

Facility for Antiproton and Ion Research

The FAIR Project Status and New Developments

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PANIC, Santa Fe, October 24th 2005

- The Facility
- The Physics
- Organisation

Introduction



GSI, Darmstadt

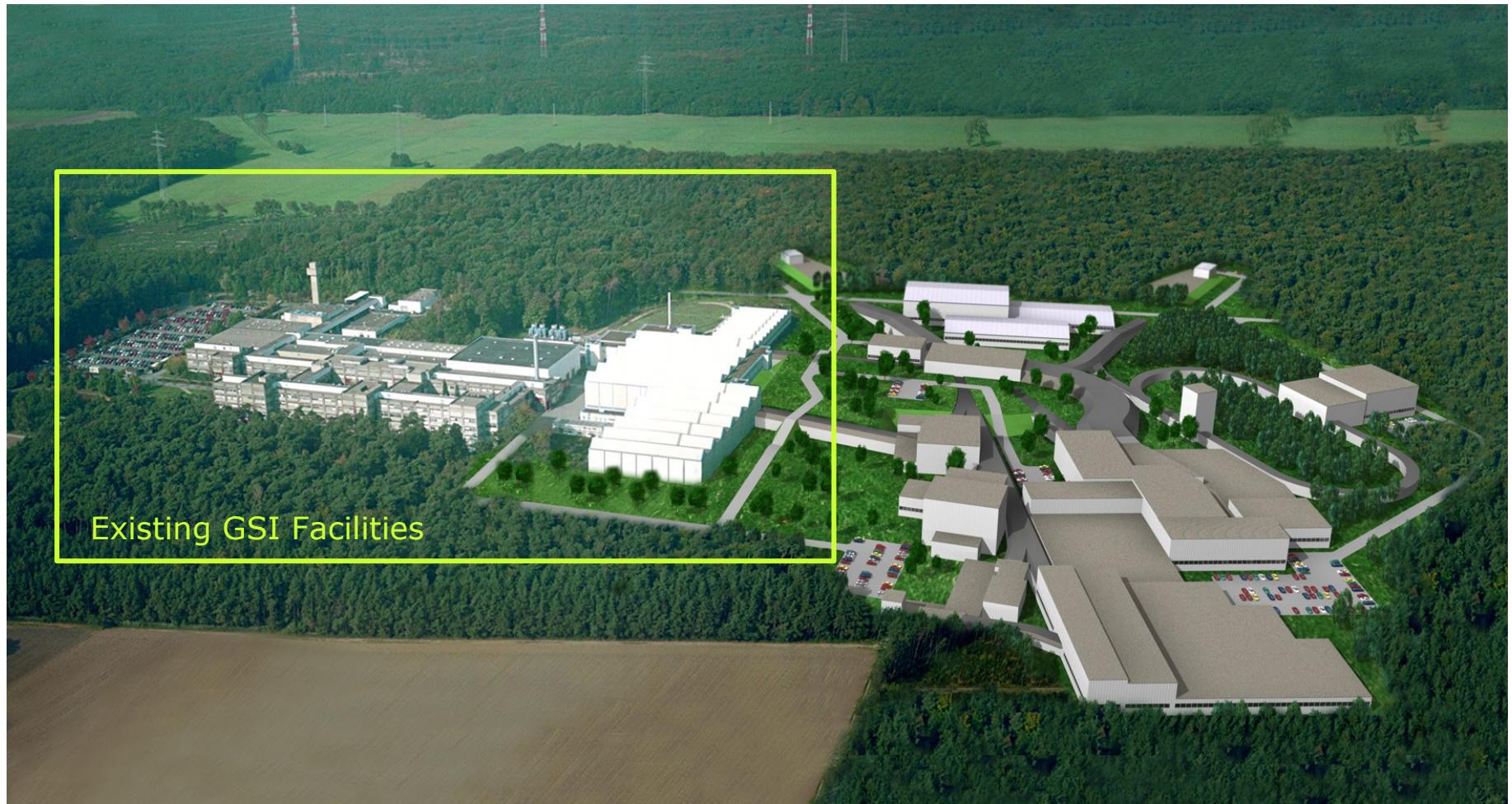
- German National Lab for Heavy Ion Research
- Highlights:
 - Heavy ion physics
 - Nuclear physics
 - Atomic and plasma physics
 - Cancer research

FAIR: New facility at GSI

- RIB
- Heavy ions
- higher intensities & energies
- Antiprotons

The Facility

Aerial view of GSI and projection of the future facility FAIR



Five Pillars of Research

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 with **highly charged Ions**
and **low energy Antiprotons**

+ **Accelerator Physics**

Layout of the Facility

Primary Beams

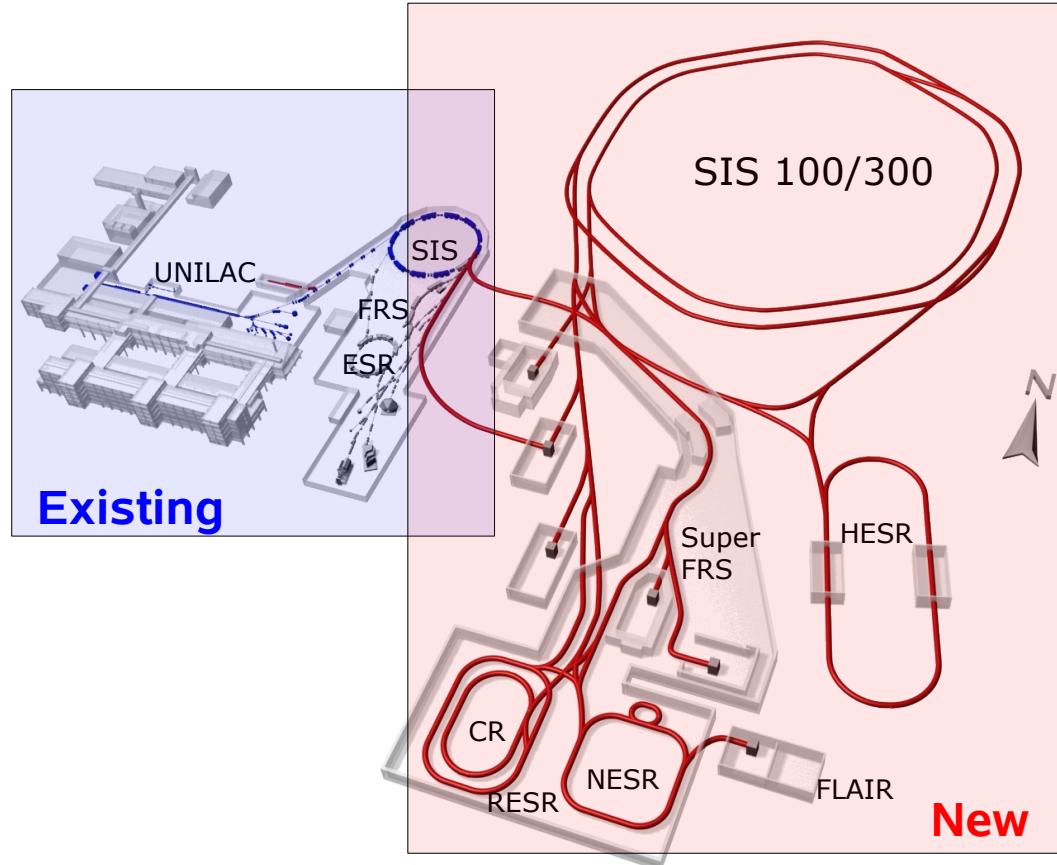
- $^{238}\text{U}^{28+}$: $10^{12}/\text{s}$ @ 1.5-2 AGeV;
- $^{238}\text{U}^{92+}$: $10^{10}/\text{s}$ @ up to 35 AGeV
- **Protons** : $2 \times 10^{13}/\text{s}$ @ 30 GeV; up to 90 GeV
- Factor 100-1000 over present intensity

Secondary Beams

- Broad range of radioactive beams up to 1.5 - 2 AGeV
- up to factor 10 000 in intensity over present
- Antiprotons 0 - 15 GeV

Storage and Cooler Rings

- Radioactive beams
- $e^- - A$ (or Antiproton-A) collider
- 10^{11} stored and cooled antiprotons 0.8 - 14.5 GeV/c
- Polarized antiprotons(?)



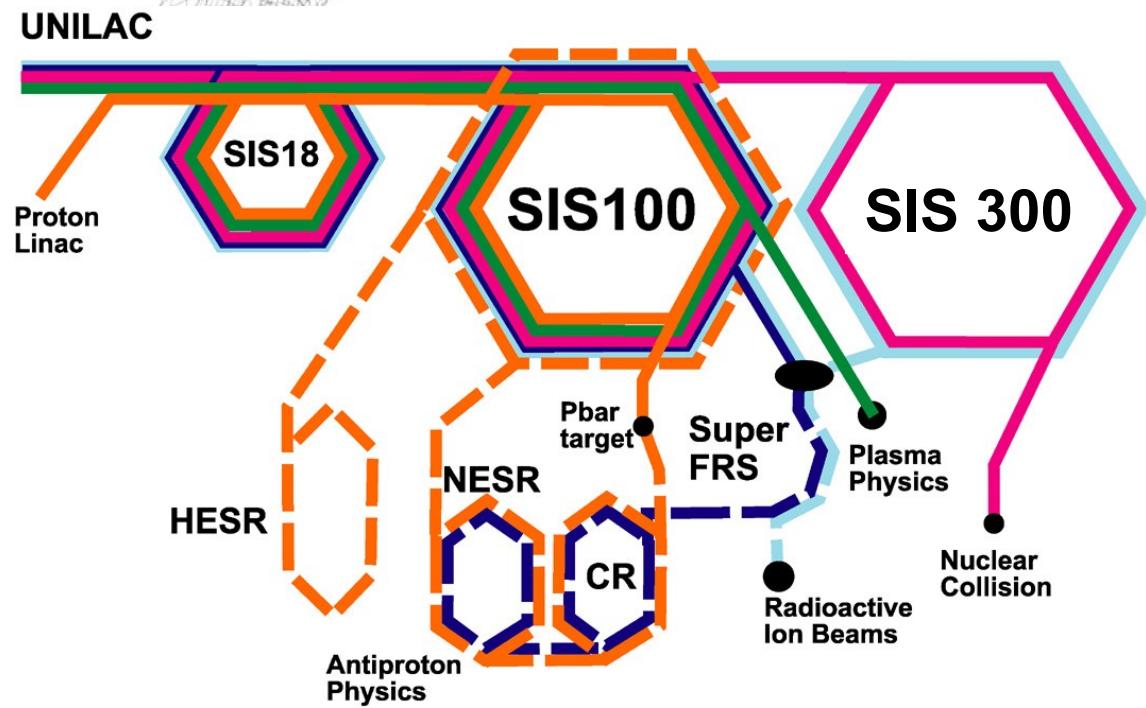
Key Technical Features

- Cooled beams
- Rapidly cycling superconducting magnets
- Parallel Operation

Accelerator Highlights

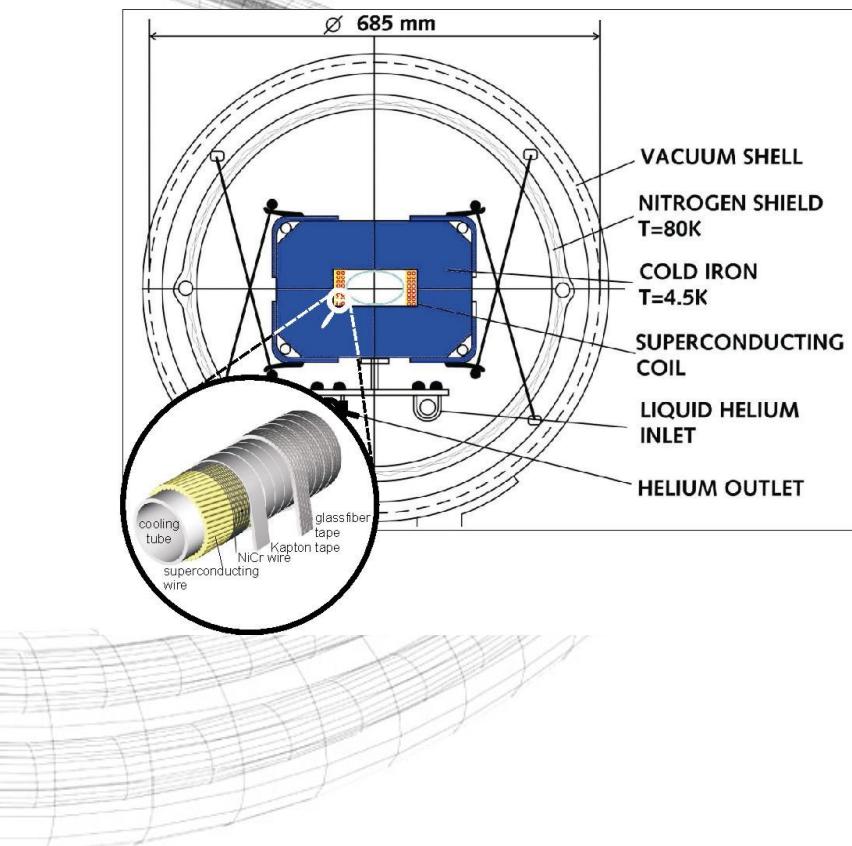
Parallel Operation

- High duty cycle
- Optimal usage
- Synergy effects
- Rapidly cycling magnets



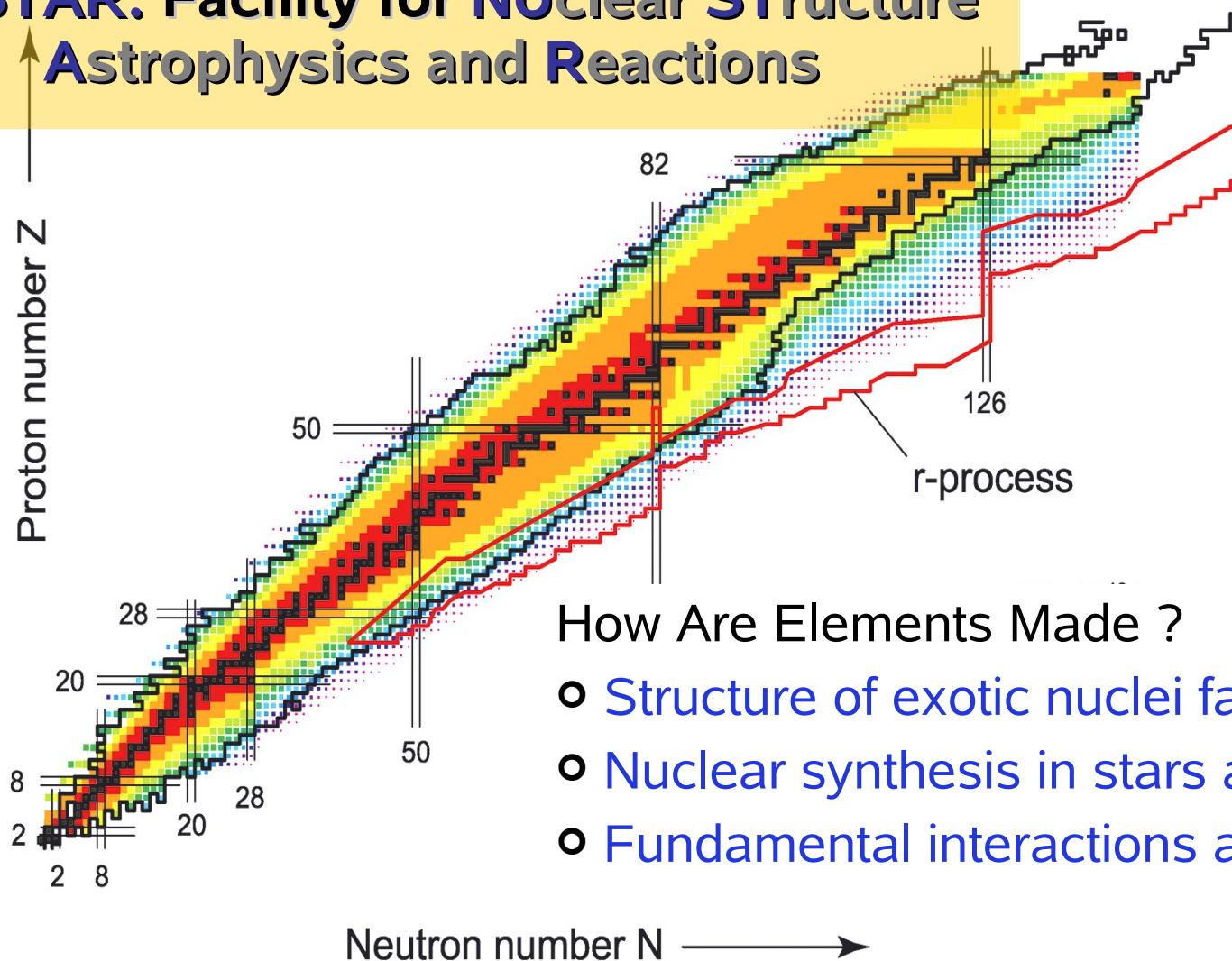
Superconducting, fast ramping synchrotron magnets

SIS 100/300 dipole magnet



NUSTAR - Radioactive Ion Beams

**NUSTAR: Facility for NUclear STructure
Astrophysics and Reactions**



NUSTAR - Super Fragment Separator

SUPERconducting FRagment Separator
High-Energy Reaction Setup
Multi-Storage Rings (CR, NESR, eA)
Energy-Bunched Stopped Beams

Pre-Separator

Main-Separator

Low-Energy Branch

High-Energy Branch

SIS 300

100 m

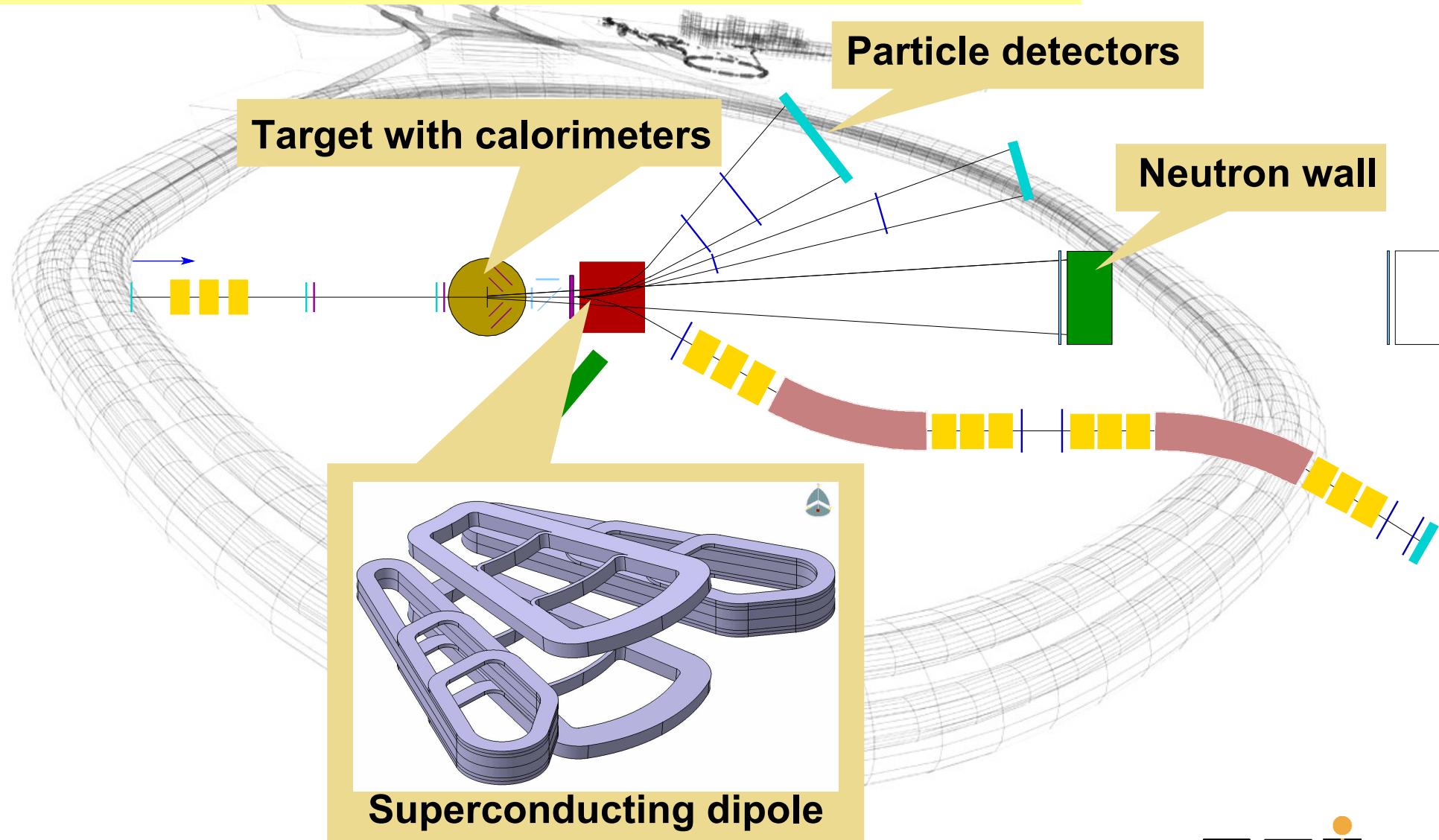
Key characteristics :

- all elements, H to U
- intensity $> 10^{12}$ ions/sec.
- high and low energies
- pulsed and CW beams

Ring Branch

NUSTAR - High Energy Branch

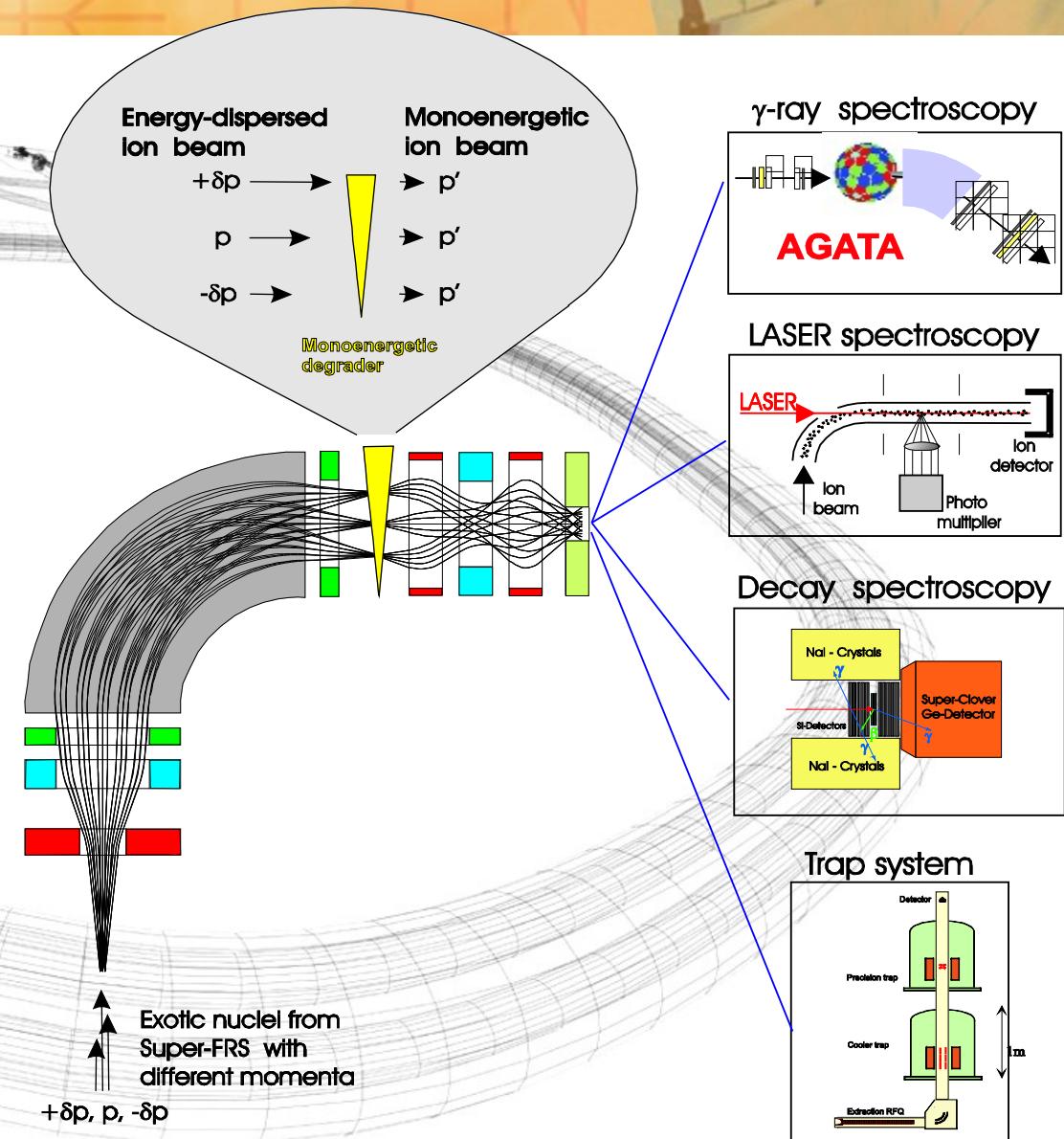
R3B: Reactions with Relativistic Radioactive Beams



NUSTAR - Low Energy Branch

Energy-bunched
slowed-down and
stopped beams

- Decay spectroscopy (DESPEC)
- In-flight γ spectroscopy
(3 – 100 MeV/u) (HISPEC)
- Laser spectroscopy (LASPEC)
- Ion traps (MATS)
- Neutron capture (NCAP)

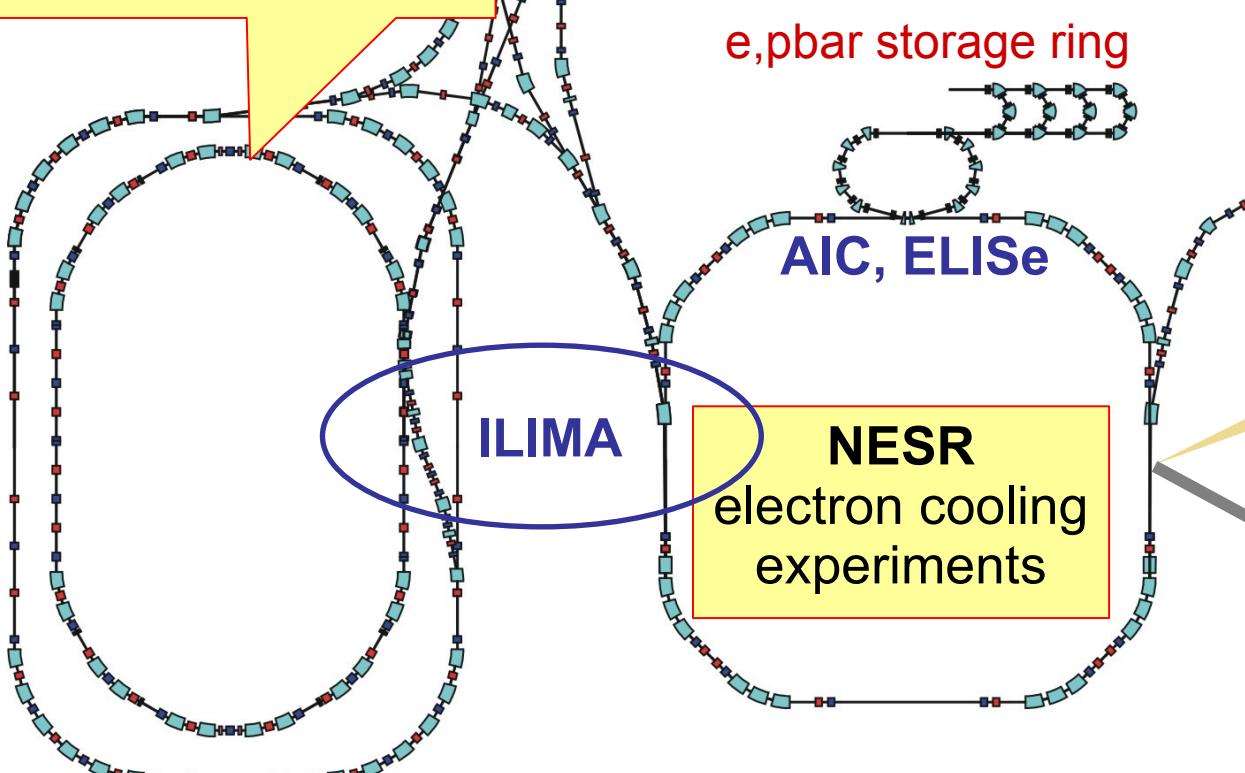


NUSTAR - Ring Branch

Collector Ring

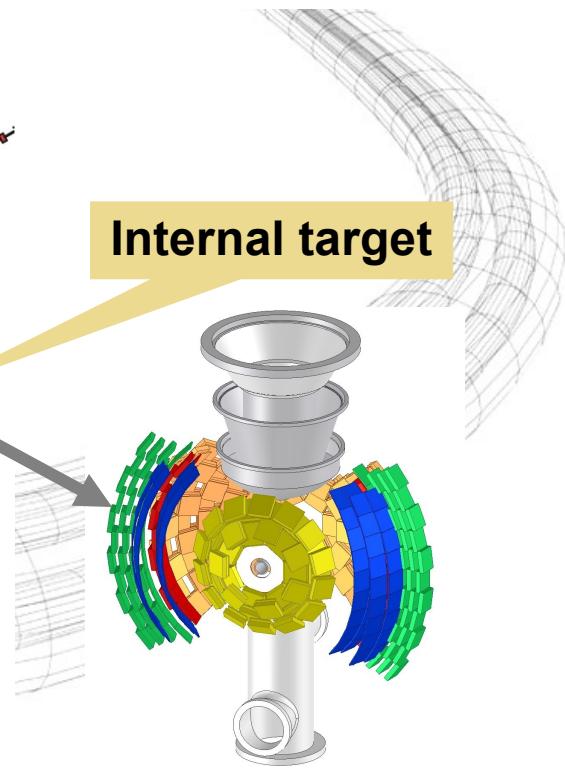
- bunch rotation
- adiabatic debunching
- fast stochastic cooling
- isochronous mode

from Super-FRS



EXL: EXotic nuclei in Light ion induced reactions

- Target-Recoil and Gamma Detector
- around internal target



P.Beller, A. Dolinskii, B. Franzke, M. Steck

FLAIR - Low Energy Antiprotons

Facility for Low energy Antiproton and Ion Research

Continue & extend program of CERN AD

Spectroscopy as Test for CPT and QED

Antiprotonic atoms ($\bar{p}\text{He}$, $\bar{p} \text{ p}$), anti-hydrogen

High-brilliant
Low energy
beams

Gravitation of anti-matter

Trapped and laser-cooled anti-hydrogen

USR

Atomic Collisions

Ionization, energy loss, anti-matter-matter

DC beam,
rare ions

Antiprotons as hadronic Probes

X-rays of light \bar{p} -Atoms: Low energy QCD

X-rays of neutron rich nuclei: nuclear structure (halo)

Antineutron interaction

Strangeness -2 production

Higher
energies

Medical application: Tumor therapy

FLAIR - Facility

NESR

\bar{p} & Ions
30 – 400 MeV

LSR:

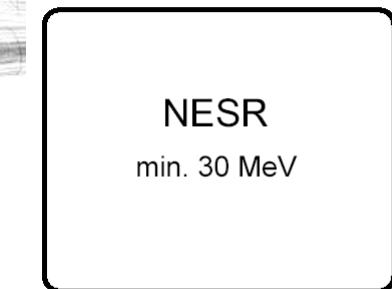
Standard Ring
< 300 keV

USR

Electrostatic
< 20 keV

HITRAP

\bar{p} & Ions stopped
& extracted @ 5 keV

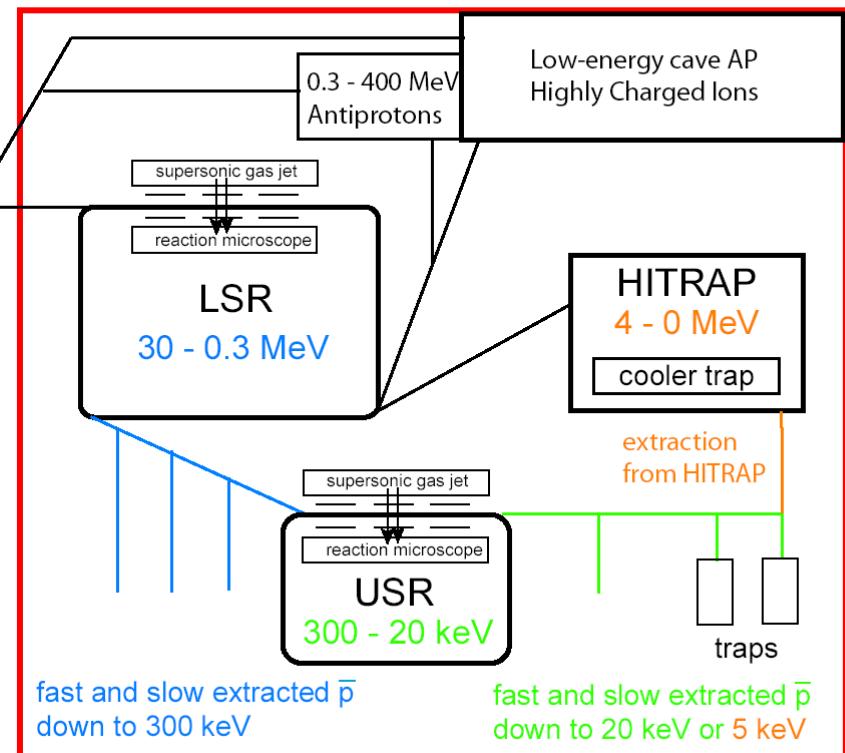


CRYRING

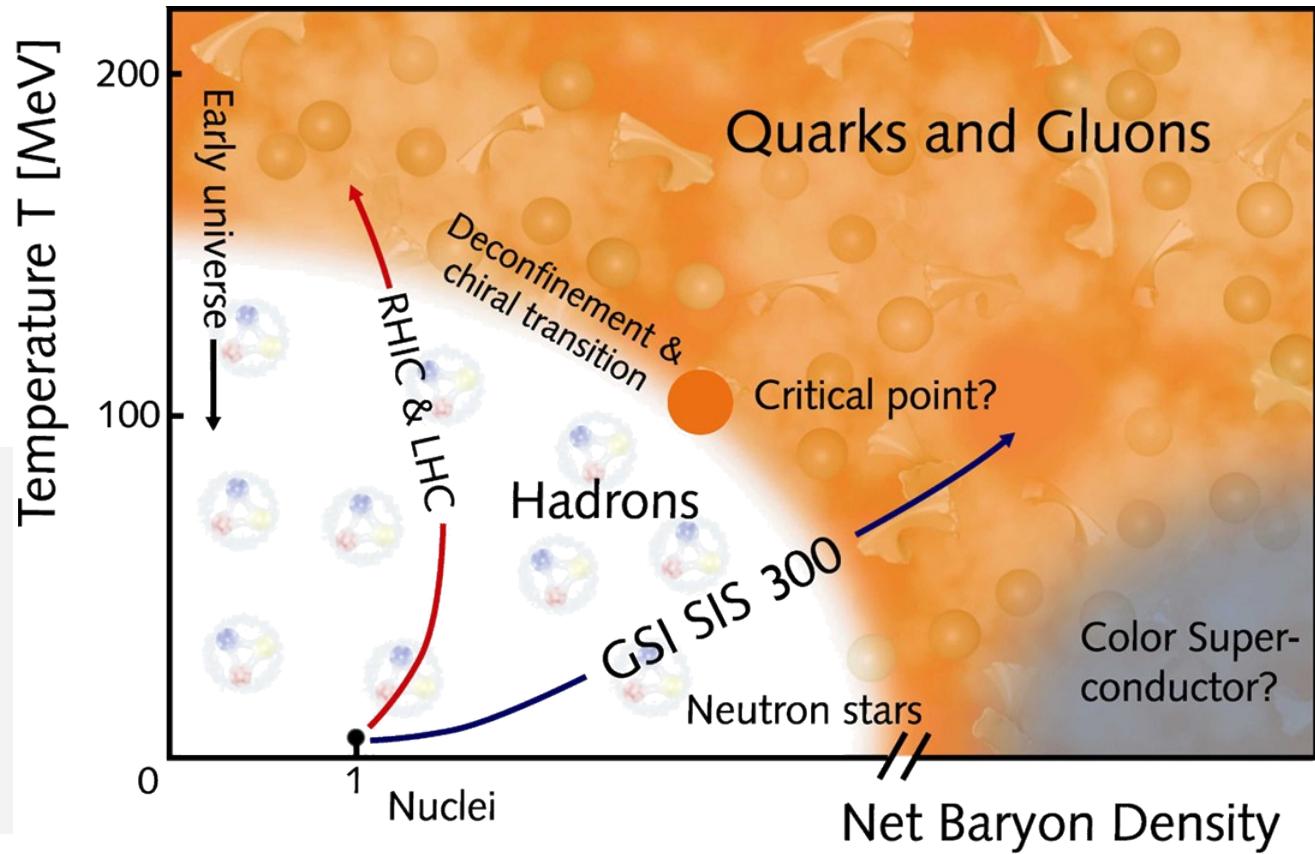
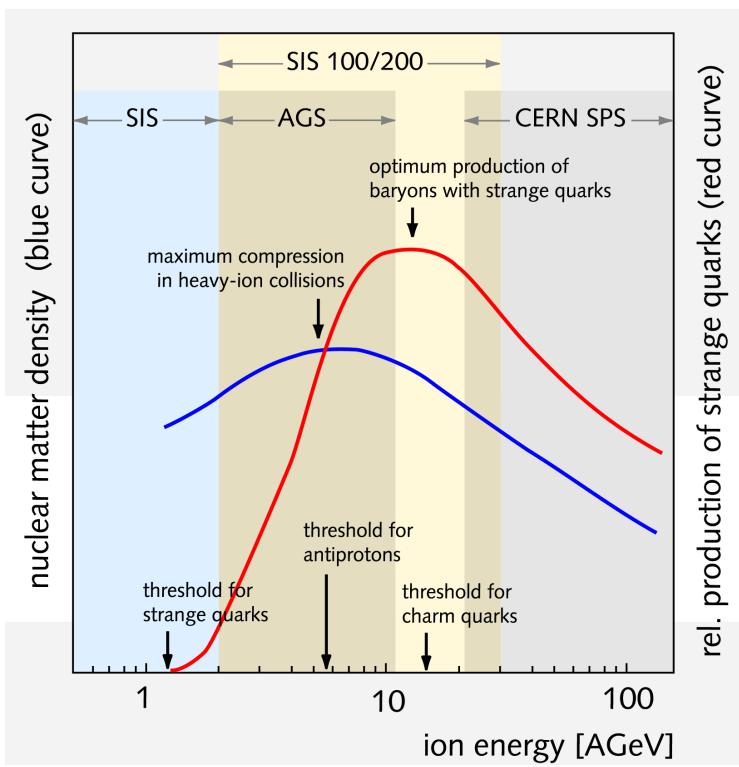
Challenge! new
MPI-K HD

In construction for
ESR @ GSI
with Hall A
of CDR

New low-energy antiproton and ion facility



CBM - Compressed Baryonic Matter



CBM - Physics

In-medium modifications of hadrons

onset of chiral symmetry restoration at high ρ_B

measure: ρ , ω , $\phi \rightarrow e^+e^-$ and open charm (D mesons)

Strangeness in matter (strange matter?)

enhanced strangeness production ?

measure: K , Λ , Σ , Ξ , Ω

Indications for deconfinement at high ρ_B

anomalous charmonium suppression ?

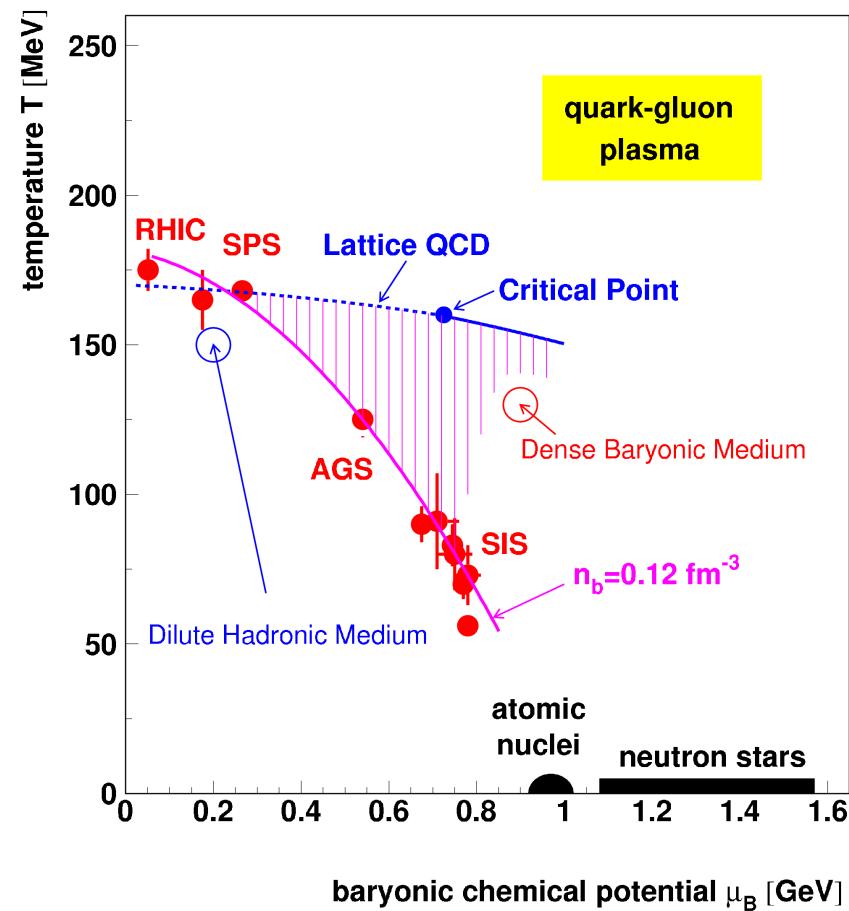
measure: J/ψ , D

Critical point

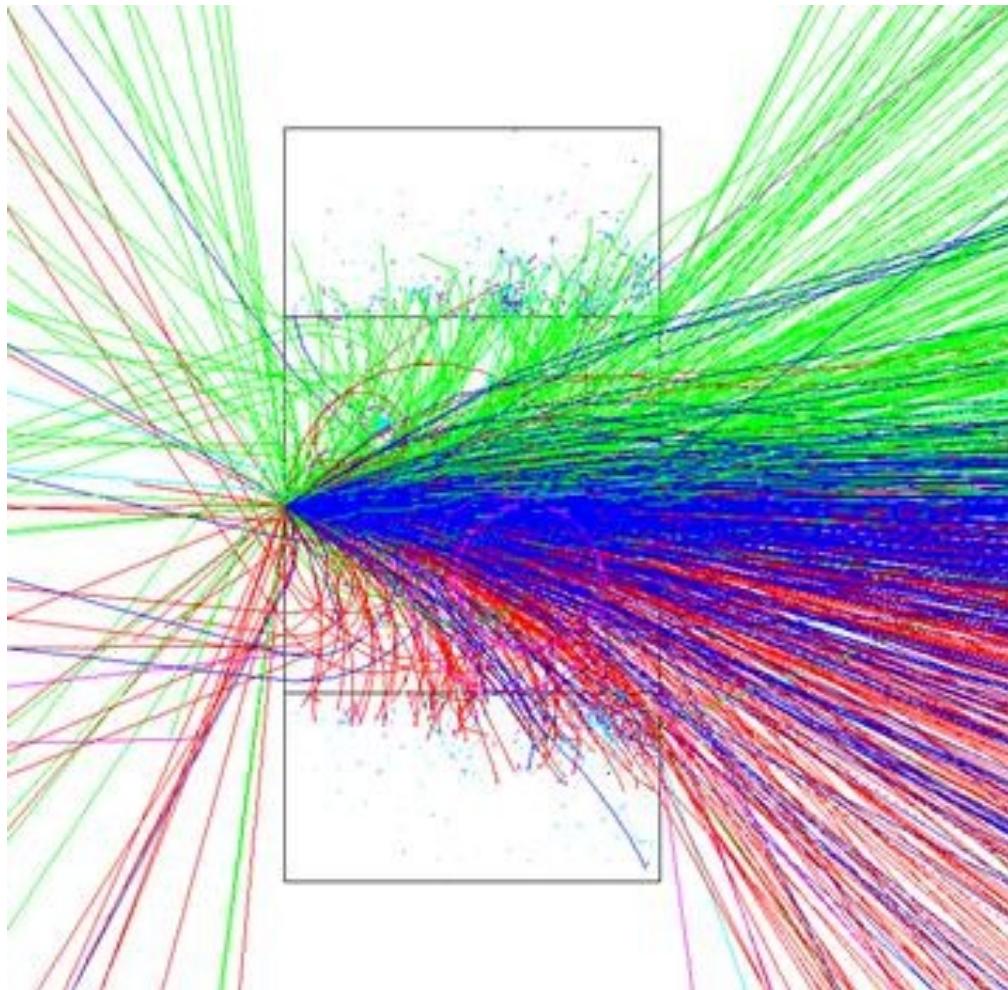
event-by-event fluctuations

Color superconductivity

precursor effects ?



CBM - Experimental Challenge

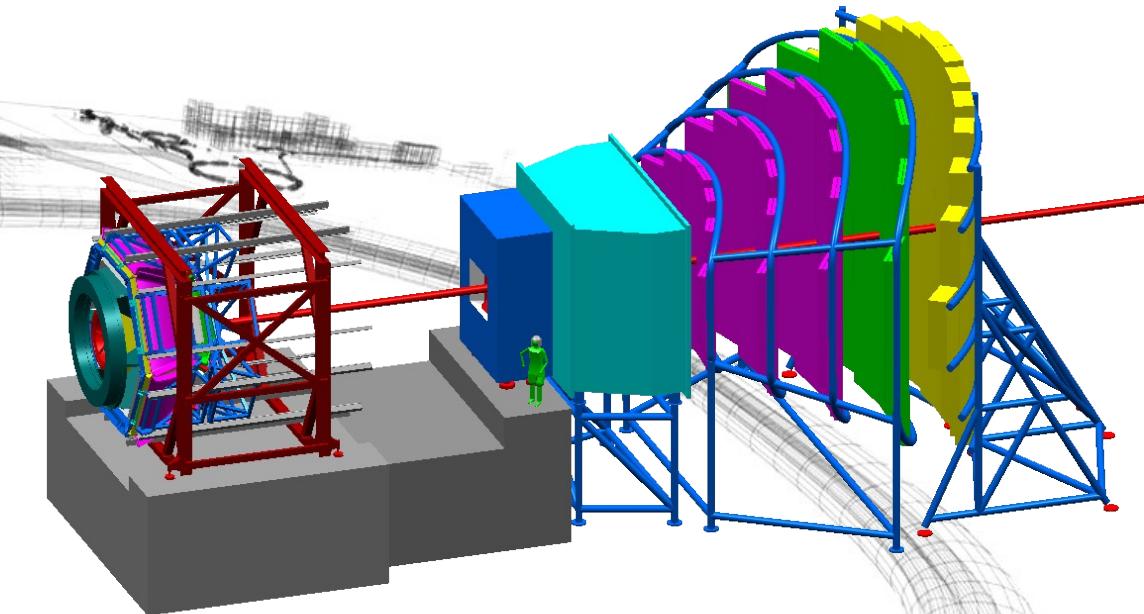
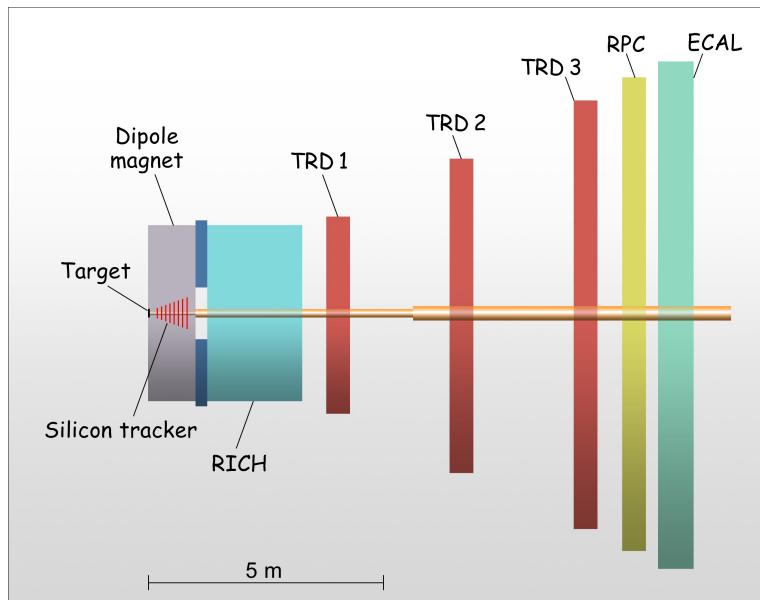


Central Au+Au collision
at 25 AGeV:
URQMD + GEANT

160 p	360 π^-	41 K^+	170 n	330 π^+	13 K^-	$360 \pi^0$	42 K^0
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- 10^7 Au+Au interactions/sec
- 10^9 tracks/sec to reconstruct for first level event selection
- Find D vertices displaced by few 100 μm

CBM - Apparatus



Radiation hard Silicon (pixel/strip) Tracking System
in a magnetic dipole field

Electron detectors: RICH & TRD & ECAL:
pion suppression better 10^4

Hadron identification: TOF-RPC

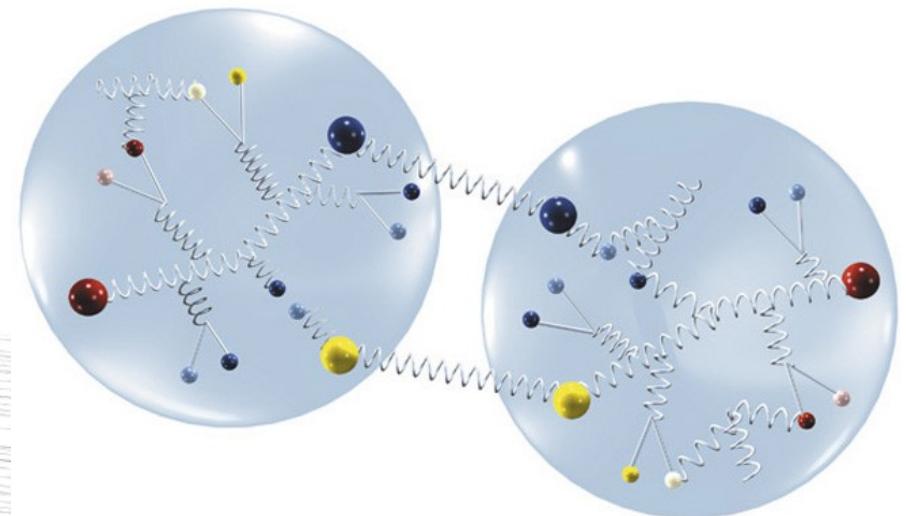
Measurement of photons, π , η , and muons:
electromagnetic calorimeter (ECAL)

High speed data acquisition and trigger system

PANDA - Hadron Physics with Antiprotons

PANDA – antiProton Annihilations at DArmstadt

- Antiproton beam, 1.5 - 15 GeV
- Hadron physics
 - Spectroscopy
 - Medium Modifications
 - Hypernuclei
- High rate spectrometer
- Triggerless readout



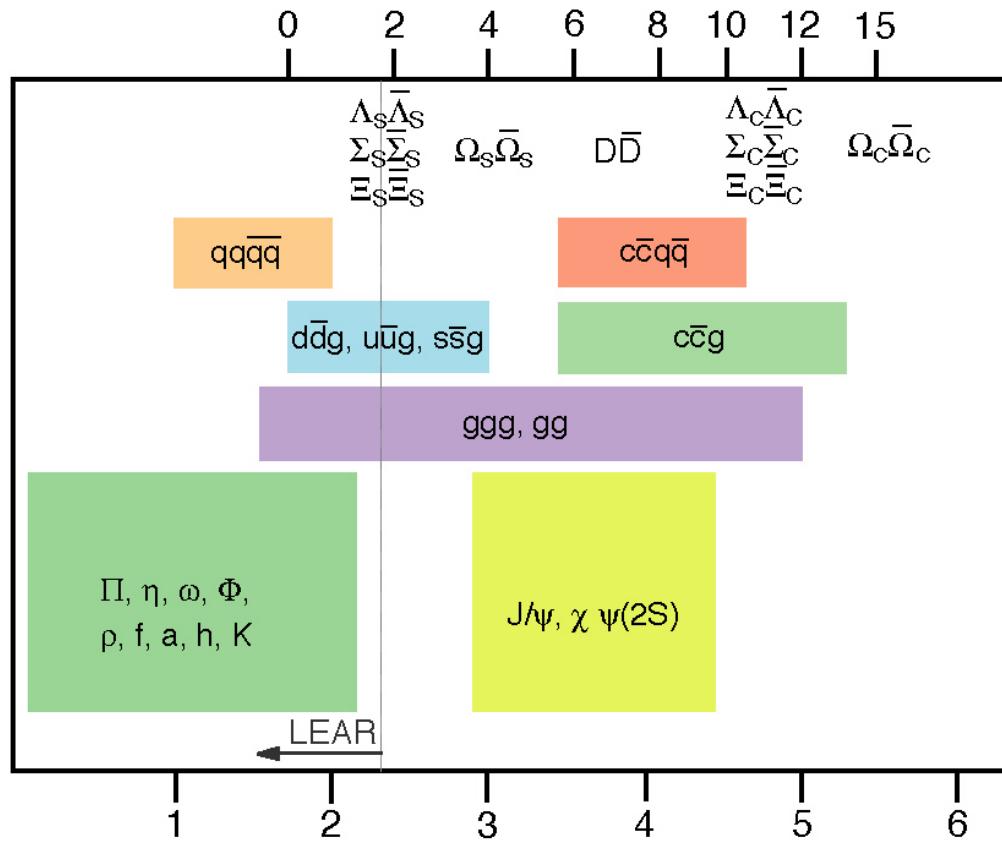
PANDA - Spectroscopy

Spectroscopy with antiprotons

- $p\bar{p}$ machine allows $\Delta E \sim 100$ keV vs. $\Delta E \sim 10$ MeV in e^+e^-
- obtain m and Γ with high precision
- e^+e^- produces only $J^{PC} = 1^{--} (\gamma)$
- $p\bar{p}$ accesses all states

Charm spectroscopy

- Charmonium: Positronium of QCD
- Charm hybrids
 - $c\bar{c}$ -states narrow, understood
 - Little interference between $c\bar{c}g$ and $c\bar{c}$ -states
 - Mass 4–4.5 GeV, $c\bar{c}g$ narrow,
 - $\sim \sigma(p\bar{p} \rightarrow c\bar{c})$
- Charm meson spectroscopy



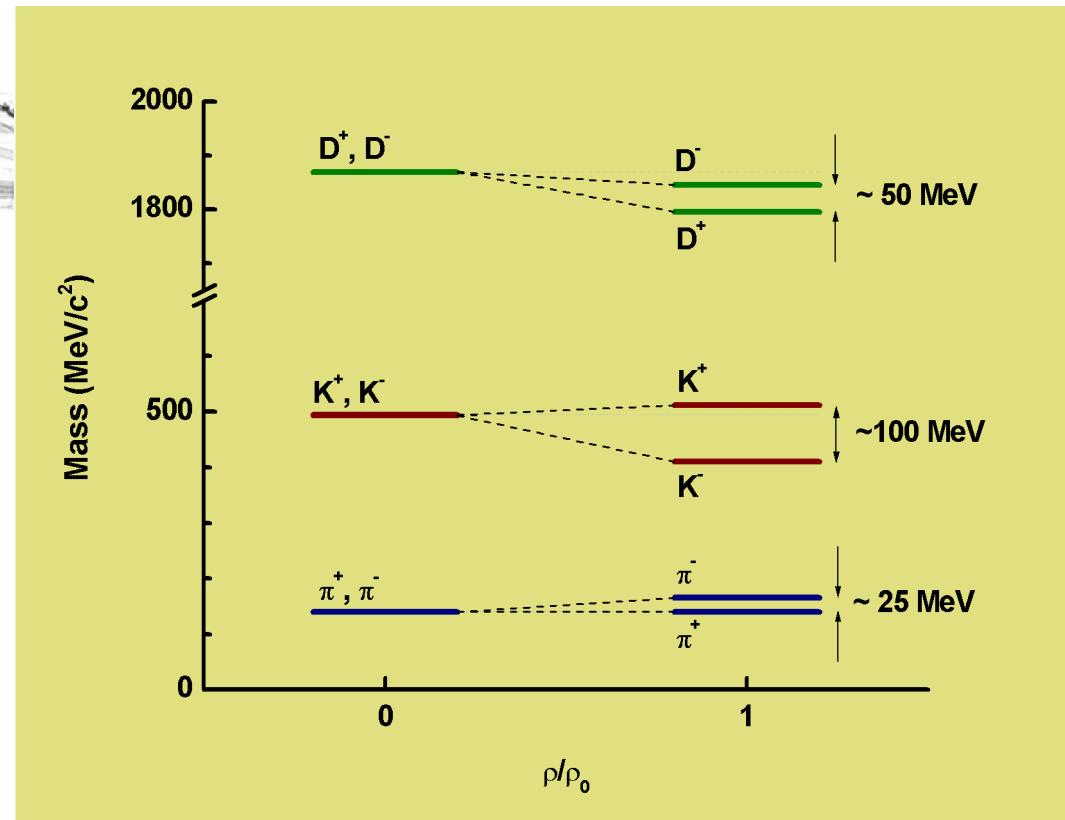
PANDA - Nuclear Physics

Charm in the Medium

- Mesons in nuclear matter
 - Masses change in nuclei
 - D-mass lower
- Enhanced charmonium states due to lower D \bar{D} threshold
- J/ ψ absorption in nuclei

Hypernuclei

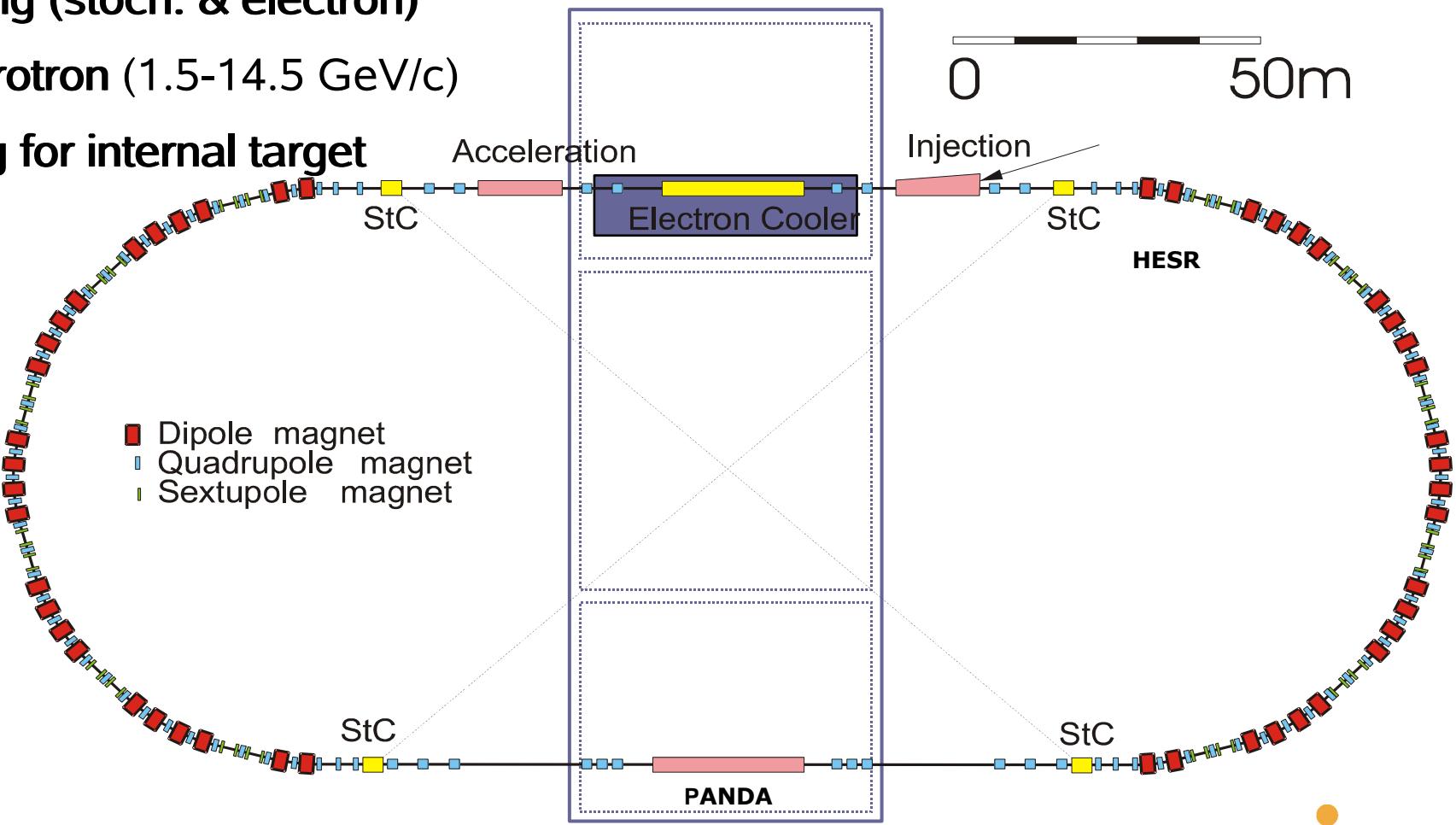
- 3rd dimension in nuclear chart
- Study interactions of nucleons in the nuclear potential
- PANDA: Double Hypernuclei
- ➔ $\Lambda\Lambda$ interaction in nucleus



High Energy Storage Ring

HESR

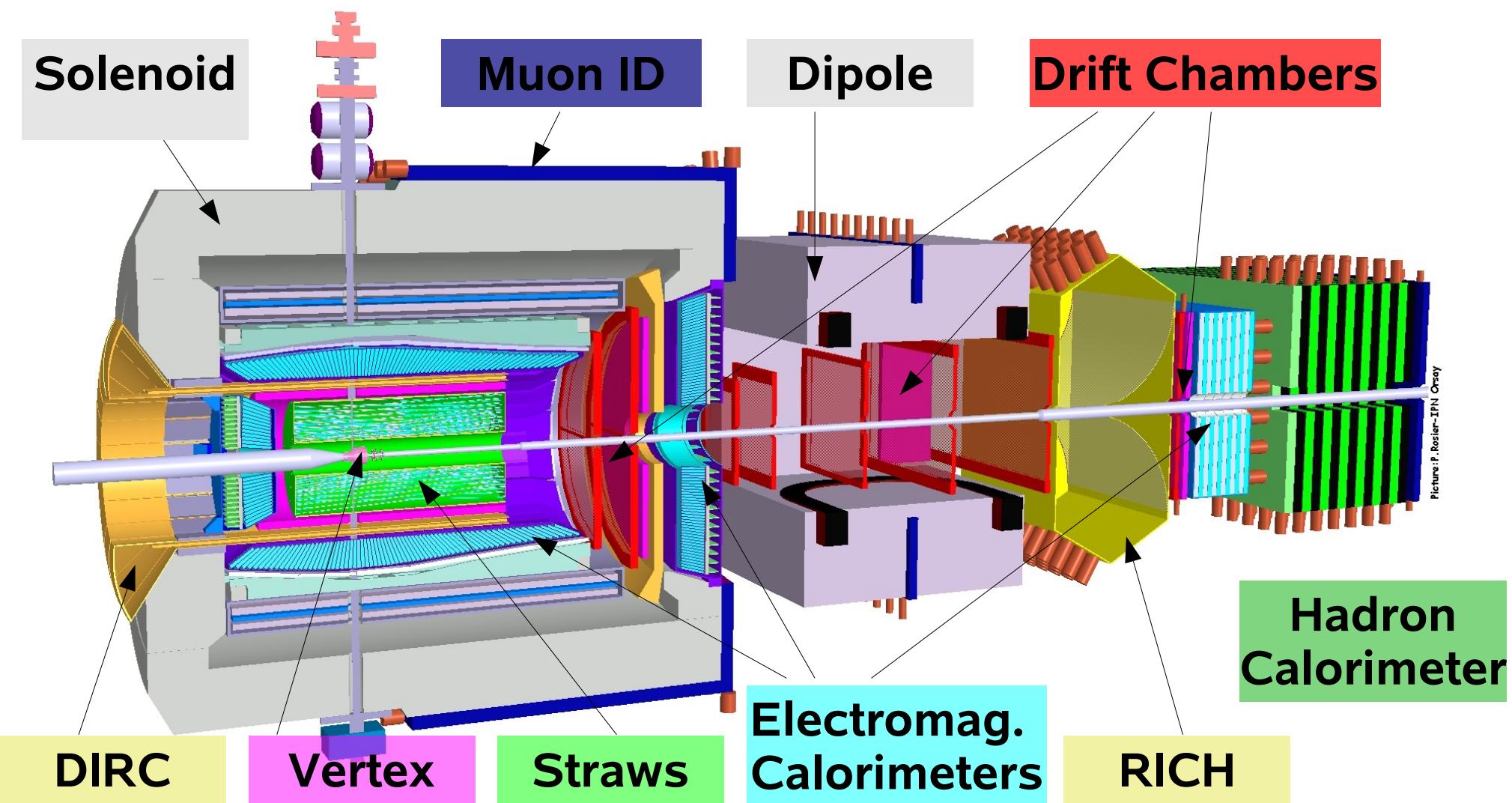
- Injection of \bar{p} at 3.7 GeV
- Beam cooling (stoch. & electron)
- Slow synchrotron (1.5-14.5 GeV/c)
- Storage ring for internal target operation



PANDA Spectrometer

TARGET SPECTROMETER

FORWARD SPECTROMETER



PAX - Polarized Antiprotons

Polarized Antiprotons

Complementary Access to Spin Physics

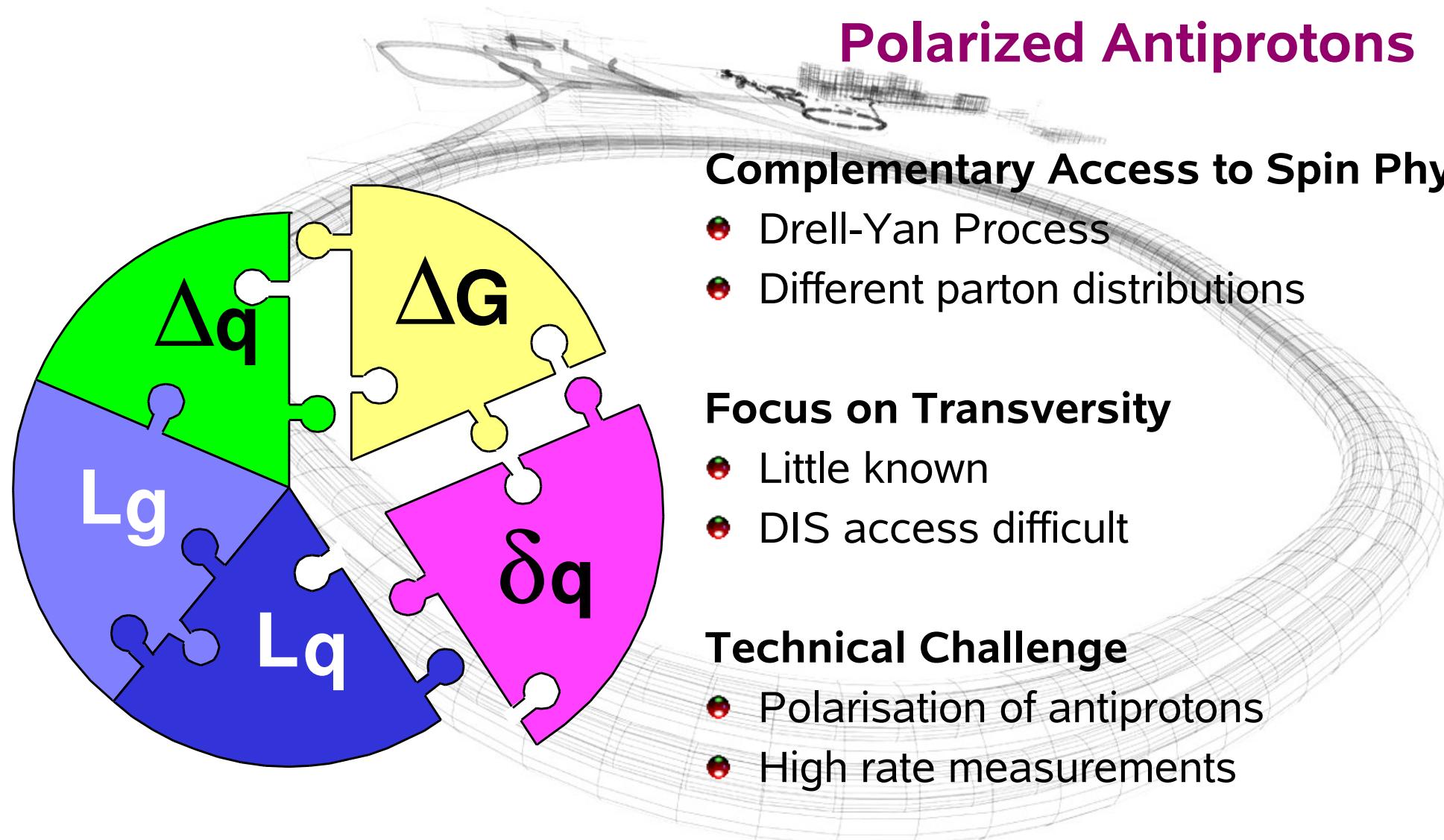
- Drell-Yan Process
- Different parton distributions

Focus on Transversity

- Little known
- DIS access difficult

Technical Challenge

- Polarisation of antiprotons
- High rate measurements



PAX - Spin Structure

Deep inelastic semi-inclusive cross section

$$\sigma^{ep \rightarrow eh} \sim \sum DF^{p \rightarrow q} \otimes \sigma^{eq \rightarrow eq} \otimes FF^{q \rightarrow h}$$

DF: Parton Distribution Function;

FF: Hadron Fragmentation Function

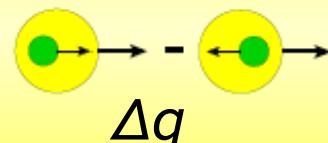
Twist-2 Distributions functions

Unpolarized f_1



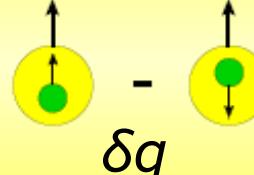
q

Helicity g_1

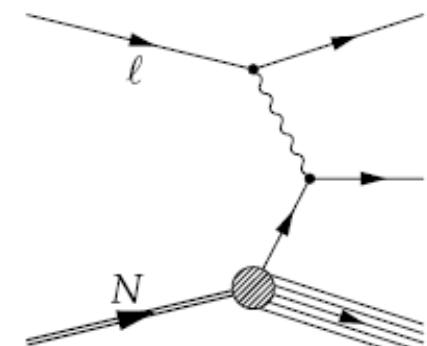


Δq

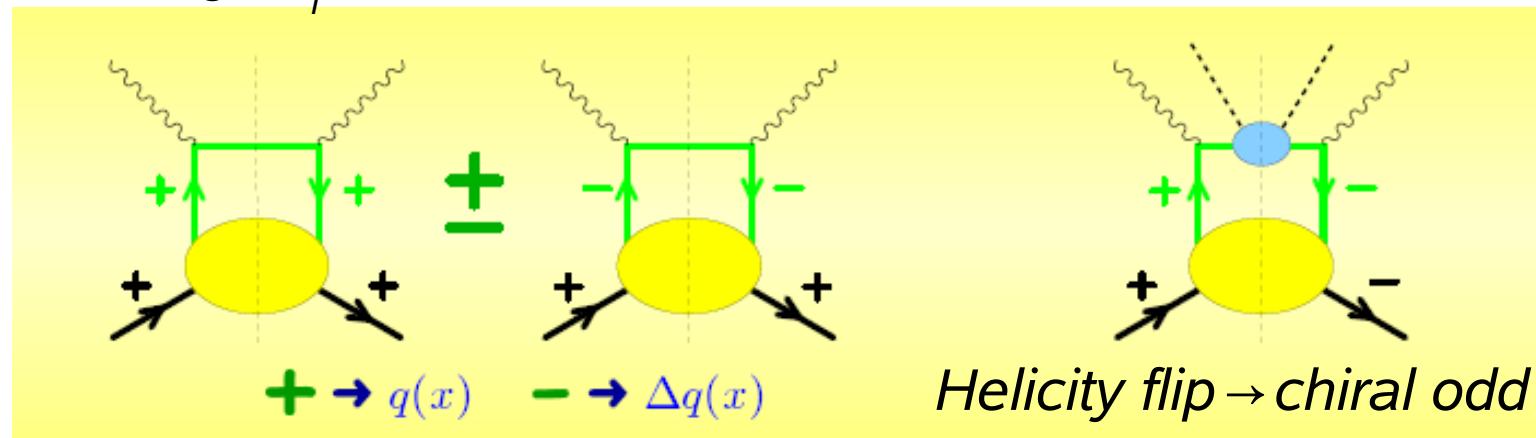
Transversity h_1



δq



Transversity h_1



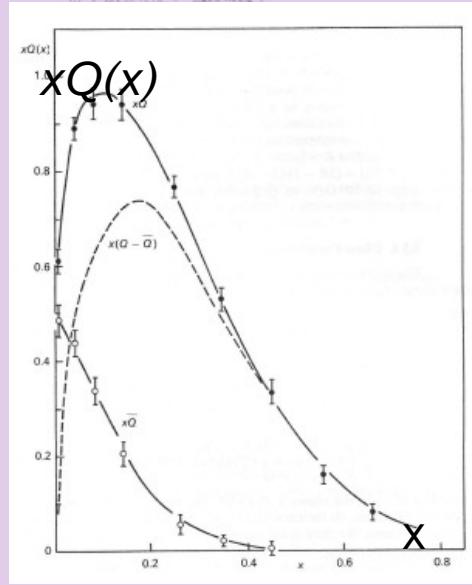
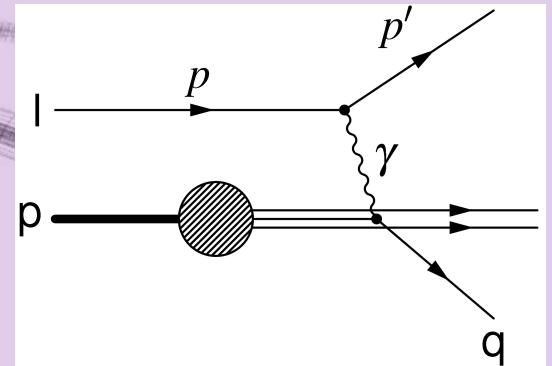
PAX - Transversity

Accessing Transversity

Deep Inelastic Scattering

Access to δq via
fragmentation

COMPASS, HERMES



Drell-Yan Process

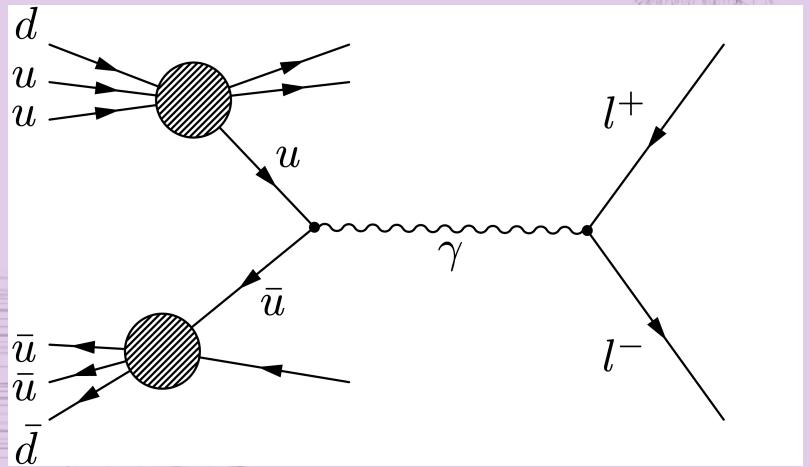
Direct access
to δq

RHIC

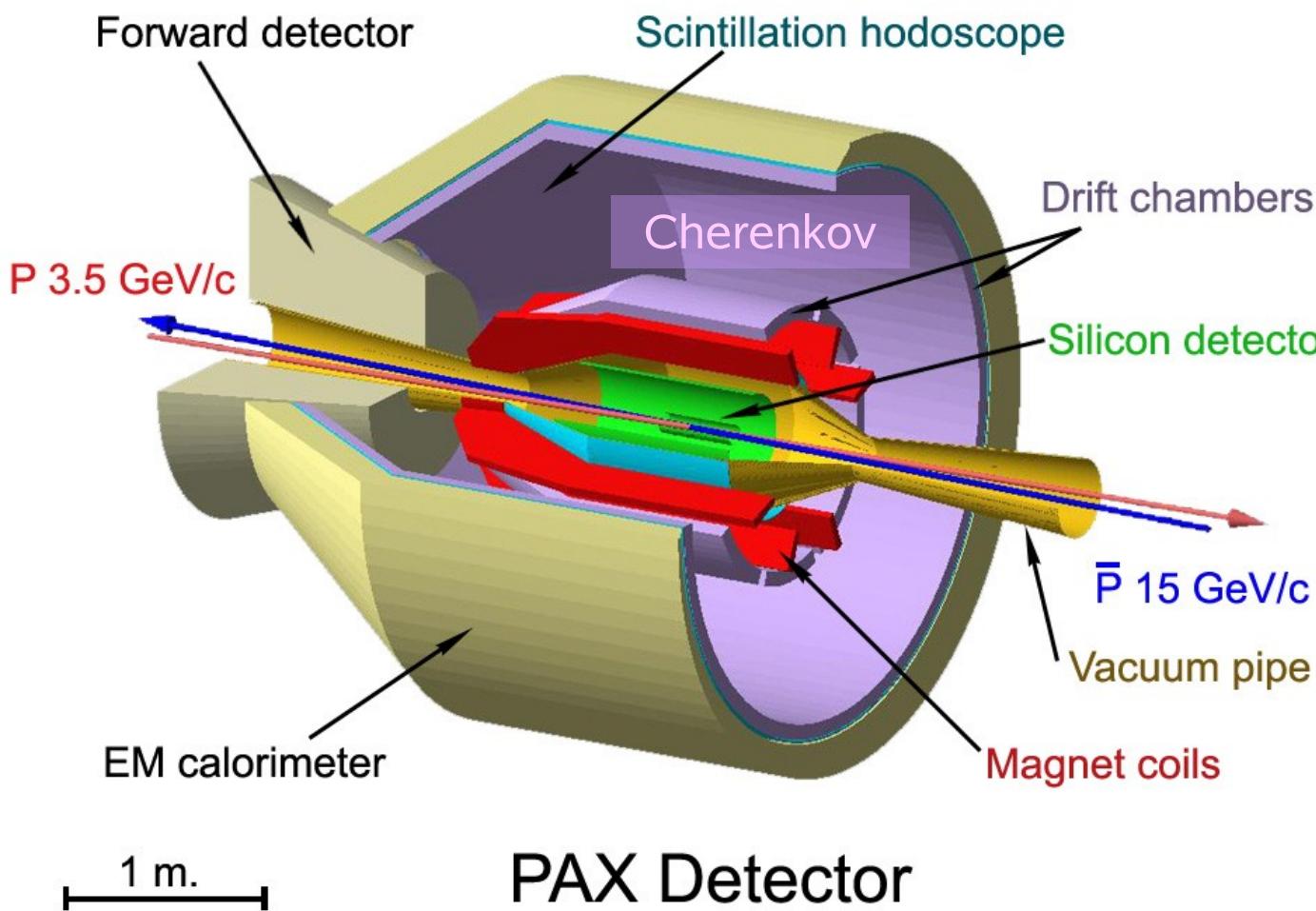
\bar{q} from sea

PAX

valence \bar{q}



PAX Apparatus



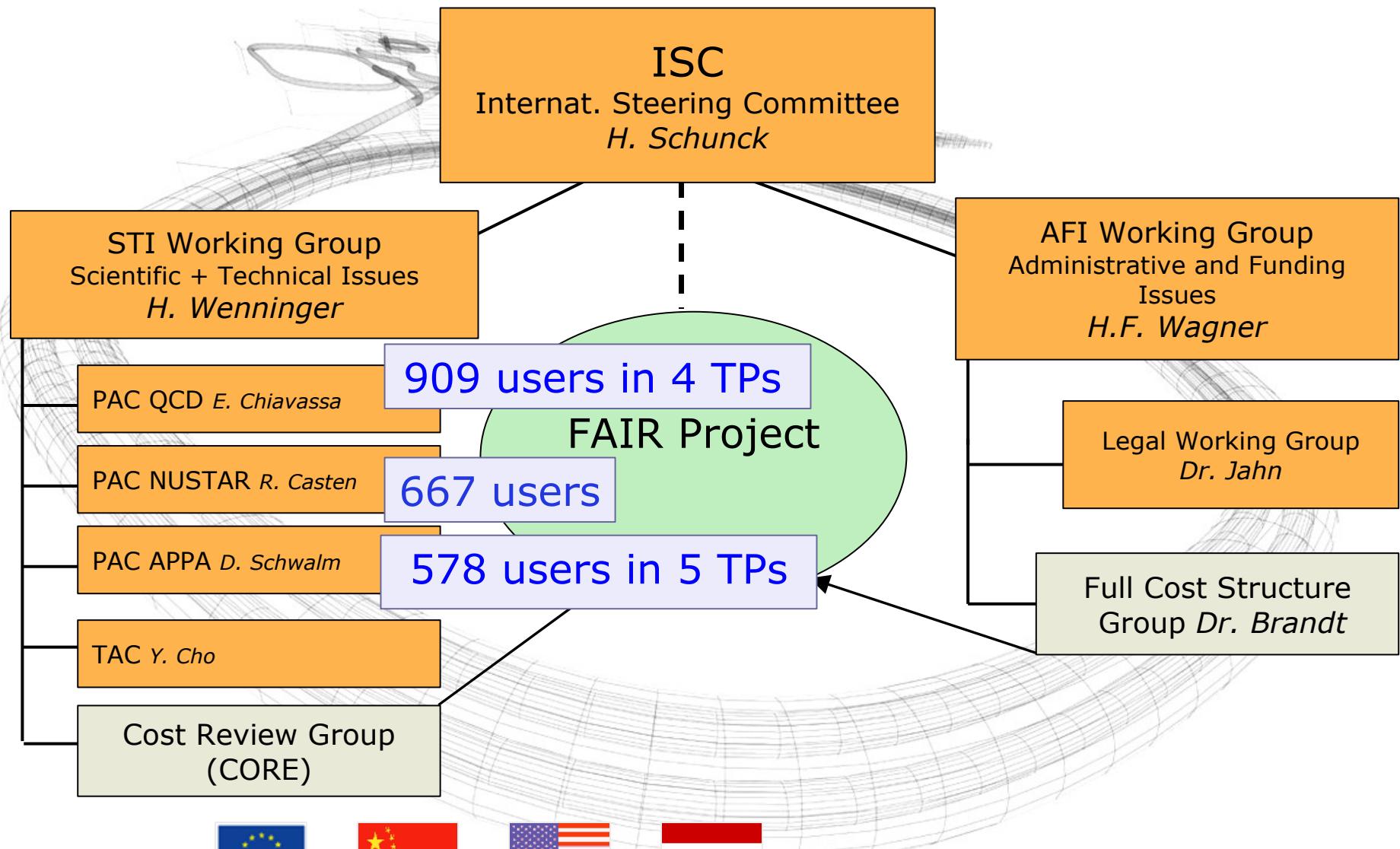
\bar{p} Polarisation

- Spin filter method: Polarisation transfer from electrons
- Siberian snake
- Polarise at low E, then accelerate

PAX Setup

- Optimized for collider
- Azimuthal symmetry
- PID for semi-inclusive
- Silicon for vertex

The International Steering Committee for FAIR

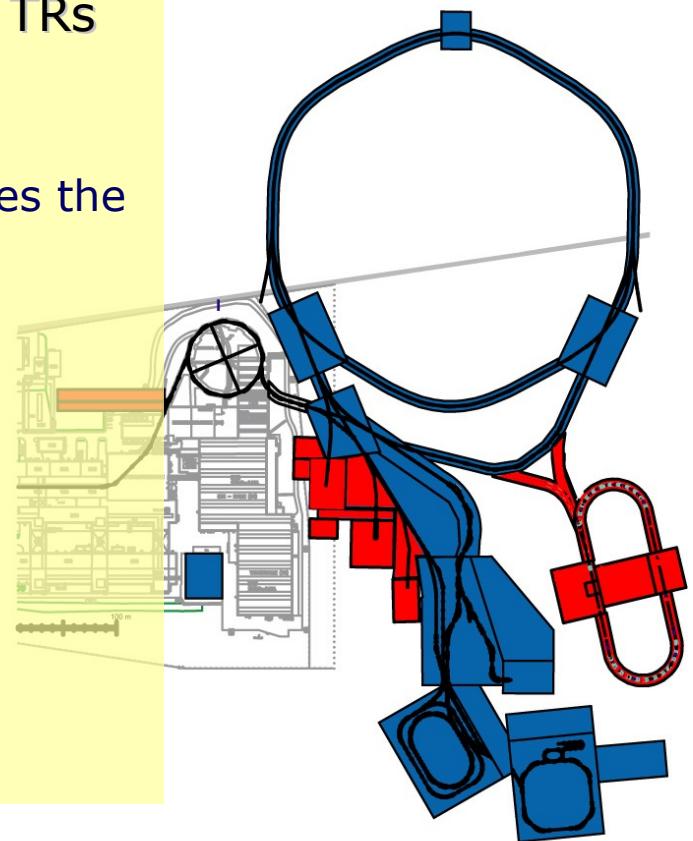


Outlook

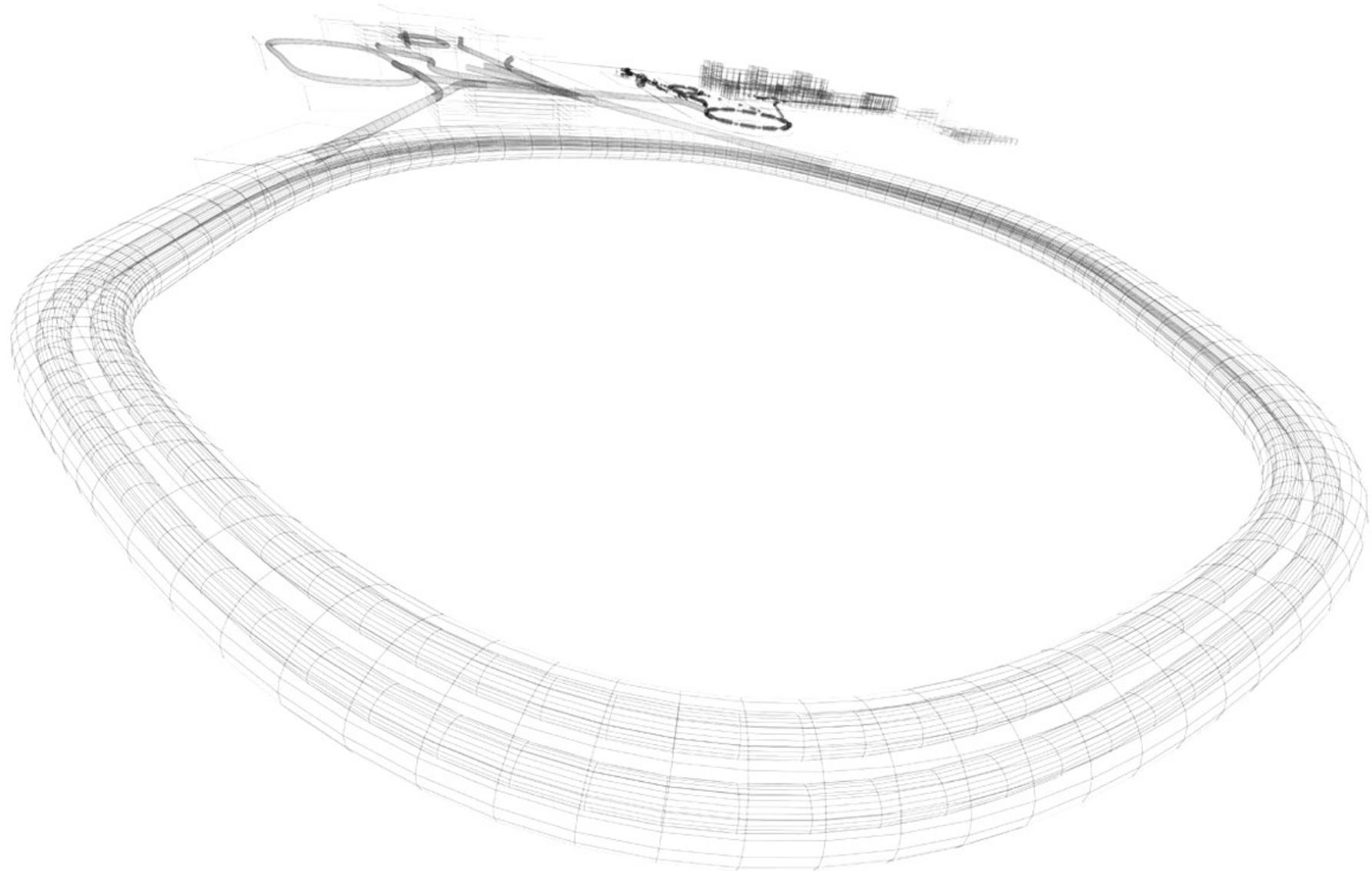
- Submission and Evaluation of TRs (Technical Reports -Accelerator) and TPs (Technical Proposals)
- Determination of costs of each subproject

→ New Planning based on new information from TRs and TPs

- 2005** International Steering Committee (ISC) defines the Project based on the scientific merits and the resources available, prepares Contract Determination of Legal Structure of FAIR
- 2006** Contract on FAIR signed by Member States, followed by Start of construction of FAIR
- 2006 – 2010** Technical Design Reports (TDR) for the sub systems
- 2008** Start of civil construction
- 2011 – 2014** Commissioning of FAIR



Backup



PANDA Trigger and DAQ

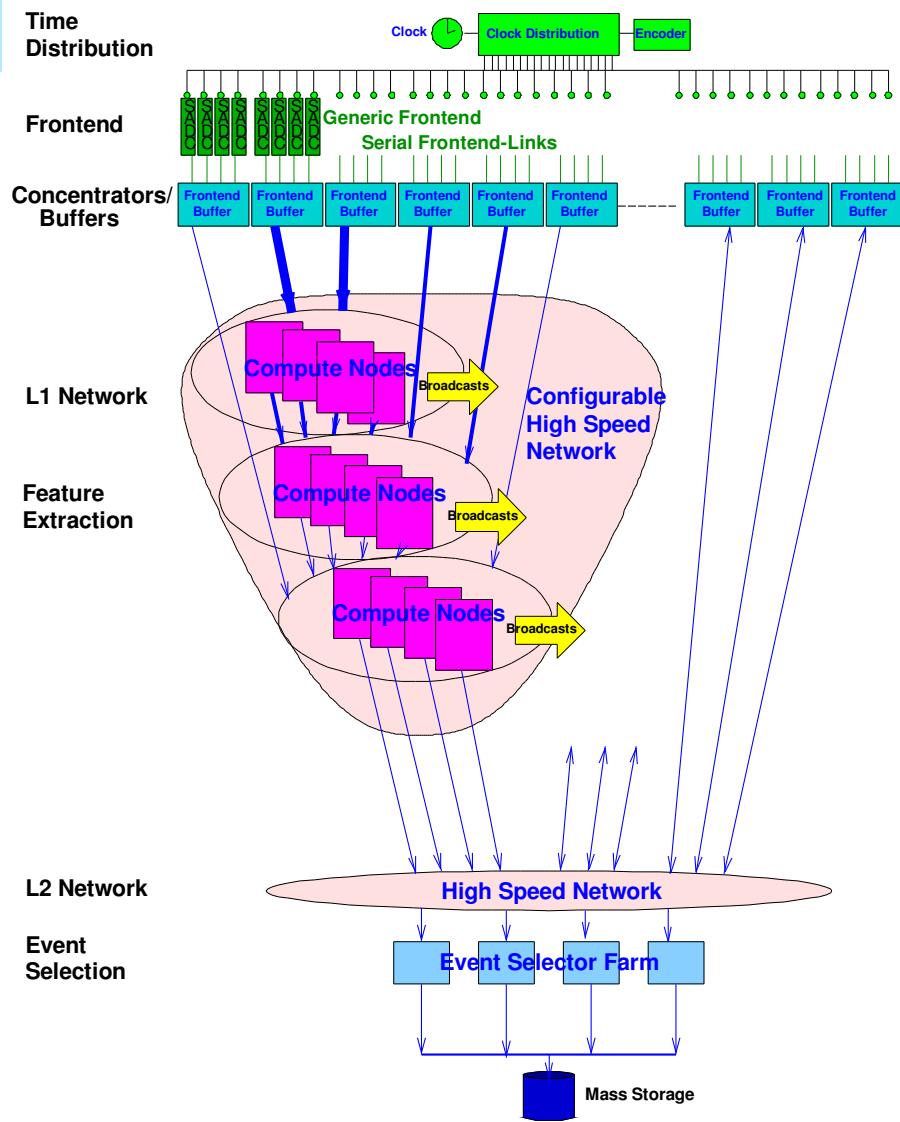
Programmable Physics Machine

Components

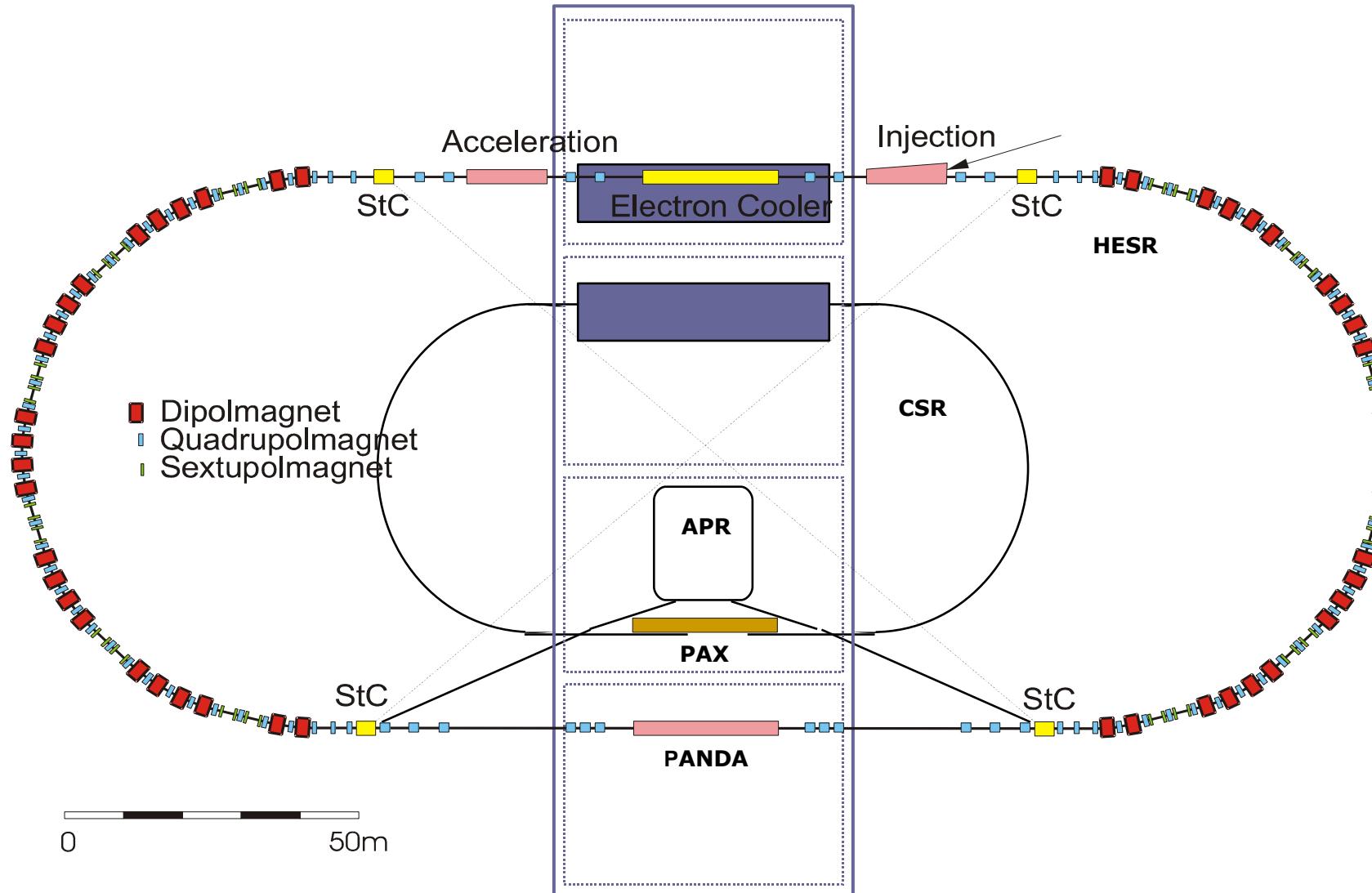
- Time distribution system
- Intelligent frontends
- Powerful compute nodes
- Configurable high speed network

Data Flow

- Data reduction
- First selection at high rate
- Further selections at lower rates, but with more detectors
- Data logging after online reconstruction



PAX - Storage Ring Setup



PAX - Polarisation of Antiprotons

\bar{p} Polarisation

- Spin filter method: Polarisation transfer from electrons
- Polarise at low E, then accelerate
- Siberian snake

