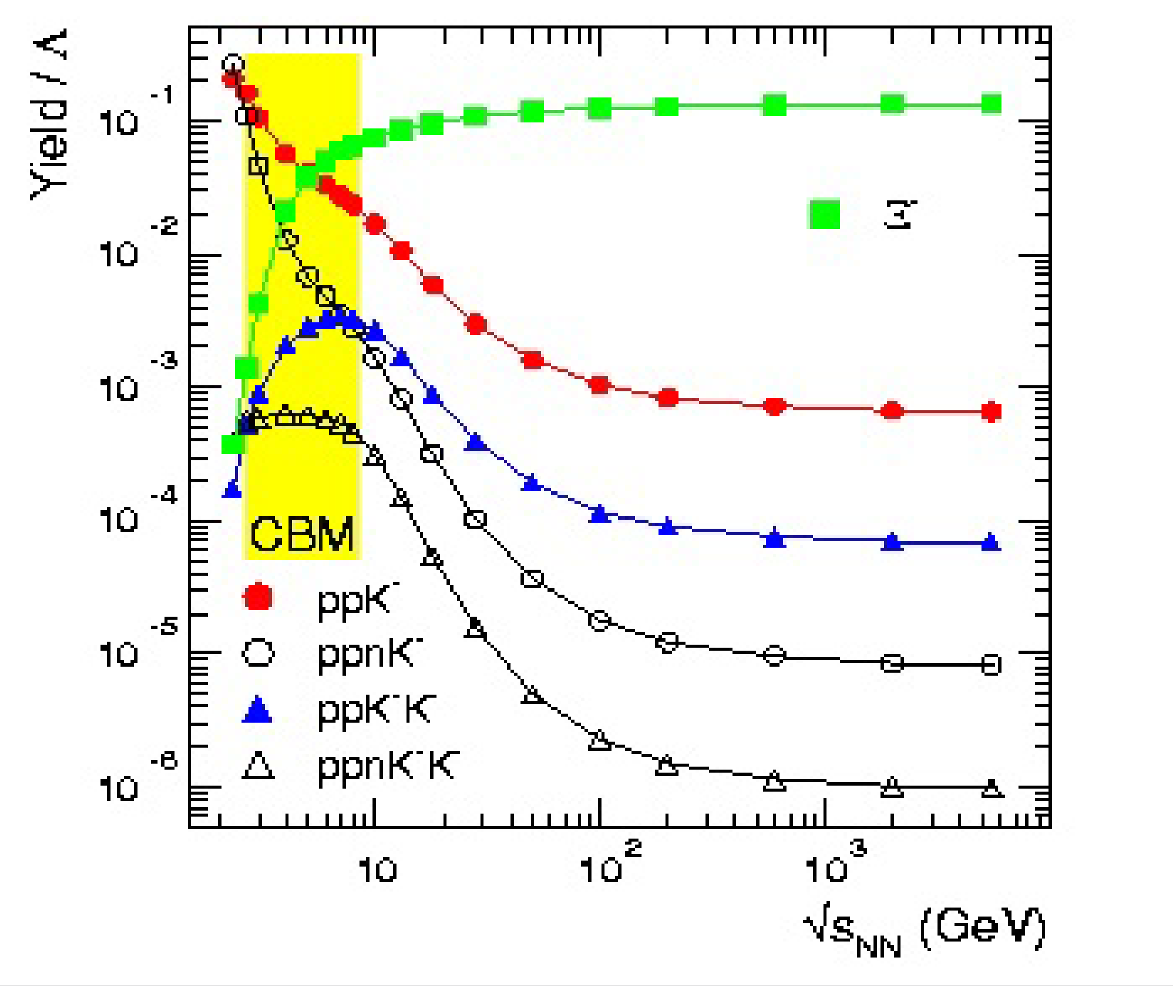
FIG. 2: Calculated density contours of ppn, ppnK$^-$ ar ppnK$^-$K$^-$.

How to study K$^-$ clusters

$$
\begin{array}{ll}
i) & ppK^- \to \Lambda + p, \\
ii) & ppnK^- \to \Lambda + d, \\
iii) & pppK^- \to \Lambda + p + p, \\
iv) & ppnnK^- \to \Lambda + t, \\
v) & pppnK^- \to \Lambda + {}^3\mathrm{He}, \\
vi) & ppK^-K^- \to \Lambda + \Lambda, \\
vii) & pppK^-K^- \to \Lambda + \Lambda + p, \\
viii) & pppnK^-K^- \to \Lambda + \Lambda + d.
\end{array}
$$

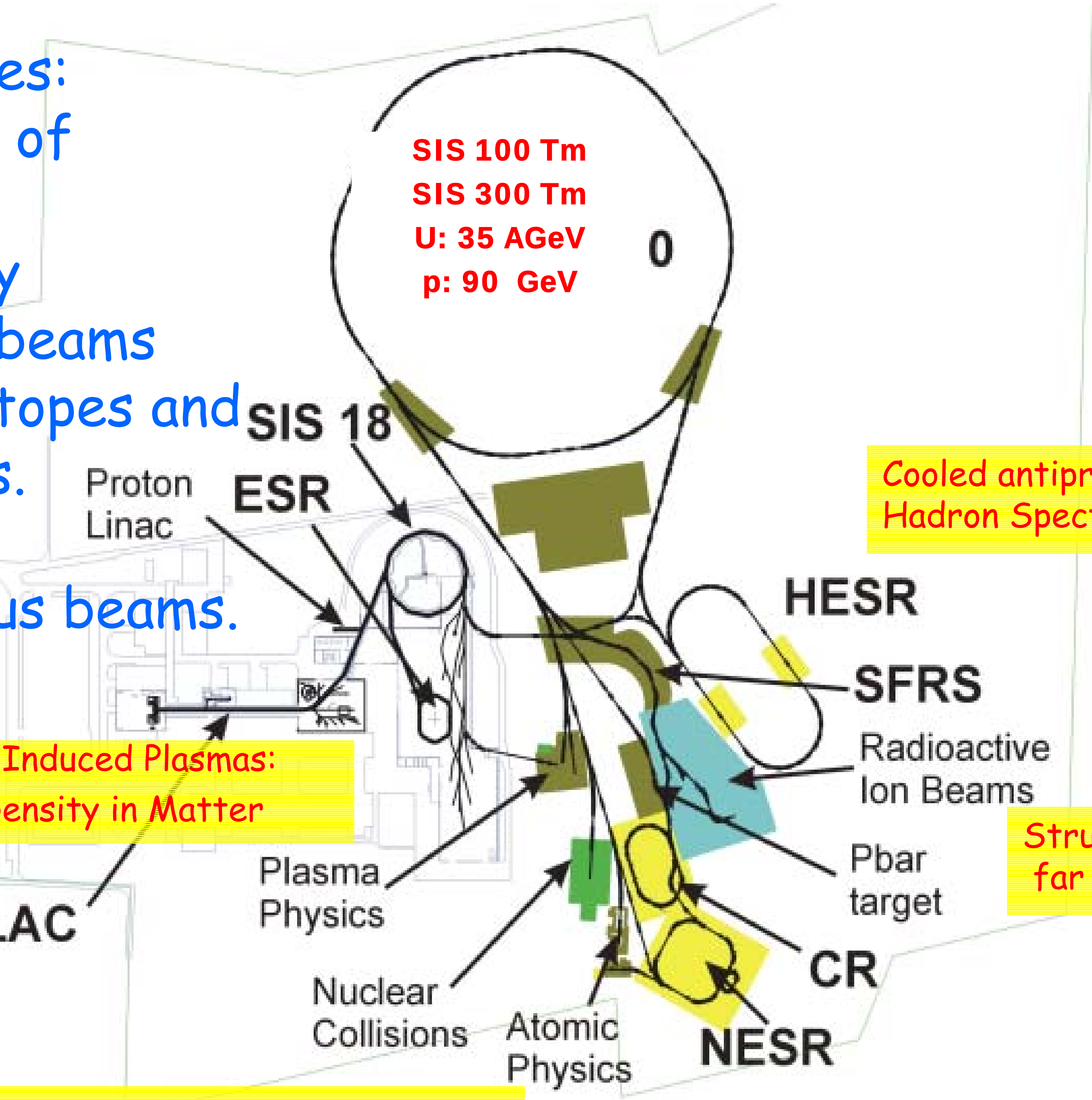
Excitation Function for such Clusters

Calculations with thermal model give measurable yields at SIS300



The future international accelerator facility FAIR

Key features:
Generation of intense, high-quality secondary beams of rare isotopes and antiprotons.
Two rings: simultaneous beams.



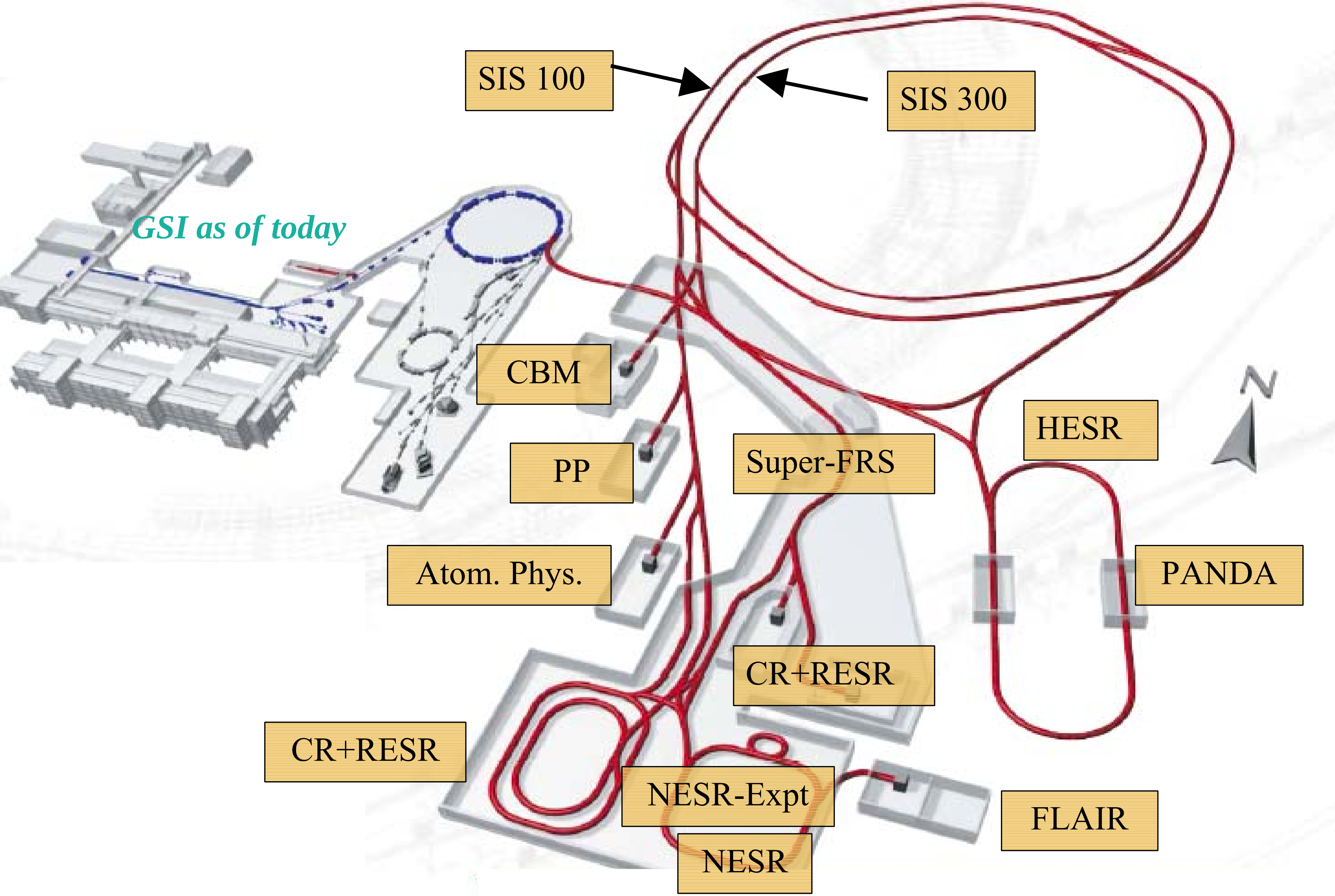
Cooled antiproton beam: Hadron Spectroscopy

Structure of Nuclei far from Stability

Ion and Laser Induced Plasmas: High Energy Density in Matter

Compressed Baryonic Matter

FAIR: a challenging acclerator project



Five Scientific Pillars for FAIR

- Nuclear Structure Physics and Nuclear Astrophysics with RIBs

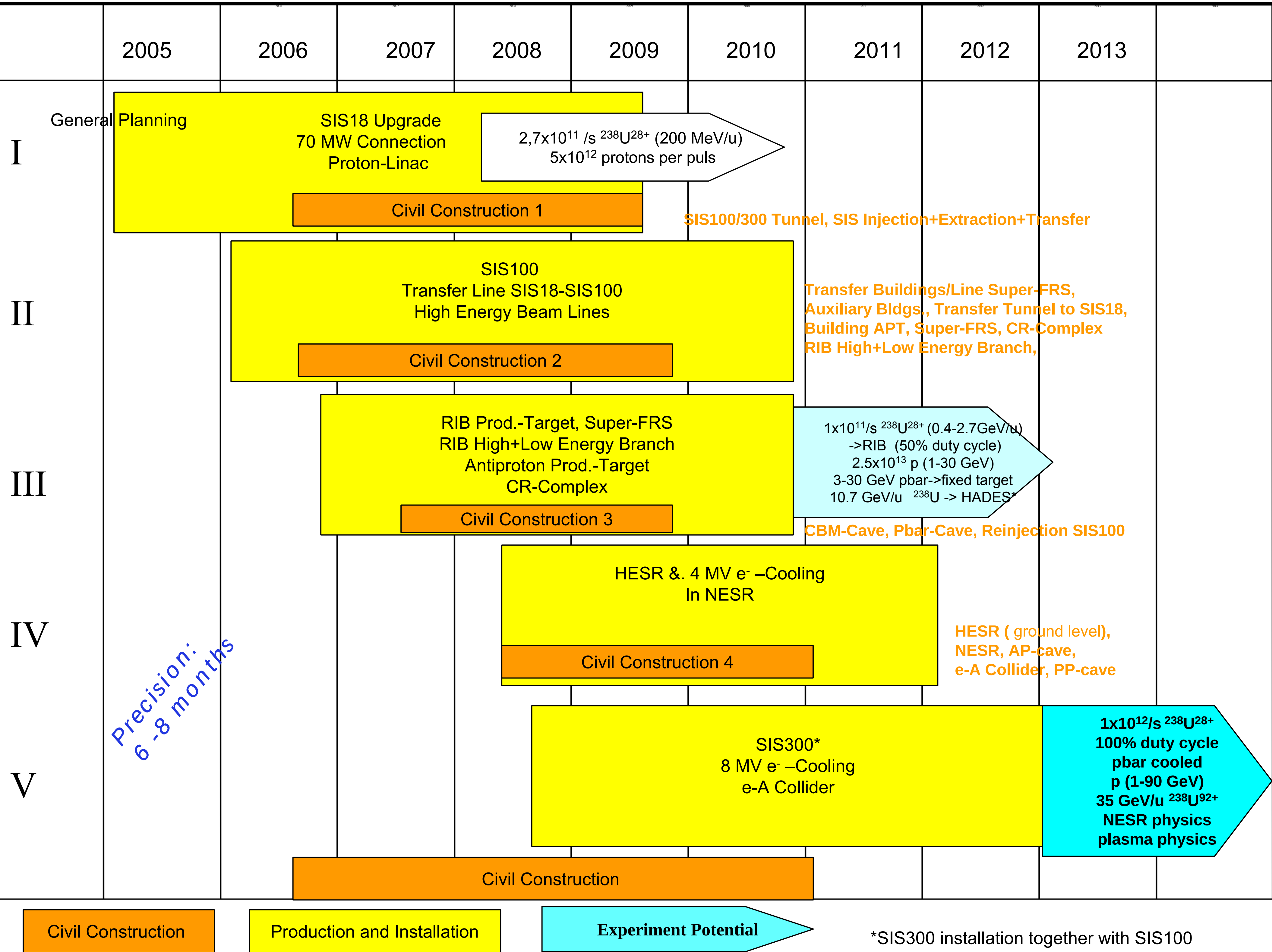
- Hadron Physics with Antiproton Beams

- Physics of Nuclear Matter with Relativistic Nuclear Collisions

- Plasma Physics with highly Bunched Beams

- Atomic Physics and Applied Science

plus
- Accelerator Physics



	2005	2006	2007	2008	2009	2010	2011	2012	2013

I

General Planning

SIS18 Upgrade
70 MW Connection
Proton-Linac

$2{,}7 \times 10^{11}$ /s $^{238}U^{28+}$ (200 MeV/u)
5×10^{12} protons per puls

Civil Construction 1

SIS100/300 Tunnel, SIS Injection+Extraction+Transfer

II

SIS100
Transfer Line SIS18-SIS100
High Energy Beam Lines

Civil Construction 2

Transfer Buildings/Line Super-FRS,
Auxiliary Bldgs., Transfer Tunnel to SIS18,
Building APT, Super-FRS, CR-Complex
RIB High+Low Energy Branch,

III

RIB Prod.-Target, Super-FRS
RIB High+Low Energy Branch
Antiproton Prod.-Target
CR-Complex

Civil Construction 3

1×10^{11}/s $^{238}U^{28+}$ (0.4-2.7GeV/u)
->RIB (50% duty cycle)
2.5×10^{13} p (1-30 GeV)
3-30 GeV pbar->fixed target
10.7 GeV/u ^{238}U -> HADES*

CBM-Cave, Pbar-Cave, Reinjection SIS100

IV

HESR &. 4 MV e⁻ –Cooling
In NESR

Civil Construction 4

HESR (ground level),
NESR, AP-cave,
e-A Collider, PP-cave

Precision:
6 -8 months

V

SIS300*
8 MV e⁻ –Cooling
e-A Collider

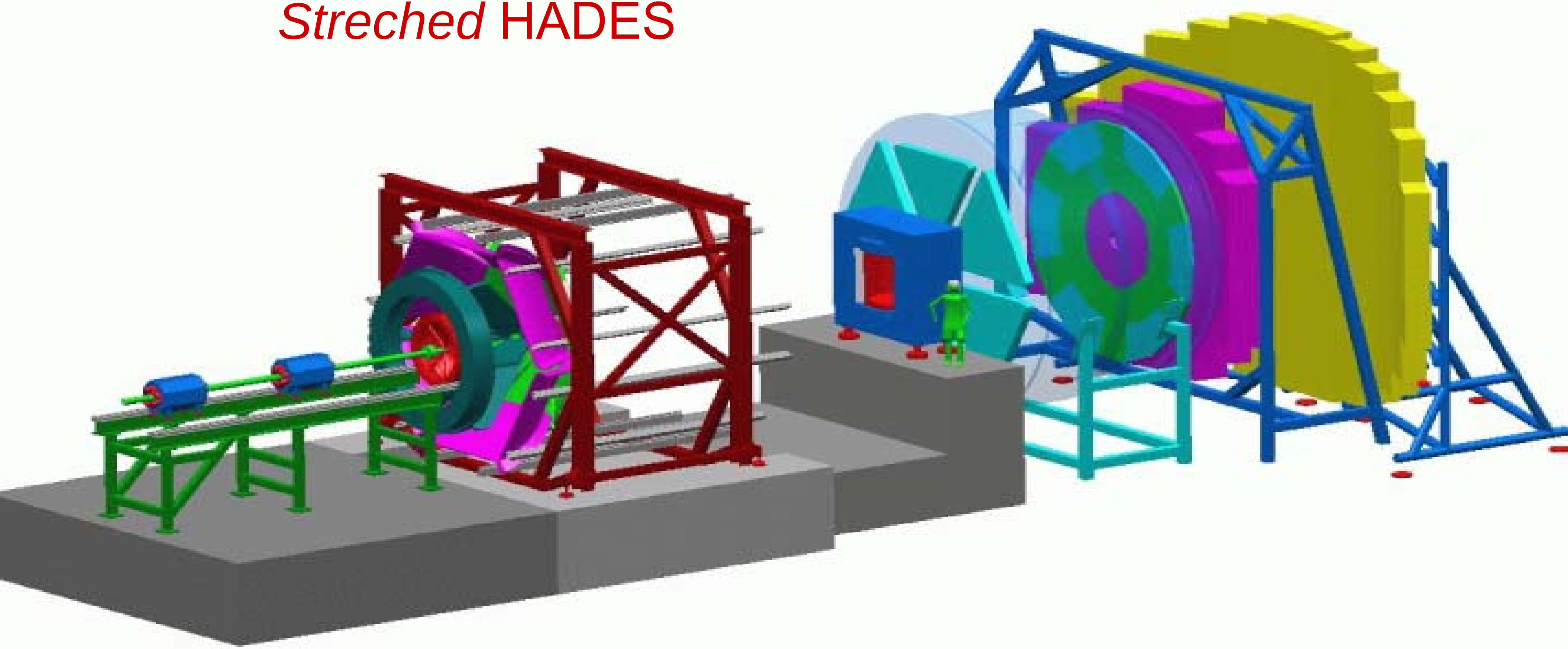
1×10^{12}/s $^{238}U^{28+}$
100% duty cycle
pbar cooled
p (1-90 GeV)
35 GeV/u $^{238}U^{92+}$
NESR physics
plasma physics

Civil Construction

🟧 Civil Construction
🟨 Production and Installation
Experiment Potential

*SIS300 installation together with SIS100

Nuclear reaction experiments at the future accelerator facility



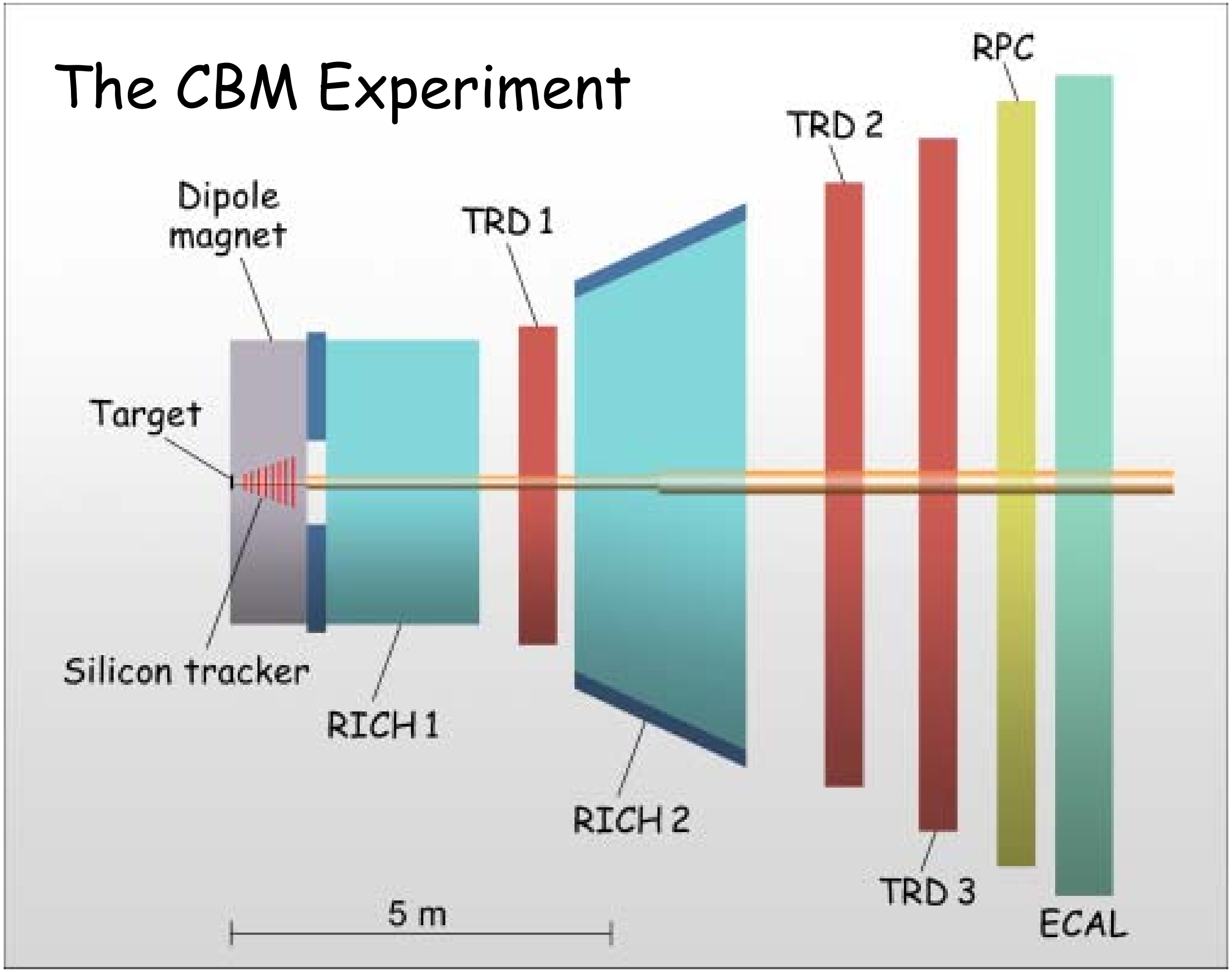
At 10^7 interactions per second!!

CBM

Streched HADES

A+A at 2-8 AGeV

A+A at 8-40 AGeV

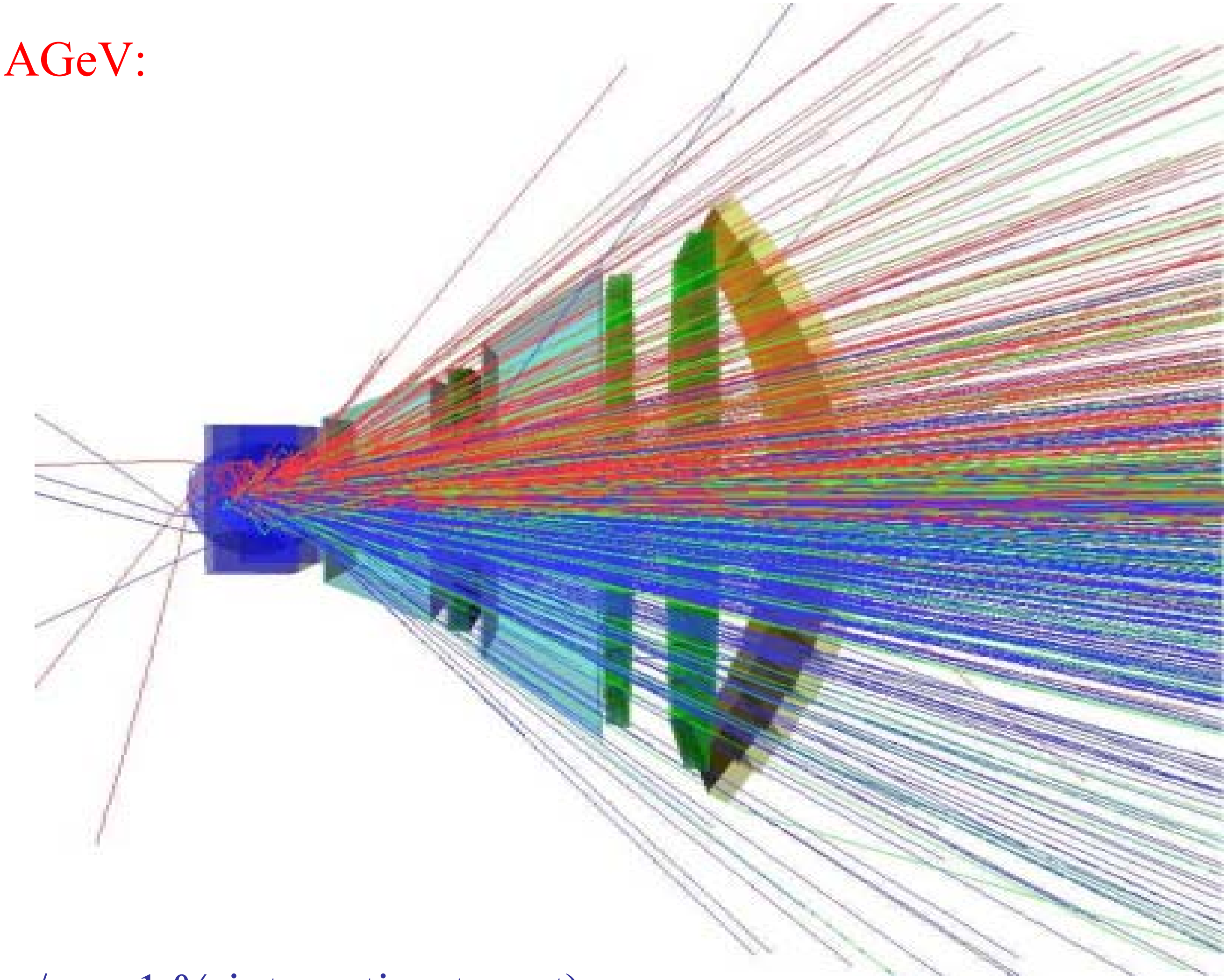


- Radiation hard Silicon pixel/strip detectors in a magnetic dipole field
- Electron detectors: RICH & TRD & ECAL: pion suppression up to 10^5
- Hadron identification: RPC, RICH
- Measurement of photons, p^0, gη, and muons: electromagn. calorimeter (ECAL)
- High speed data acquisition and trigger system

Experimental challenges

Central Au+Au collision at 25 AGeV:
URQMD + GEANT4

160 p
400 π^-
400 π^+
44 K^+
13 K^-



10^7 Au+Au reactions/sec
(beam intensities up to 10^9 ions/sec, 1 % interaction target)

□ determination of (displaced) vertices with high resolution (□ 30 mm)

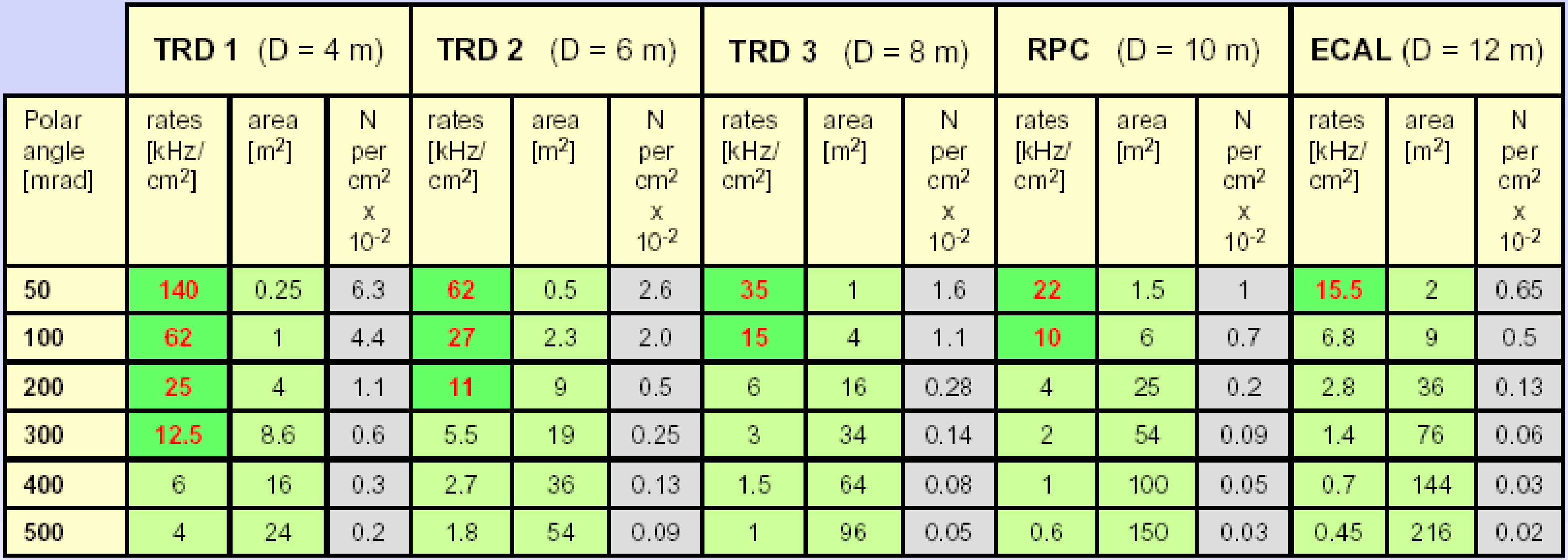
□ identification of electrons and hadrons

Fast TRD/Tracker

- Xe gas filled
- Pion rejection > 100 at 90 % electron efficiency
- Position resolution 200 – 300 μm, excellent granularity
- Very high rate capability: 200 kHz/cm^2, ultra-thin detectors
- 9 stations for tracking and TR performance

Experimental environment

Expected rates for 10^7/s minimum bias Au+Au collisions at 25 AGeV:



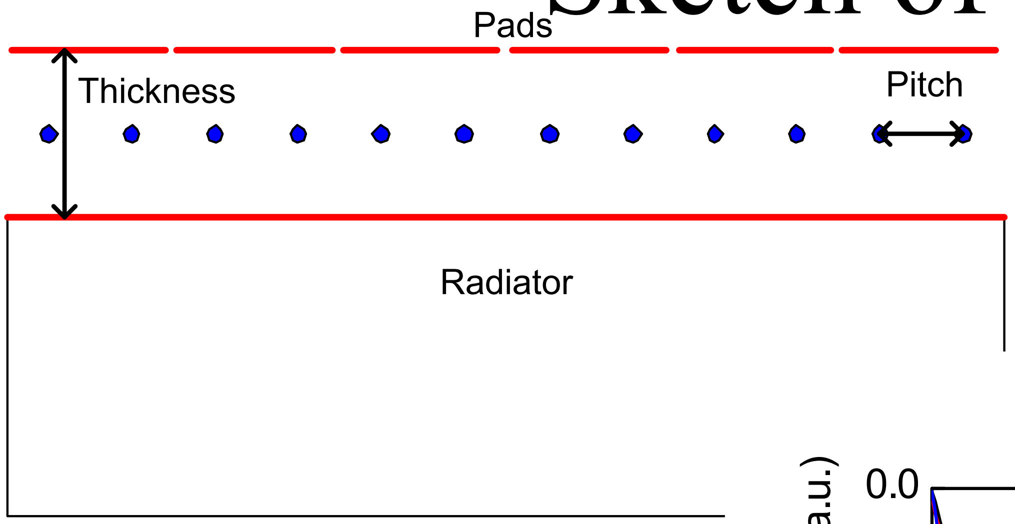
	TRD 1 (D = 4 m)			**TRD 2** (D = 6 m)			**TRD 3** (D = 8 m)			**RPC** (D = 10 m)			**ECAL** (D = 12 m)		
Polar angle [mrad]	rates [kHz/cm^2]	area [m^2]	N per cm^2 x 10^{-2}	rates [kHz/cm^2]	area [m^2]	N per cm^2 x 10^{-2}	rates [kHz/cm^2]	area [m^2]	N per cm^2 x 10^{-2}	rates [kHz/cm^2]	area [m^2]	N per cm^2 x 10^{-2}	rates [kHz/cm^2]	area [m^2]	N per cm^2 x 10^{-2}
50	140	0.25	6.3	62	0.5	2.6	35	1	1.6	22	1.5	1	15.5	2	0.65
100	62	1	4.4	27	2.3	2.0	15	4	1.1	10	6	0.7	6.8	9	0.5
200	25	4	1.1	11	9	0.5	6	16	0.28	4	25	0.2	2.8	36	0.13
300	12.5	8.6	0.6	5.5	19	0.25	3	34	0.14	2	54	0.09	1.4	76	0.06
400	6	16	0.3	2.7	36	0.13	1.5	64	0.08	1	100	0.05	0.7	144	0.03
500	4	24	0.2	1.8	54	0.09	1	96	0.05	0.6	150	0.03	0.45	216	0.02

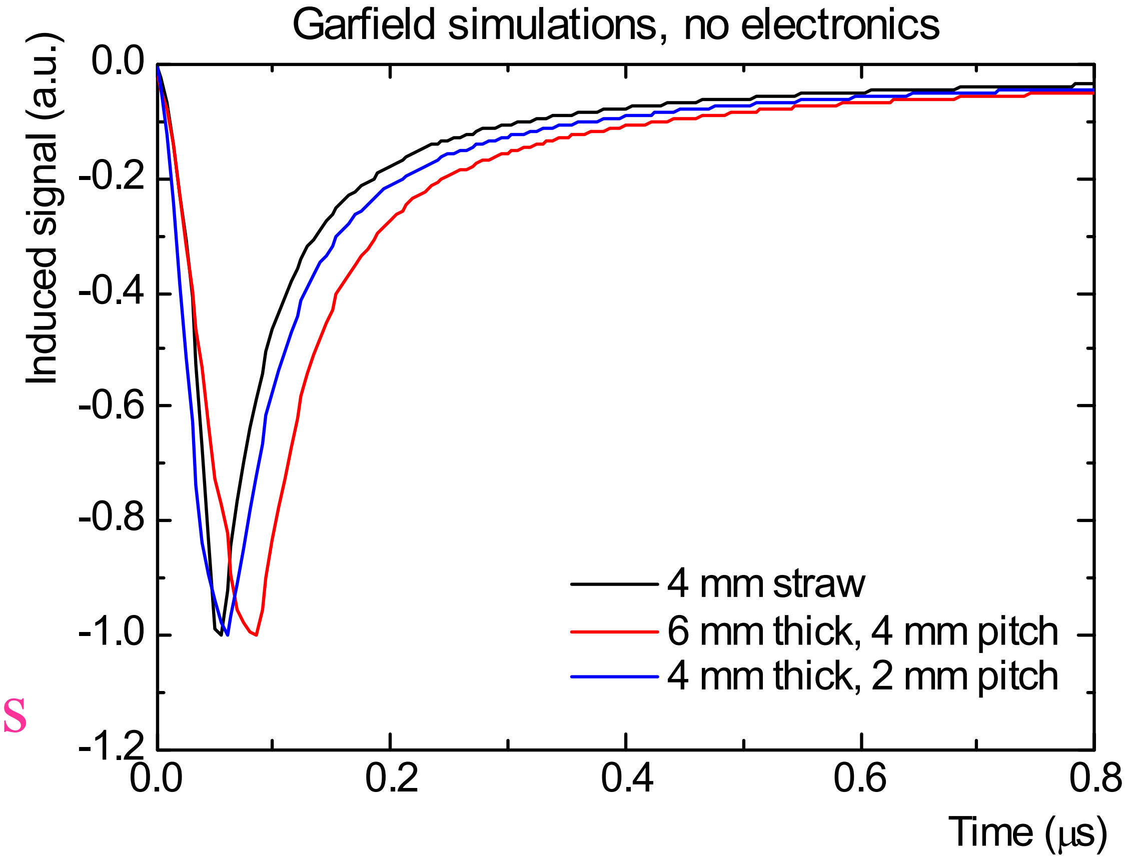
Rates of > 10 kHz/cm^2 in large part of detectors !
A major experimental challenge.

Approaches

- Gem: intrinsically fast and accurate, but has gaps in-between double and triple structures. On-going R&D
- Straw (4 mm) tubes: intrinsically fast, but poor multi-hit capability
- Thin (4-6 mm) wire chambers with pad readout: rate capability? On-going R&D
- ...
- Gas: Xe-CO_2

Sketch of Detector

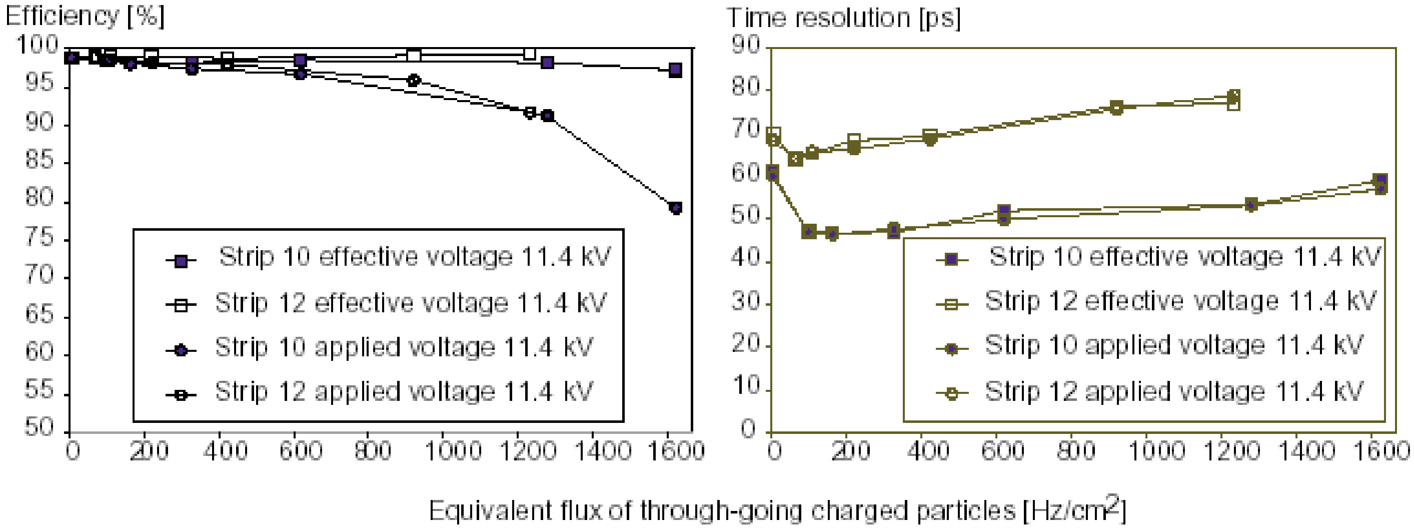




Trade-off between
rate capability,
TR absorption and
number of readout channels

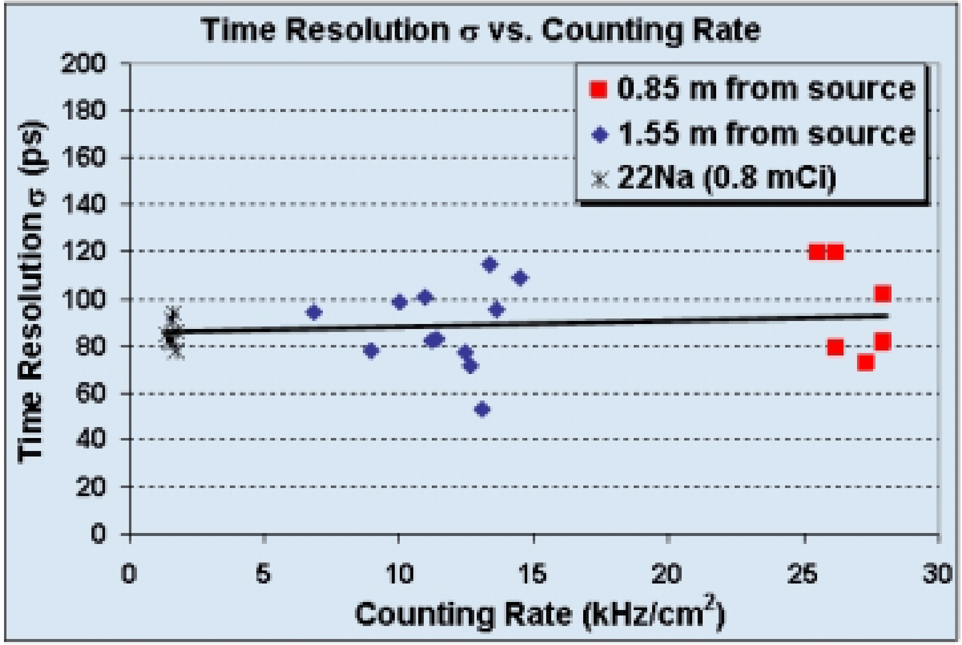
Status on High Rate RPCs

C. Williams et al. (ALICE)



10 gap RPC
Glass electrodes
Volume resistivity:
$\rho = 2 \cdot 10^{12}\ \Omega$cm
Limited to ~ 1kHz/cm^2

P. Fonte et al. (CBM, EU - JRA14)



Special purpose for high rate
Single gap device
Resistive electrode:

ENSITAL® SD (ENSINGER)

$\rho \sim 4\times10^{9}\ \Omega$ cm

Good surface finish

Commercial material

Open Problems:
Volume resistivity changes with count rate
Ionic conductor
Unknown aging effects (long term)

Design of a Silicon Pixel detector

Silicon Tracking System: 7 planar layers of pixels/strips.
Vertex tracking by two first pixel layers
at 5 cm and 10 cm downstream target

Design goals:

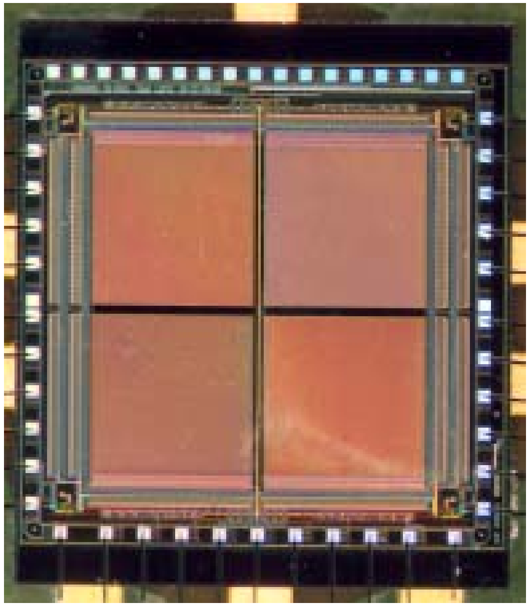
- low materal budget: d < 200 μm
- single hit resolution < 20 μm
- radiation hard (dose 10^{15} neq/cm^2)
- fast read out

Current plan:

Monolithic Active Pixel Sensors (MAPS)

- pitch 20 μm
- thickness below 100 μm
- single hit resolution: < 3 microns
- Problem: radiation hardness and readout speed

Fallback solution: Hybrid detectors



MIMOSA IV
IReS / LEPSI Strasbourg

CBM R&D working packages

Feasibility, Simulations

GEANT4: GSI

$\rho,\omega\omega, \varphi \rightarrow e^+e^-$
Univ. Krakow
JINR-LHE Dubna

$D \rightarrow K\pi + X$
GSI Darmstadt,
Czech Acad. Sci., Rez
Techn. Univ. Prague

$J/\psi y \rightarrow e^+e^-$
INR Moscow

Hadron ID
Heidelberg Univ,
Warsaw Univ.
Kiev Univ.
NIPNE Bucharest
INR Moscow

Tracking
KIP Univ. Heidelberg
Univ. Mannheim
JINR-LHE Dubna

Design & construction of detectors

Silicon Pixel
IReS Strasbourg
Frankfurt Univ.,
GSI Darmstadt,
RBI Zagreb,
Univ. Krakow

Silicon Strip
SINP Moscow State U.
CKBM St. Petersburg
KRI St. Petersburg

RPC-TOF
LIP Coimbra,
Univ. Santiago de Com.,
Univ. Heidelberg,
GSI Darmstadt,
Warsaw Univ.
NIPNE Bucharest
INR Moscow
FZ Rossendorf
IHEP Protvino
ITEP Moscow

Fast TRD
JINR-LHE, Dubna
GSI Darmstadt,
Univ. Münster
INFN Frascati

Straw tubes
JINR-LPP, Dubna
FZ Rossendorf
FZ Jülich
Tech. Univ. Warsaw

ECAL
ITEP Moscow
GSI Darmstadt
Univ. Krakow

RICH
IHEP Protvino
GSI Darmstadt

Magnet
JINR-LHE, Dubna
GSI Darmstadt

Data Acquis., Analysis

Trigger, DAQ
KIP Univ. Heidelberg
Univ. Mannheim
GSI Darmstadt
JINR-LIT, Dubna
Univ. Bergen
KFKI Budapest
Silesia Univ. Katowice
Univ. Warsaw

Analysis
GSI Darmstadt,
Heidelberg Univ,

CBM R&D Collaboration : 39 institutions , 14 countries

Croatia:
RBI, Zagreb

Cyprus:
Nikosia Univ.

Czech Republic:
Czech Acad.
Science, Rez
Techn. Univ. Prague

France:
IReS Strasbourg

Germany:
Univ. Heidelberg,
PI, KIP
Univ. Frankfurt
Univ. Mannheim
Univ. Marburg
Univ. Münster
FZ Rossendorf
GSI Darmstadt

Hungaria:
KFKI Budapest
Eötvös Univ. Budapest

Korea:
Korea Univ. Seoul
Pusan Univ.

Norway:
Univ. Bergen

Poland:
Krakow Univ.
Warsaw Univ.
Silesia Univ. Katowice

Portugal:
LIP Coimbra

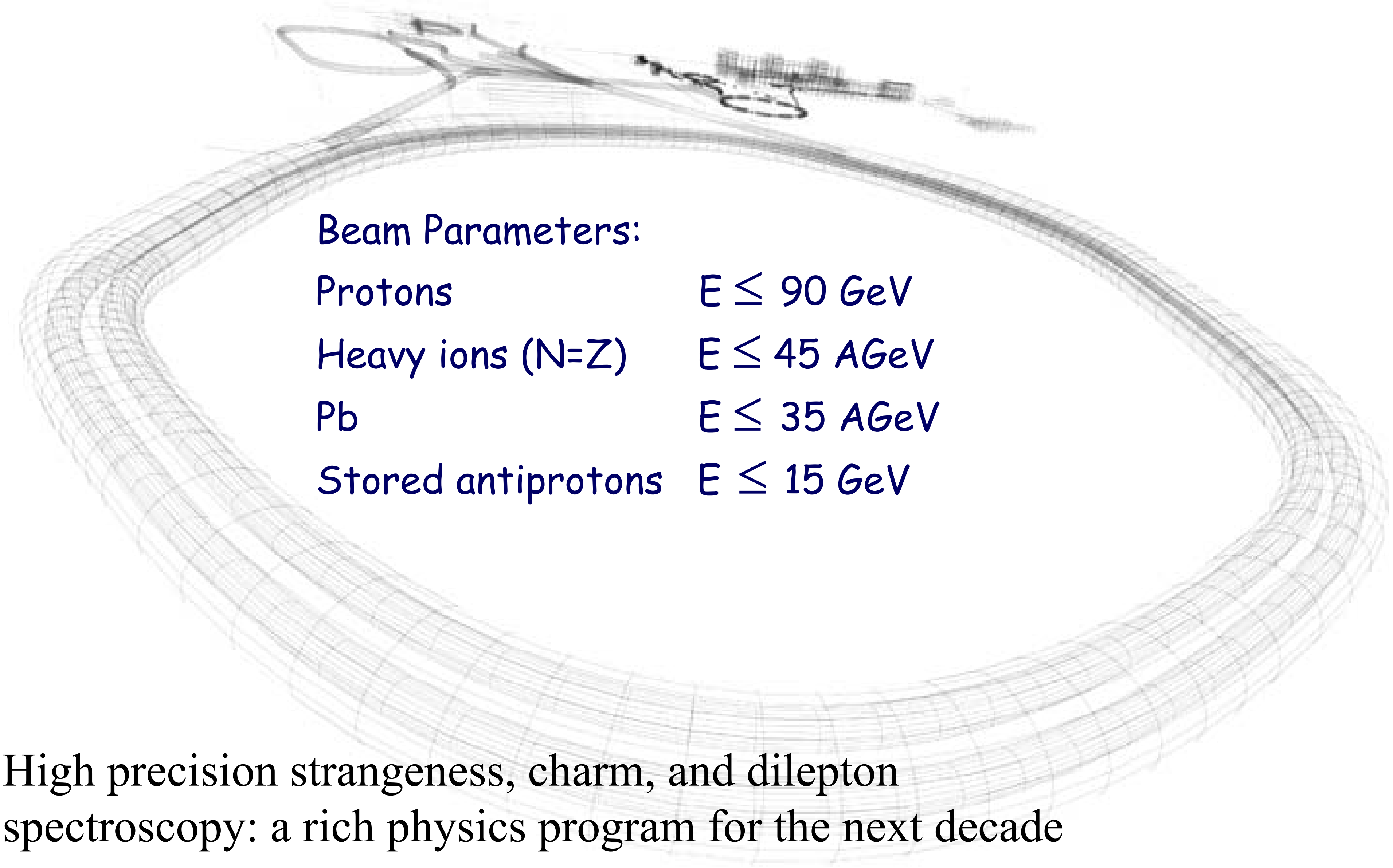
Romania:
NIPNE Bucharest

Russia:
CKBM, St. Petersburg
IHEP Protvino
INR Troitzk
ITEP Moscow
KRI, St. Petersburg
Kurchatov Inst., Moscow
LHE, JINR Dubna
LPP, JINR Dubna
LIT, JINR Dubna
Obninsk State Univ.
PNPI Gatchina
SINP, Moscow State Univ.
St. Petersburg Polytec. U.

Spain:
Santiago de Compostela
Univ.

Ukraine:
Shevshenko Univ. , Kiev
Univ. of Kharkov

Exploration of the QCD Phase Structure in the Baryon-Rich Region



Beam Parameters:

Protons	$E \leq 90$ GeV
Heavy ions (N=Z)	$E \leq 45$ AGeV
Pb	$E \leq 35$ AGeV
Stored antiprotons	$E \leq 15$ GeV

High precision strangeness, charm, and dilepton spectroscopy: a rich physics program for the next decade