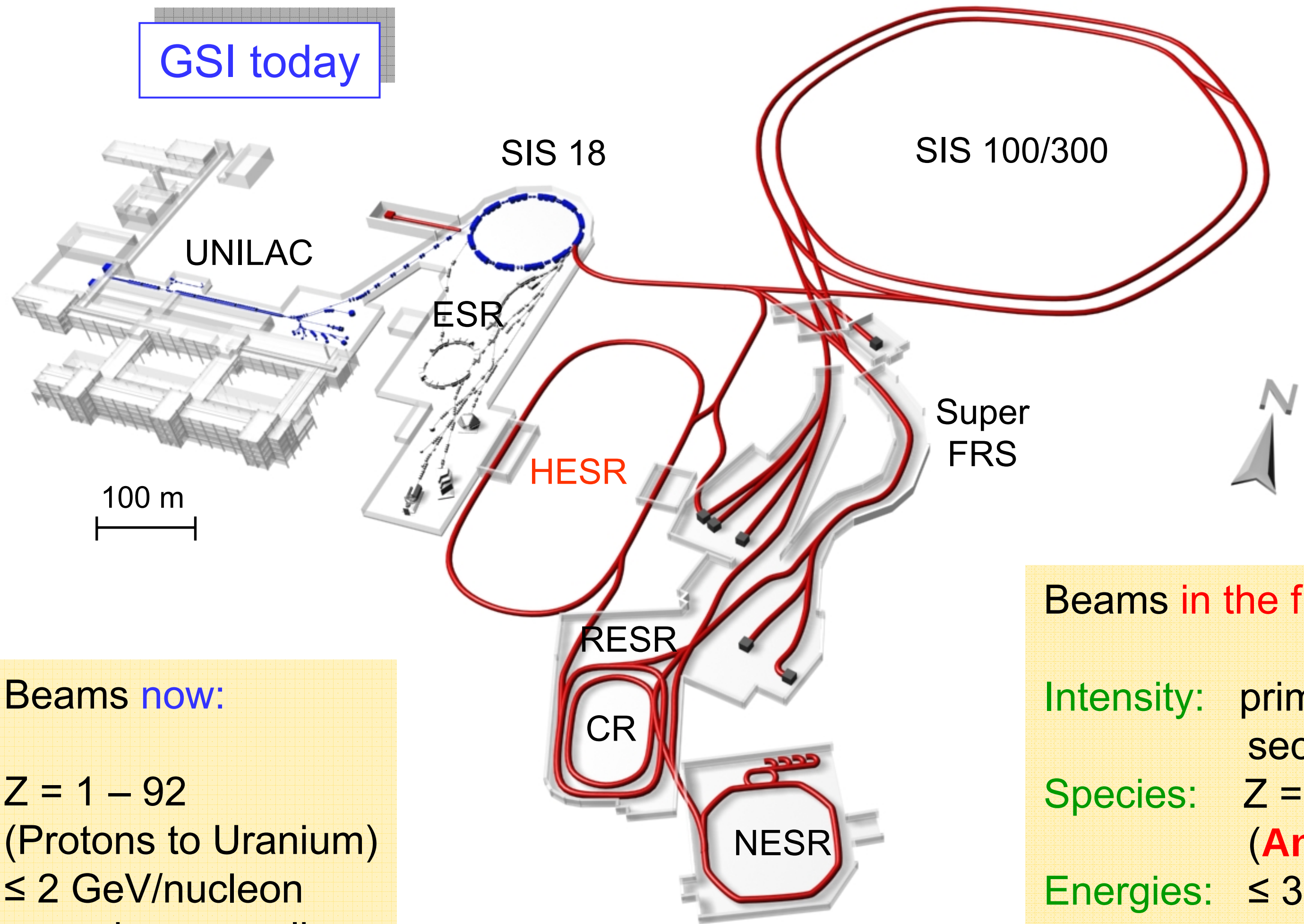
Facility for Antiproton and Ion Research


Heavy-Ion Synchrotron
Heavy-Ion Storage Ring
Linear Accelerator
Present GSI facility in Darmstadt/Germany

FAIR

GSI today

Future Facility



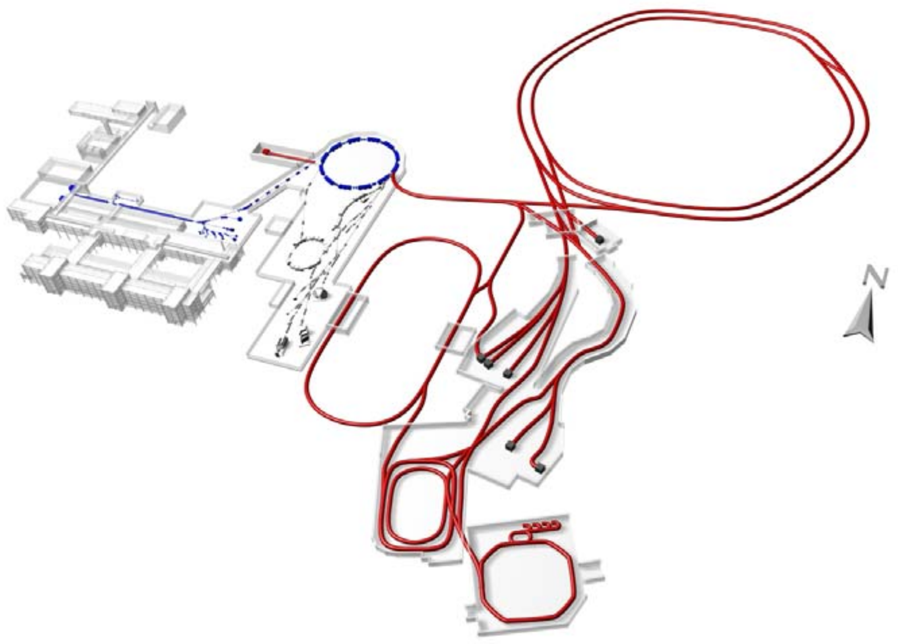
Beams now:

Z = 1 – 92
(Protons to Uranium)
≤ 2 GeV/nucleon
some beam cooling

Beams in the future:

Intensity: primary 100-fold
secondary 10 000-fold
Species: Z = **-1** to 92
(**Anti-protons** to Uranium)
Energies: ≤ 35 - 45 GeV/u
Precision: full beam cooling

FAIR characteristics



Key Technical Features

- Rapidly cycling superconducting magnets
- Cooled beams

Primary Beams

- 10^{12}/s; 1.5-2 GeV/u; $^{238}U^{28+}$
- Factor 100-1000 over present intensity
- $2(4)\times10^{13}$/s 30 GeV protons
- 10^{10}/s $^{238}U^{92+}$ up to 35 GeV/u
- up to 90 GeV protons

Secondary Beams

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

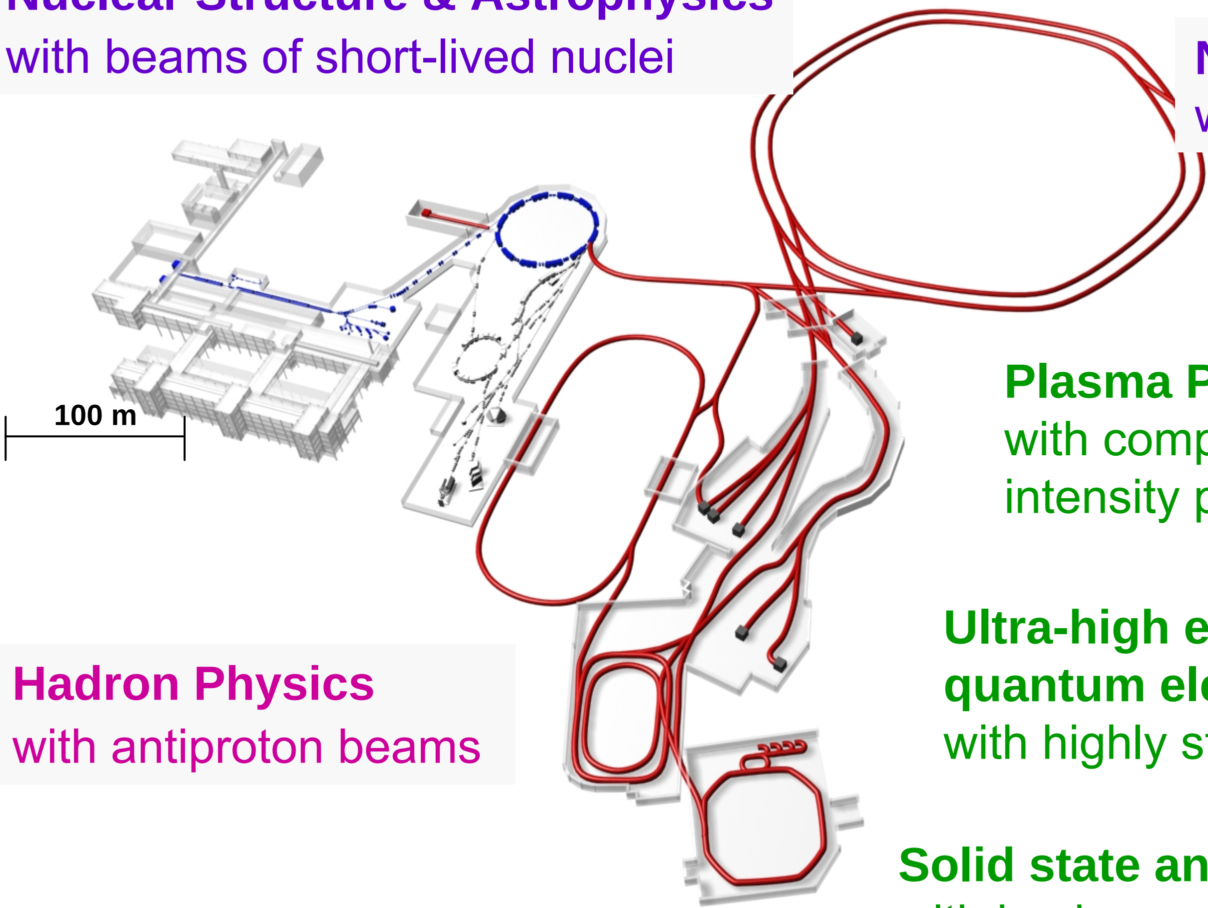
Storage and Cooler Rings

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

Six research areas at FAIR

Nuclear Structure & Astrophysics
with beams of short-lived nuclei

Nuclear Matter Physics
with 35-45 GeV/u HI beams



Plasma Physics
with compressed ion beams & high-intensity petawatt-laser

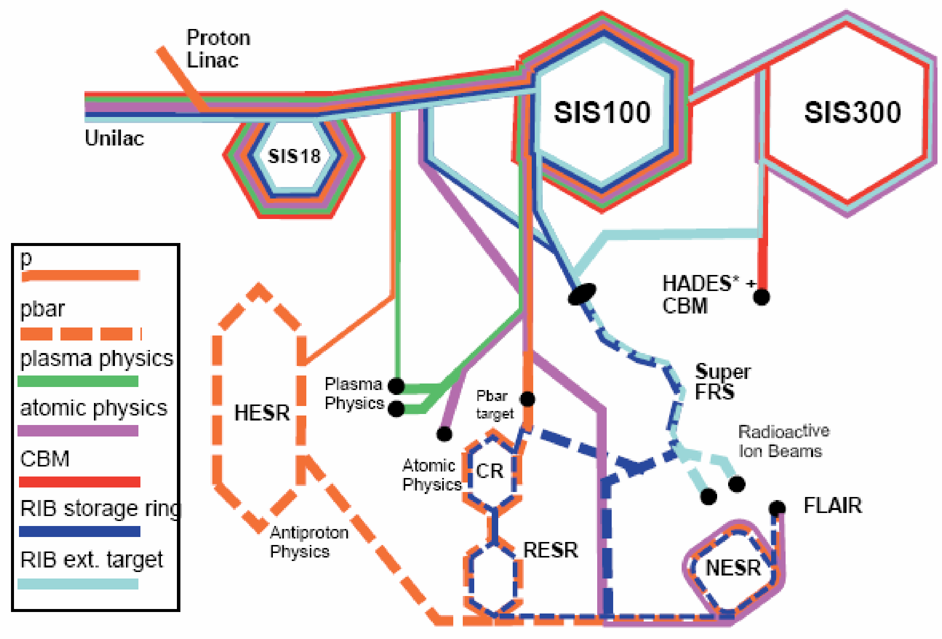
Ultra-high electromagnetic fields & quantum electrodynamics
with highly stripped ions and antimatter

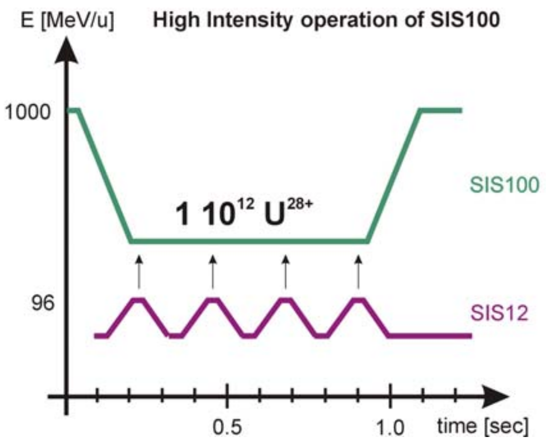
Hadron Physics
with antiproton beams

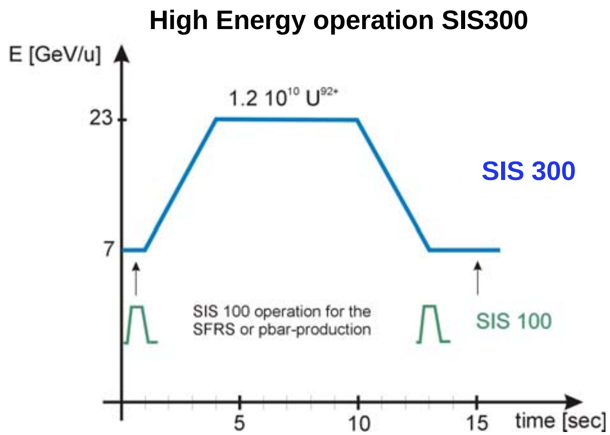
Solid state and biological applications
with ion beams

Accelerator chain

Highly Parallel Operation:

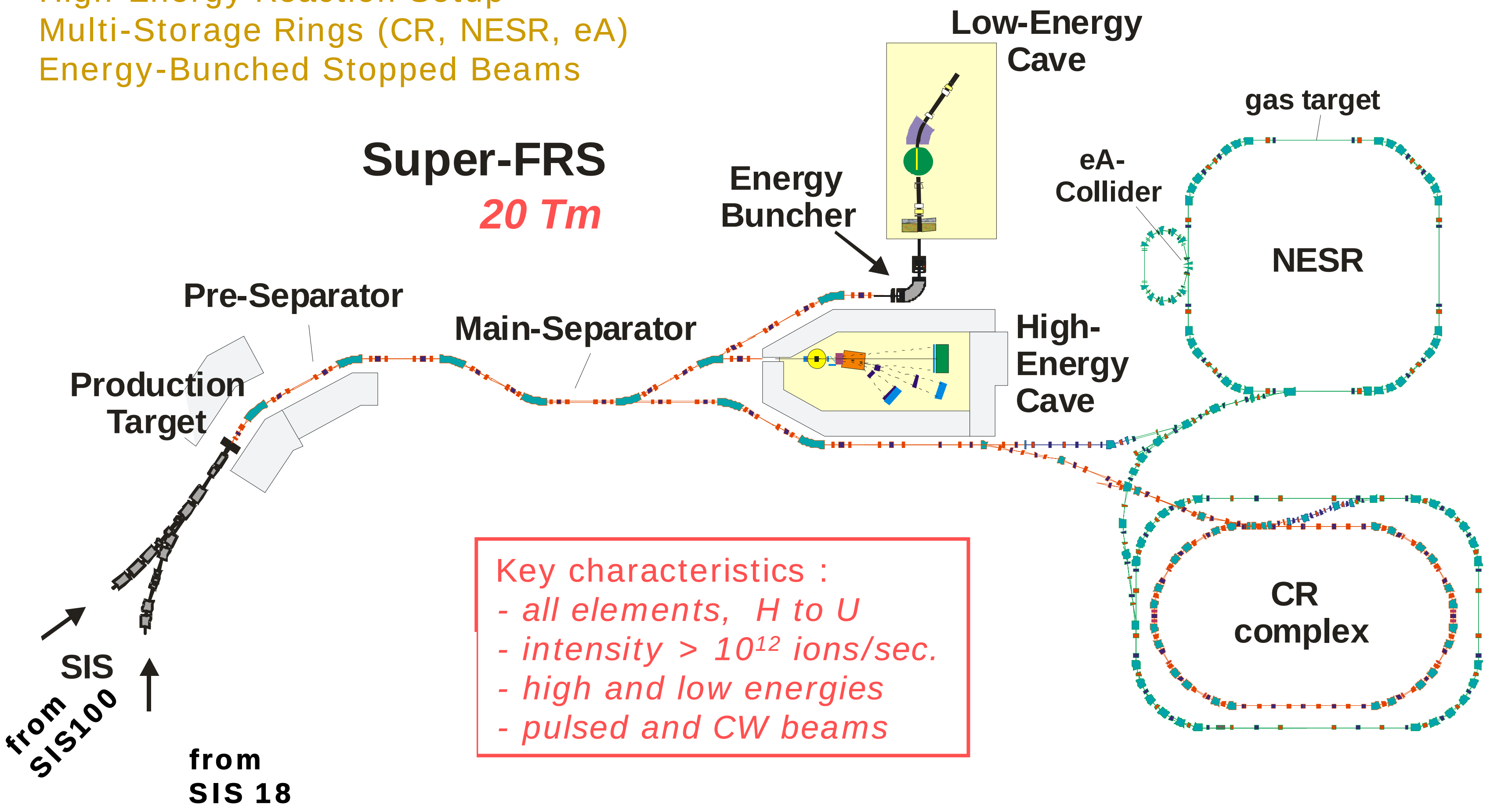






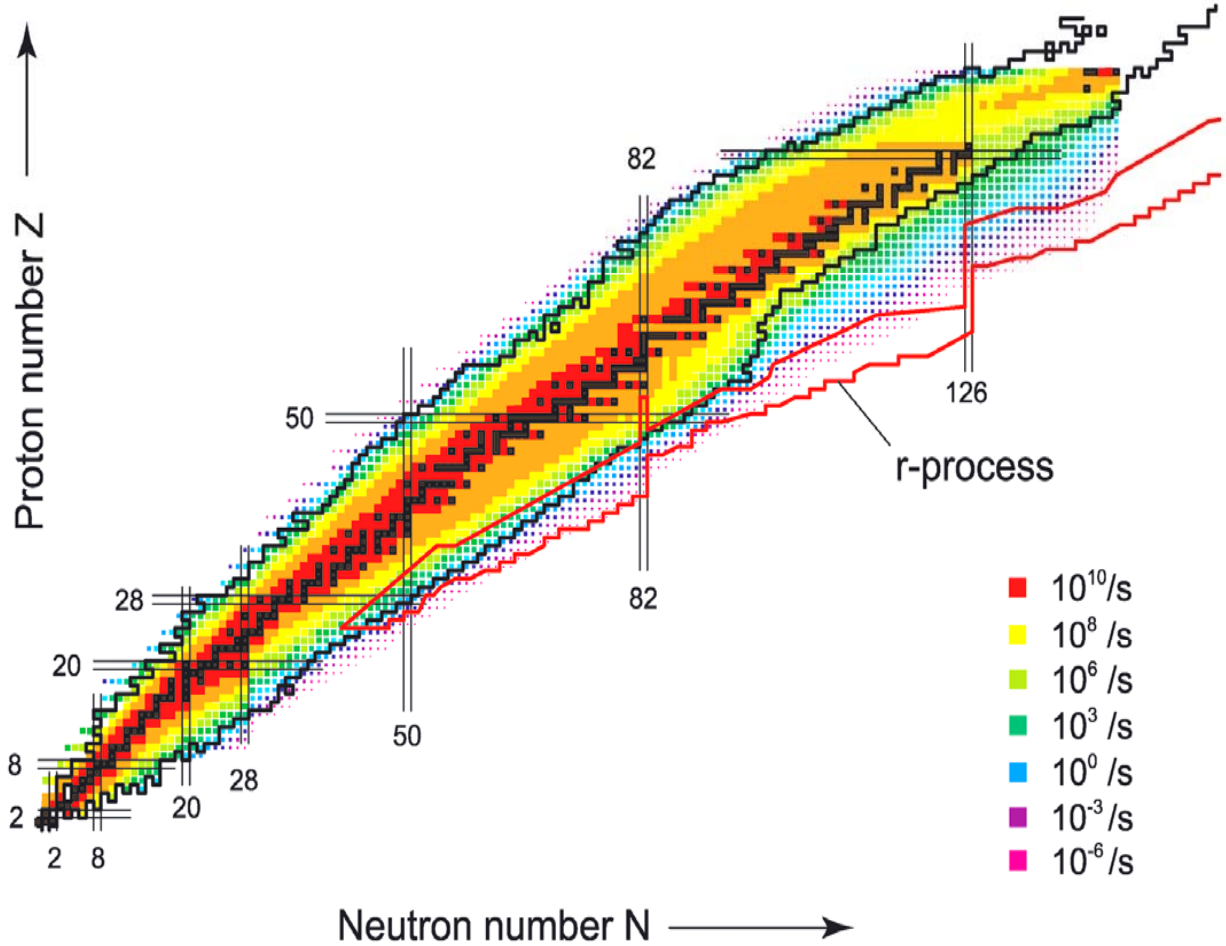
Rare isotope beams (0-1.5A GeV in flight)

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

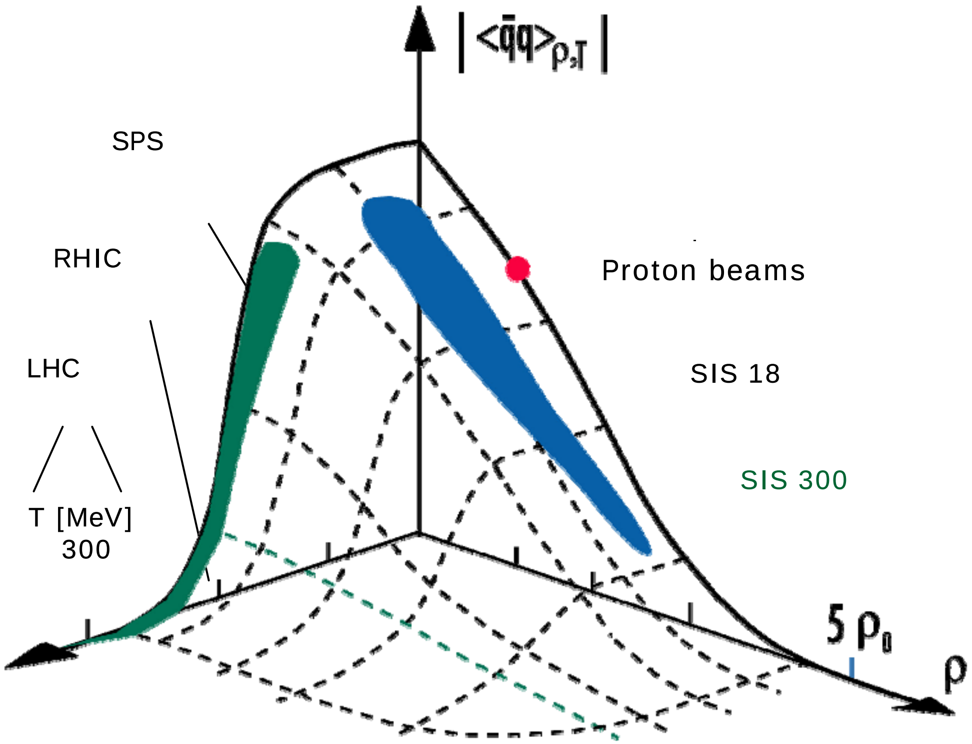


Key characteristics :
- *all elements, H to U*
- *intensity > 10^{12} ions/sec.*
- *high and low energies*
- *pulsed and CW beams*

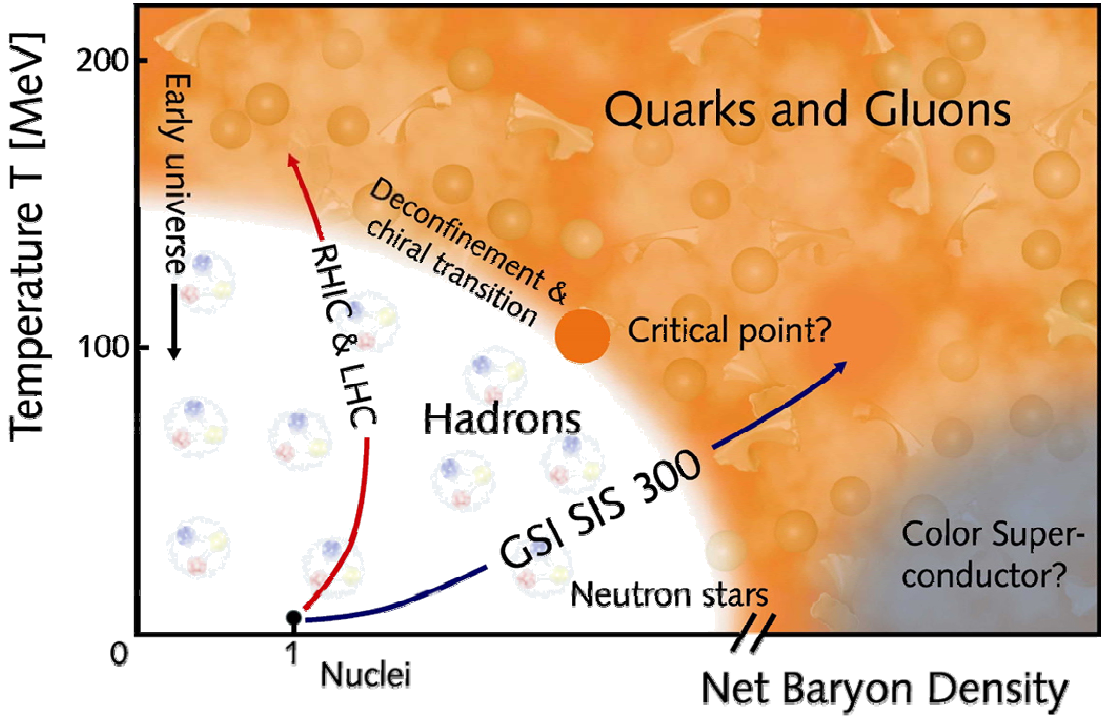
Heavy ion production rate



Compressed baryonic matter (CBM)

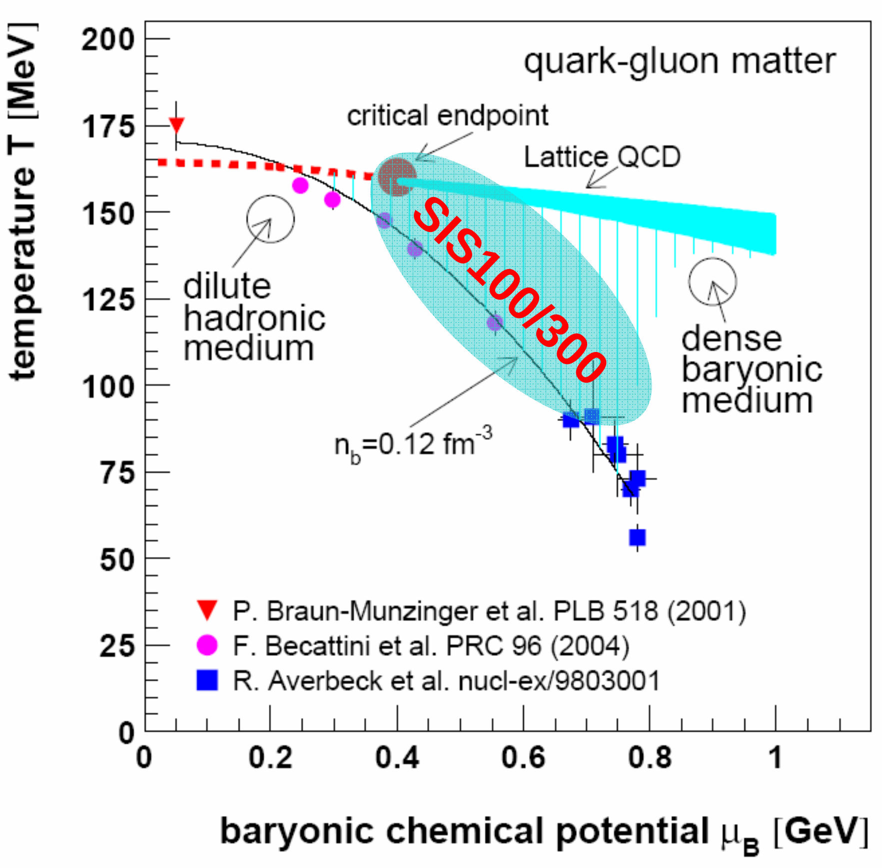


Phase diagram of strongly interacting matter

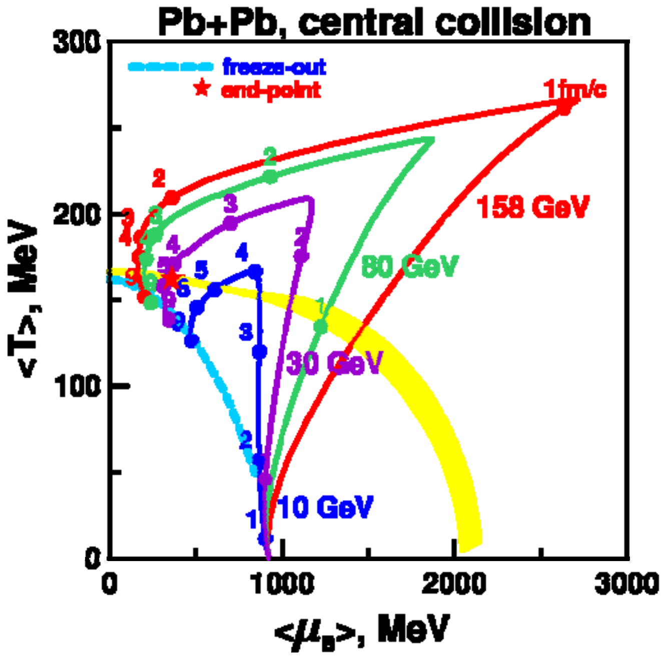


- SPS, RHIC, LHC:
  - high temperature, low baryon density
- SIS300:
  - moderate temperature, high baryon density

Mapping the QCD phase diagram



Critical end-point:
Z. Fodor, S. Katz, hep-lat/0402006, S. Ejiri et al., hep-lat/0312006

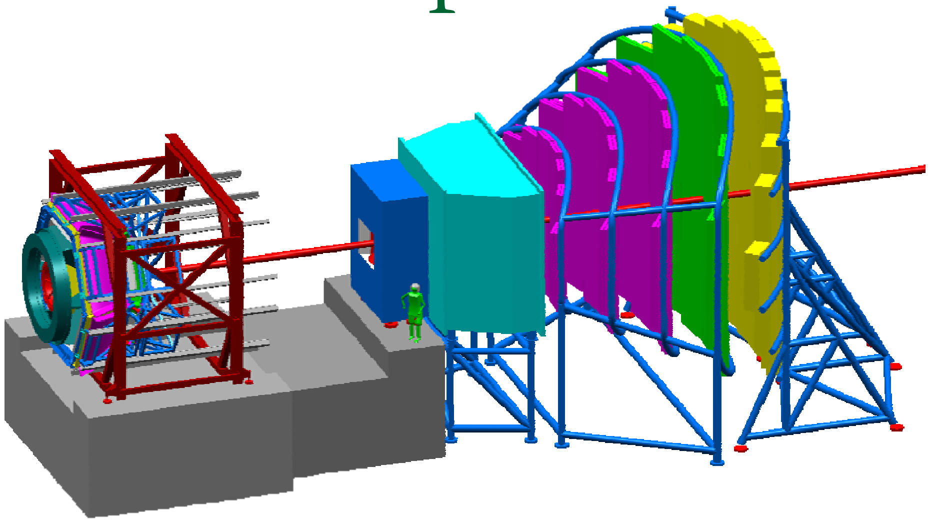


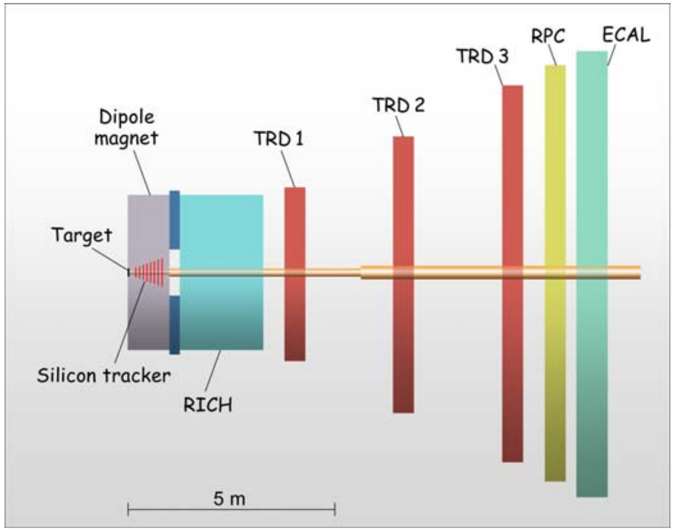
Hadron gas EOS:
V.Toneev, Y. Ivanov et al.
nucl-th/0309008

CBM Experiment - Objectives

- In-medium modifications of hadrons
  - onset of chiral symmetry restoration at high ρ_B
  - measure: ρ, ω, ϕ → 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 setup



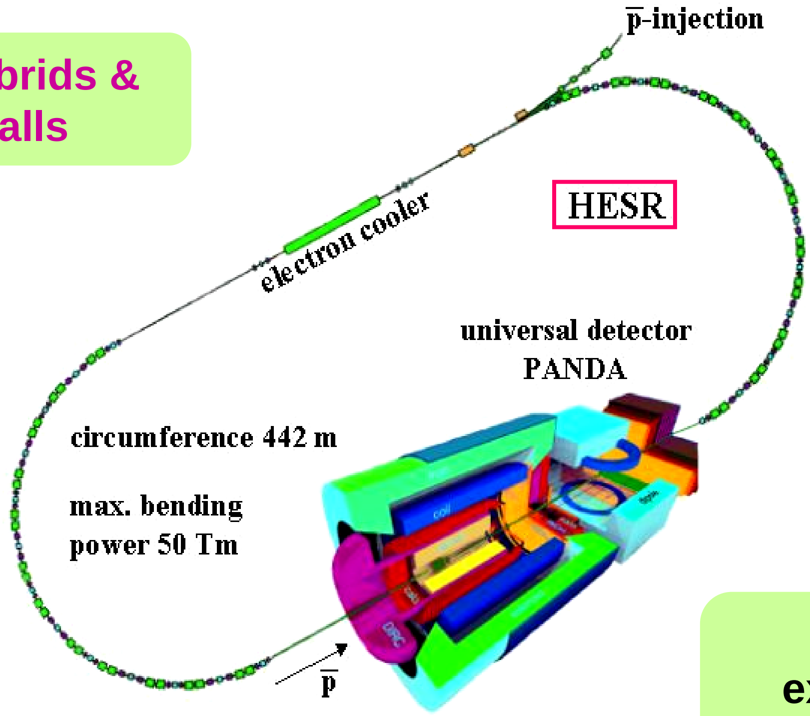


- Radiation hard Silicon (pixel/strip) Tracking System
  - in a magnetic dipole field
- Electron detectors: RICH & TRD & ECAL:
  - pion suppression better 10^4
- Hadron identification: TOF-RPC
- Measurement of photons, π, η, and muons:
  - electromagnetic calorimeter (ECAL)
- High speed data acquisition and trigger system

PANDA physics programme

Charmonium spectroscopy

Exotics: charmed hybrids & heavy glueballs



Time-like form factors

Medium modifications of charmed mesons

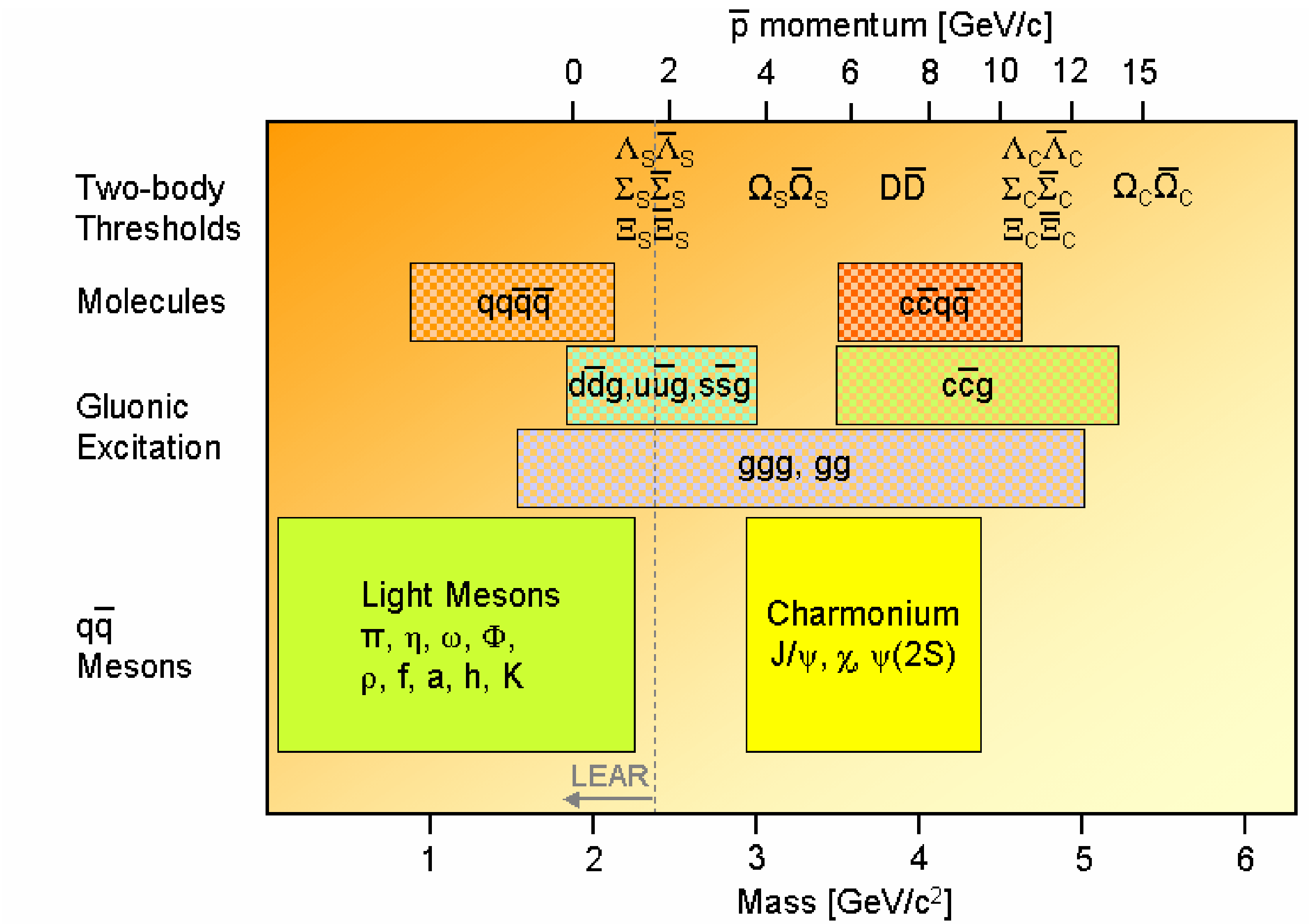
Drell-Yan processes

CP-violation (D & Λ - sector)

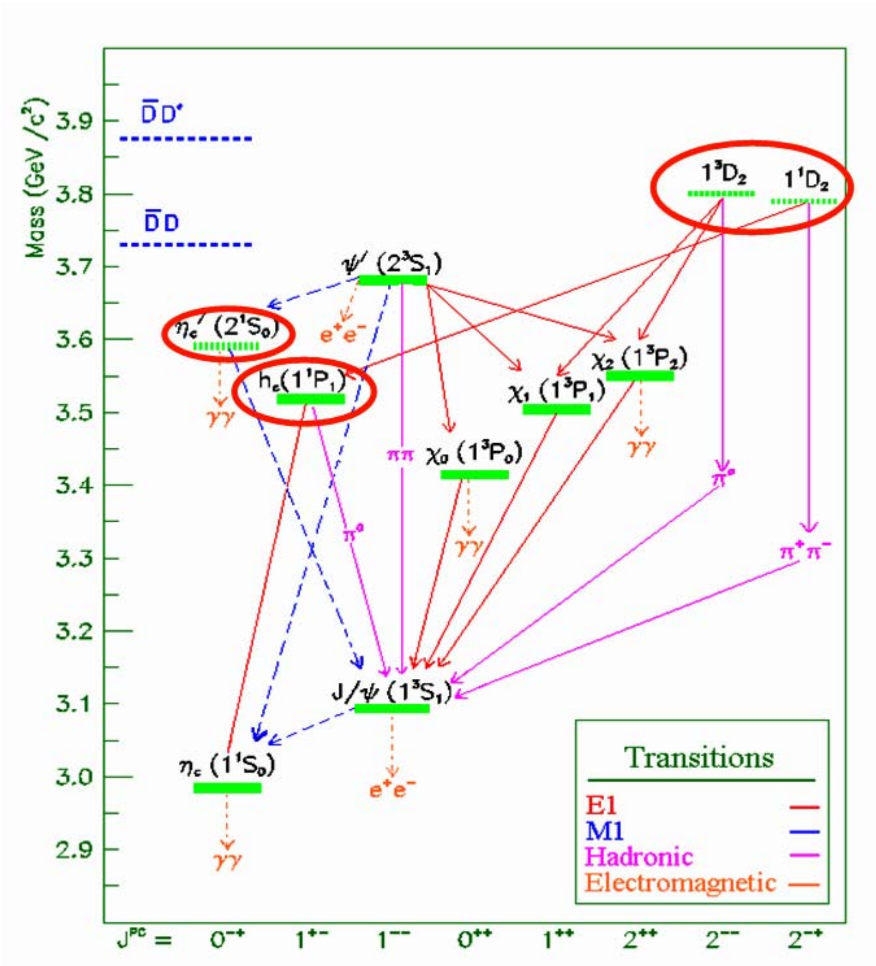
Hard exclusive processes

Hypernuclei

(Exotic) hadron spectroscopy

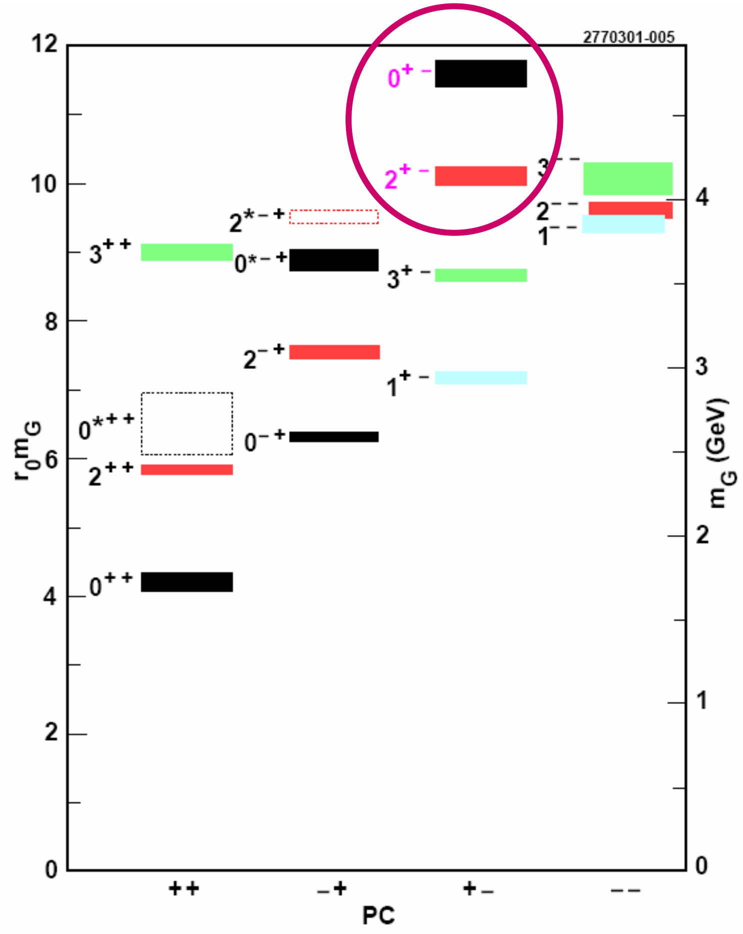


Charmonium spectroscopy –
a high-precision testing ground for **confinement**



- Direct formation of charmonium in $p^{bar}p$
- Experimental issues e.g.
  - measure $h_c(1^1P_1)$ width
  - find η_c' (2^1S_0)
  - measure transition rates
  - identify states above DD^{bar} threshold
- Refine confinement potential (spin dependence?)
- Challenge for lattice QCD

Search for heavy glueballs

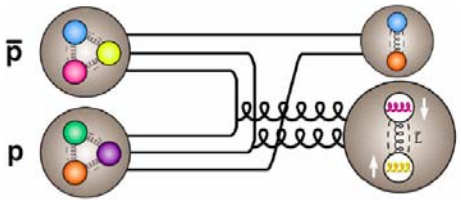


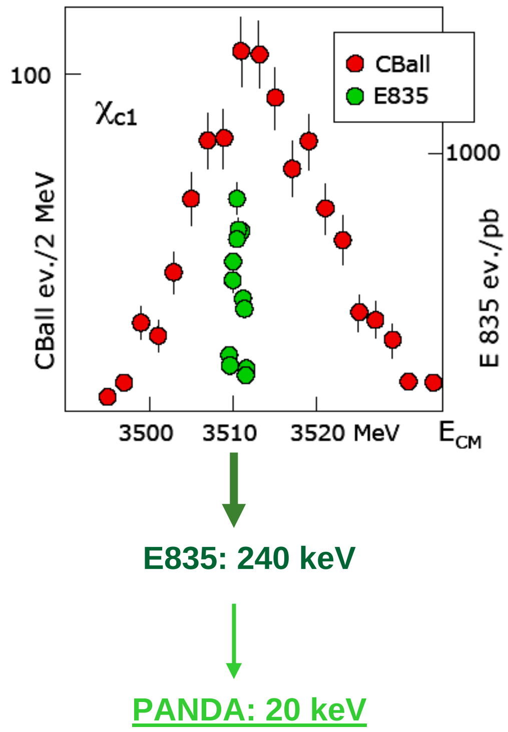
Morningstar & Peardon, PRD60(1999)34509
Morningstar & Peardon, PRD56(1997)4043

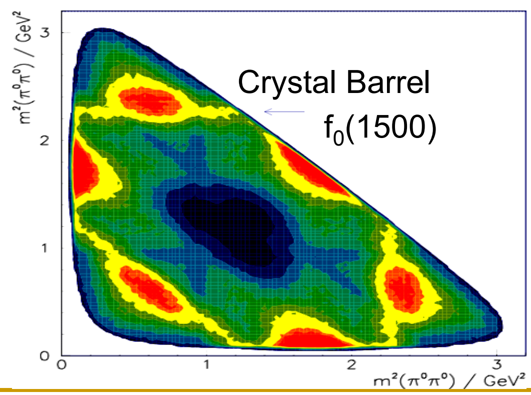
- Heavy glueballs
  - flavour blind decay
    → charmed final states!
  - Probably small widths
  - only a few charmed mesons around 3-4 MeV/c^2 :
    less mixing!
- Exotic heavy glueballs:
  no mixing!
  - $m(2^{+-})$ = 4140(50)(200) MeV
  - $m(0^{+-})$ = 4740(70)(230) MeV

What is needed experimentally?

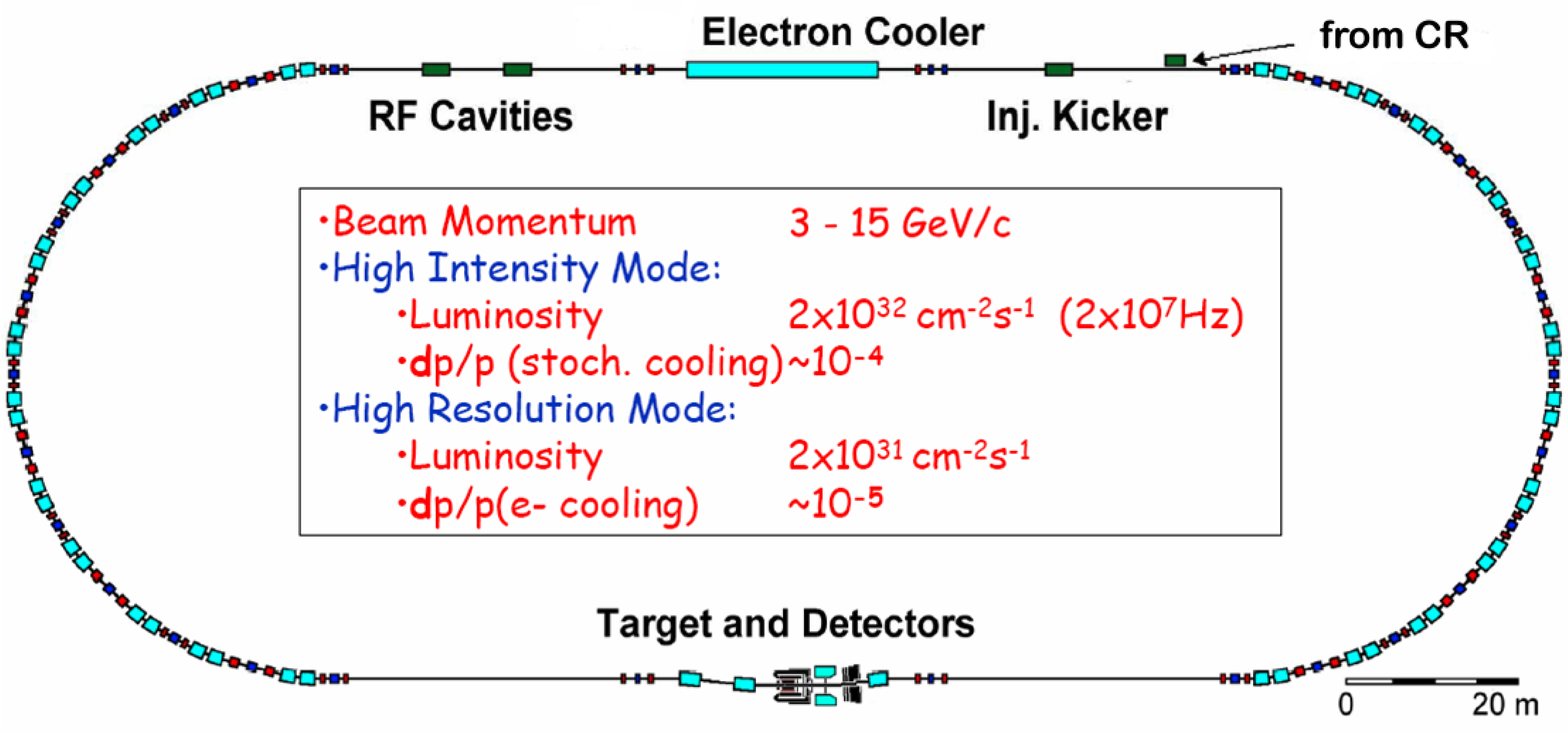
- Gluon-rich environment
  - Proton-antiproton annihilation
- Precision resonance scan
  - Cooled antiproton beam
  - High luminosity
- All quantum numbers measured
  - Large acceptance detector
- High statistics samples
  - Large cross sections
  - Several years of beamtime

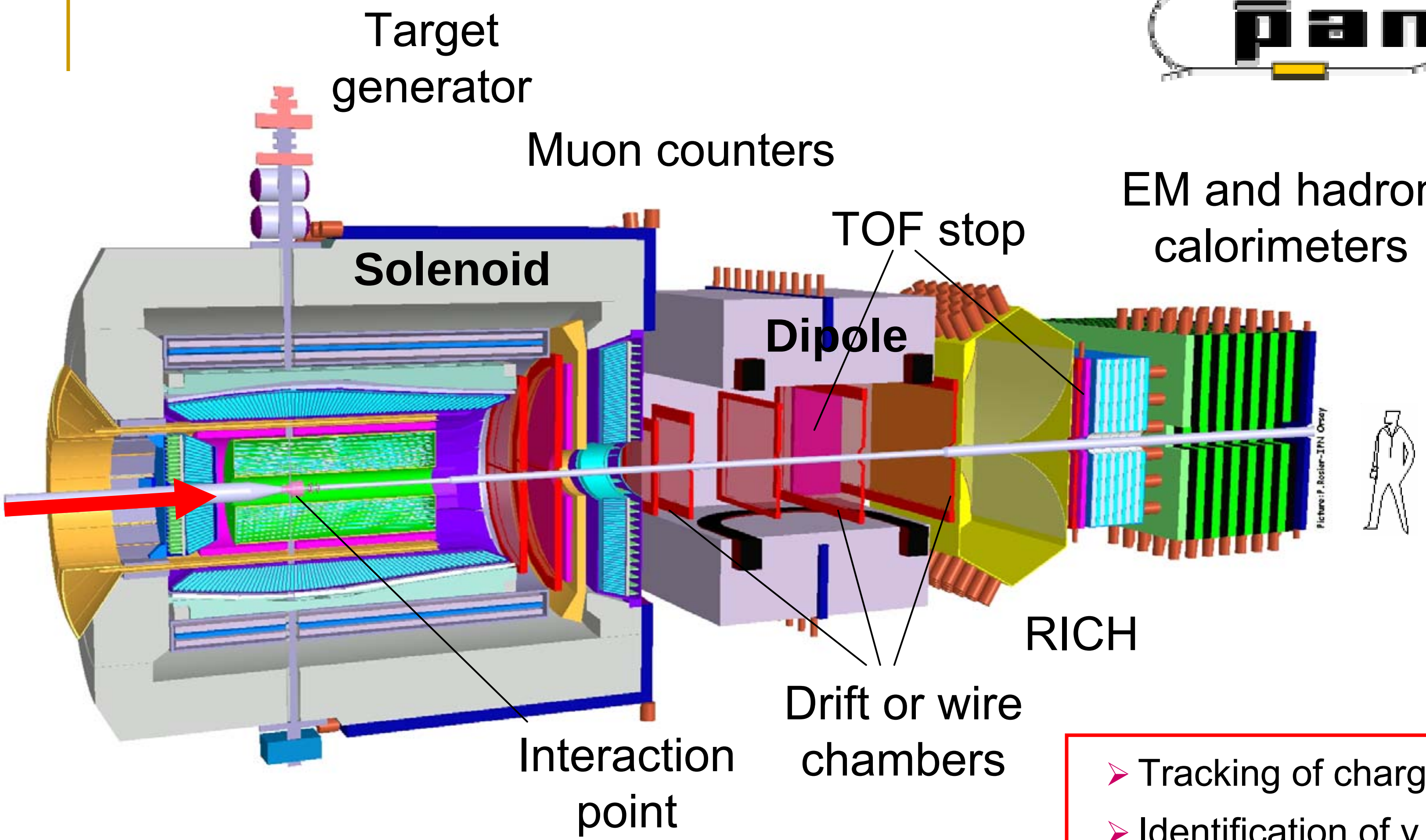






Antiproton accelerator HESR





- Tracking of charged particles
- Identification of γ, $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, $K^{\pm}$, p, anti-p
- High rate capability
- Fast trigger scheme

Charmonium Production in $p\bar{p}$

$c\bar{c}$	J^{PC}	M [MeV]	Γ_{tot} [MeV]	Decay mode	σ(M)* [pb]	Events/ day**
η_c	0^{-+}	2980	13.2	$\gamma\gamma$	550	4400
η_c	0^{-+}	2980	13.2	$\phi\phi$	3100	24800
η_c' ???	0^{-+}	3594		$\gamma\gamma$	120	960
J/ψ	1^{--}	3097	0.087	$e^+e^-/\mu^+\mu^-$	630000	5040000
ψ'	1^{--}	3686	0.277	$e^+e^-/\mu^+\mu^-$	4480	35840
ψ'	1^{--}	3686	0.277	J/ψ X	17600	140800
χ_{c0}	0^{++}	3415	14	$\gamma\gamma$	30	240
χ_{c0}	0^{++}	3415	14	γ J/ψ	52	416
χ_{c1}	1^{++}	3511	0.88	γ J/ψ	3600	28800
χ_{c2}	2^{++}	3556	2.0	γ J/ψ	3700	29600
χ_{c2}	2^{++}	3556	2.0	$\gamma\gamma$	220	1760
$c\bar{c}g$	1^{--}	(4100)	(0.2)	(J/ψη***)	(120)	(960)
$c\bar{c}g$	1^{-+}	(4000)	???	(J/ψ ω,φ,γ)	(9)	(75)

* for selected decay mode

** L = 2×10^{32} cm^{-2}s^{-1}, 50% accelerator and detector efficiency, integrated luminosity = 8 pb^{-1}/day

*** 1% B.R. for this decay mode

PANDA production rates (1-2 fb^{-1}/y)

Final State	Cross section	# reconstr. events/y
Meson resonance + anything	100µb	10^{10}
$\Lambda\bar{\Lambda}$	50µb	10^{10}
$\Xi\bar{\Xi}\,(\rightarrow_{\Lambda\Lambda} A)$	2µb	10^{8} (10^{5})
$D\bar{D}$	250nb	10^{7}
$J/\psi\,(\rightarrow e^{+}e^{-}, \mu^{+}\mu^{-})$	630nb	10^{9}
$\chi_{2}\,(\rightarrow J/\psi + \gamma)$	3.7nb	10^{7}
$\Lambda_{c}\bar{\Lambda}_{c}$	20nb	10^{7}
$\Omega_{c}\bar{\Omega}_{c}$	0.1nb	10^{5}

Common feature : Low multiplicity events, moderate particle energies
For pairs : Charge symmetry condition - trigger on one, investigate the other

Timelines

- 2006: contract signed by participating countries
- 2007/8: begin of construction
  - Phase I
    - SIS18 upgrade, CR, NESR, SuperFRS (RIB intensity factor 100↑)
    - NUSTAR, Plasma Physics (density factor 200↑)
  - Phase II
    - SIS100, RESR, HESR (stochastic cooling)
    - PANDA
  - Phase III
    - SIS300, HESR (electron cooling)
    - NUSTAR (RIB intensity factor 10^4 ↑), Plasma Physics (dens. fact. 2500↑)
    - PANDA high resolution, CBM
- Start of data taking (phase I, II, III) 2010-15