Facility for Antiproton and Ion Research

The FAIR Project

Overview of Facility and Experiments

Lars Schmitt, GSI Darmstadt

G-APD Workshop, GSI, Darmstadt, Feb 9th 2009

- The Facility
- The Physics
- Summary & Outlook

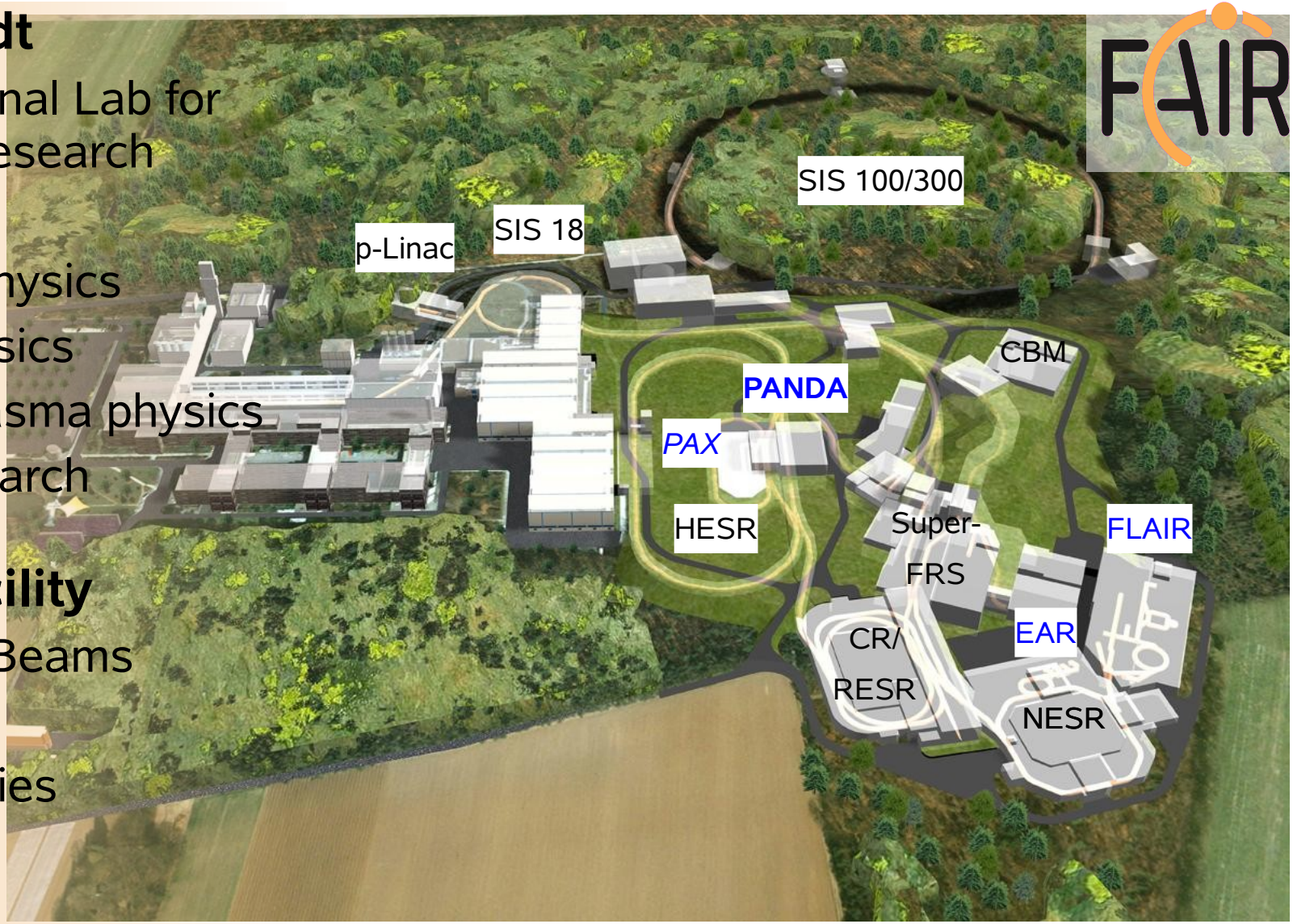
Facility for Antiproton and Ion Research

GSI, Darmstadt

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

FAIR: New facility

- Rare Isotope Beams
- Heavy ions
- ➔ higher intensities & energies
- Antiprotons



Five Pillars of Research at FAIR

- Nuclear Structure Physics and Nuclear Astrophysics with **RIBs**
- Hadron Physics with **Antiproton Beams**
- Physics of Nuclear Matter with **Relativistic Nuclear Collisions**
- Atomic Physics and Applied Science with **highly charged Ions** and **low energy Antiprotons**
- Plasma Physics with **highly Bunched Beams**

+ Accelerator Physics

Layout of the Facility

Primary Beams

- $^{238}U^{28+}$: 10^{12}/s @ 1.5-2 AGeV;
- $^{238}U^{92+}$: 10^{10}/s @ up to 35 AGeV
- **Protons** : 2 x10^{13}/s @ 30 GeV

➔ 100-1000 x present intensity

Secondary Beams

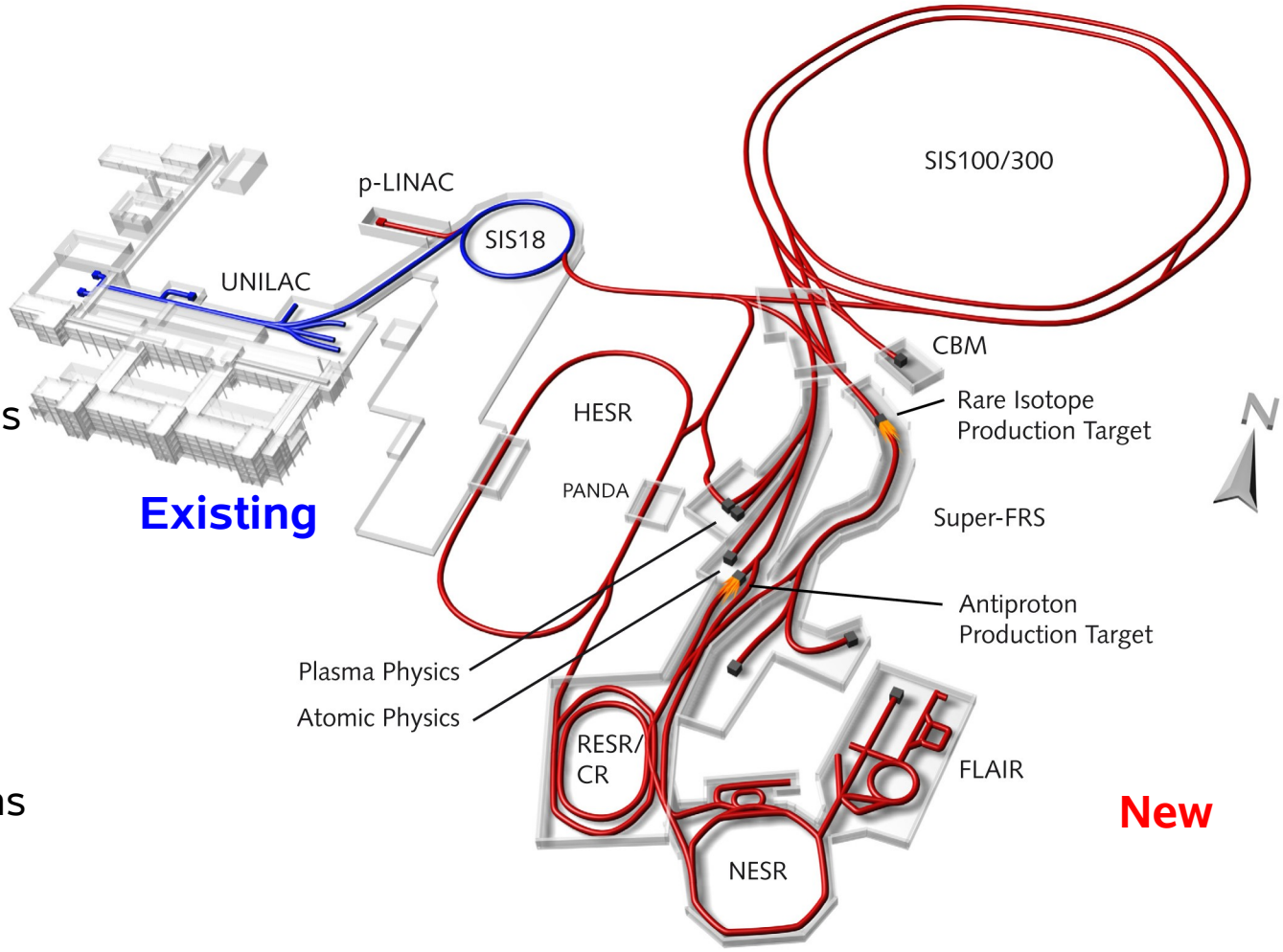
- Broad range of radioactive beams up to 1.5 - 2 AGeV
- up to 10 000 x present intensity
- Antiprotons 0 - 15 GeV

Storage and Cooler Rings

- Radioactive beams
- e^-– A (or Antiproton-A) collider
- 10^{11} stored and cooled antiprotons 1.5 - 15 GeV/c
- *Future*: Polarized antiprotons

Key Technical Features

- Cooled beams
- Rapidly cycling superconducting magnets
- Parallel Operation



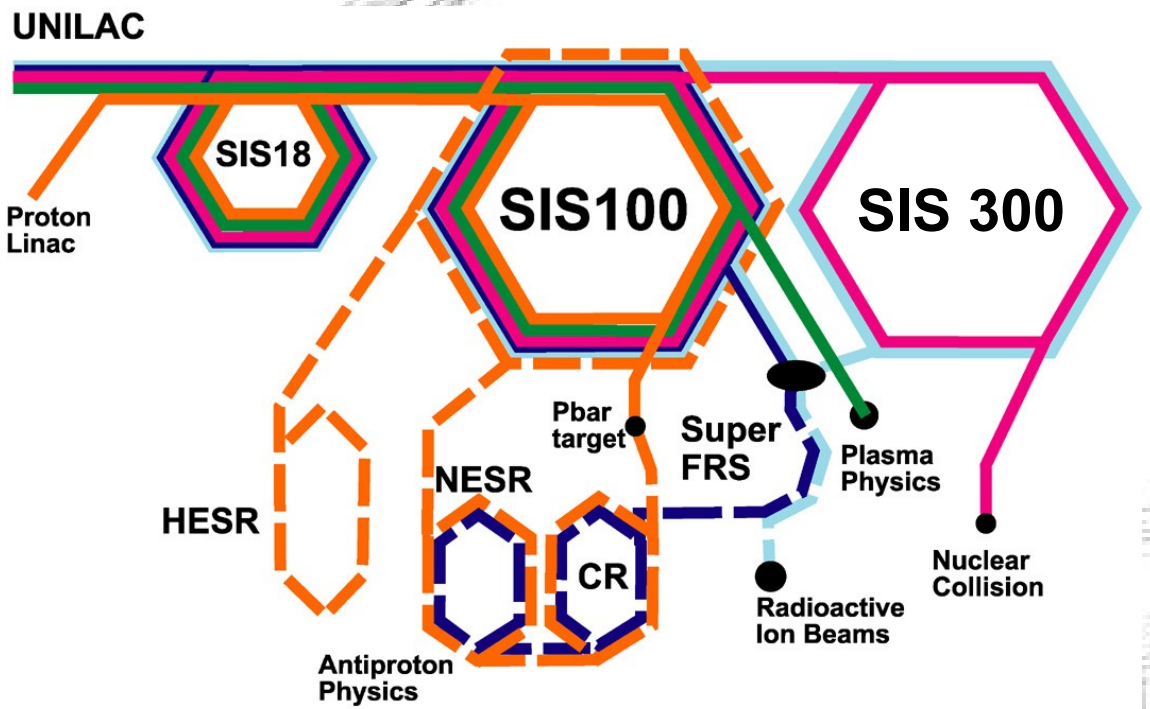
Accelerator Highlights

Parallel Operation

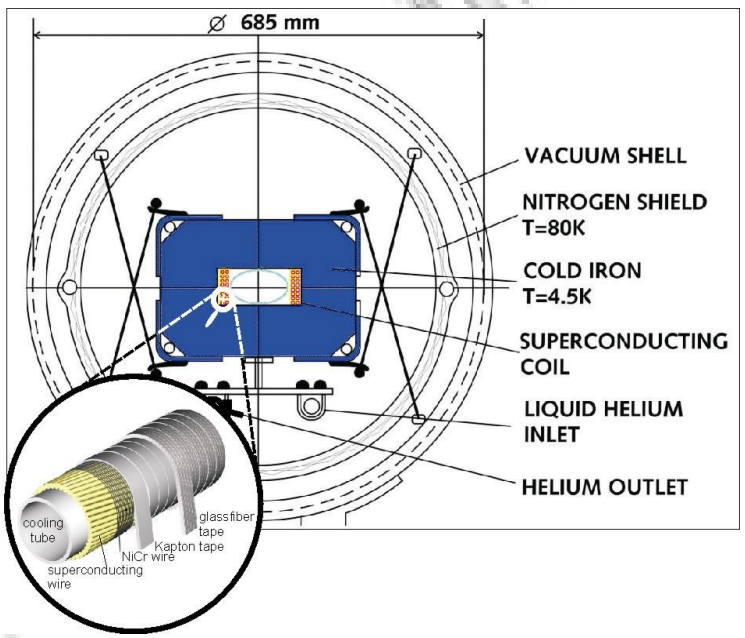
- High duty cycle
- Optimal usage
- Synergy effects

➔ Rapidly cycling magnets

Superconducting, fast ramping synchrotron magnets

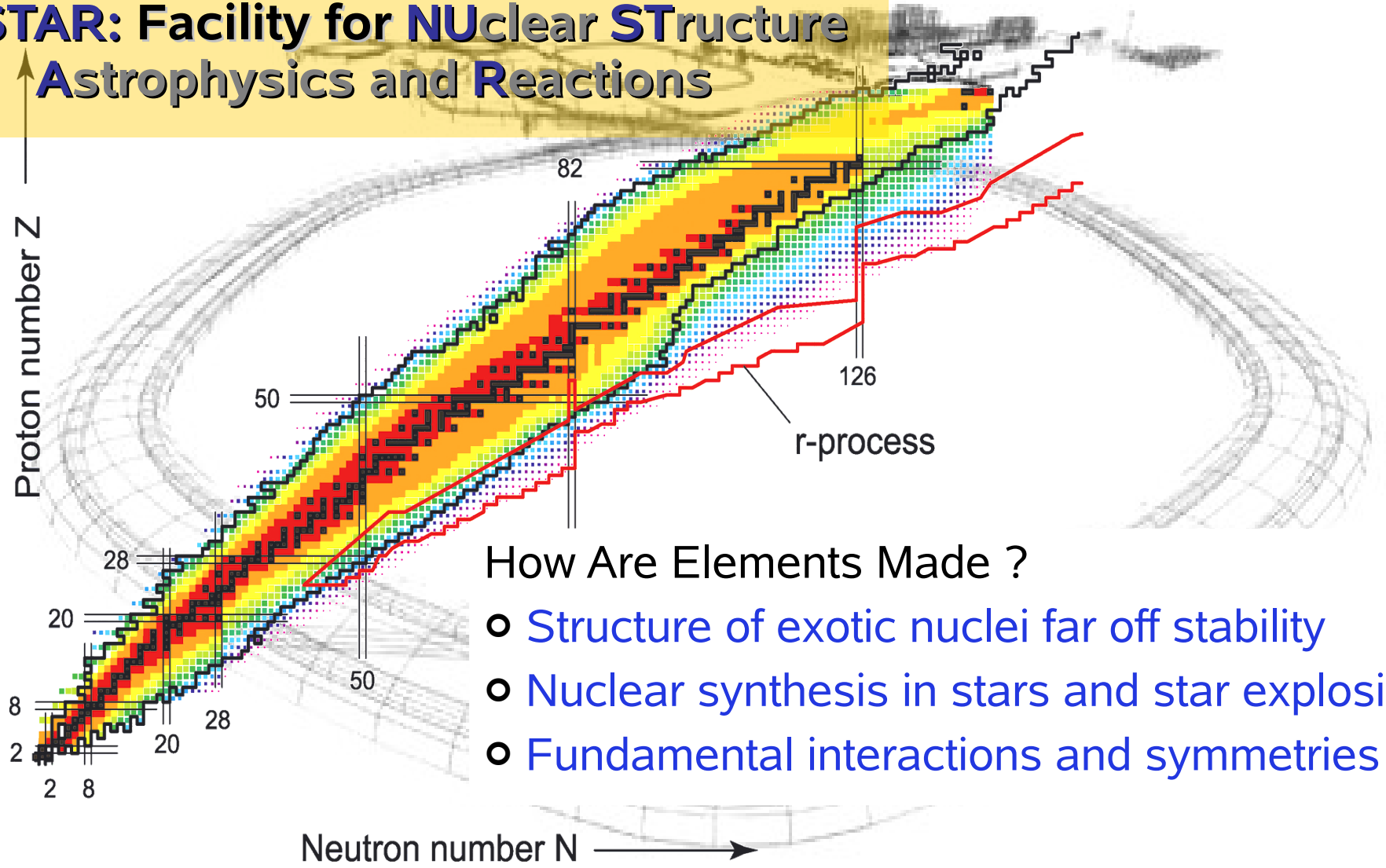


SIS 100/300 dipole magnet



NUSTAR - Radioactive Ion Beams

NUSTAR: Facility for NUclear STructure Astrophysics and Reactions



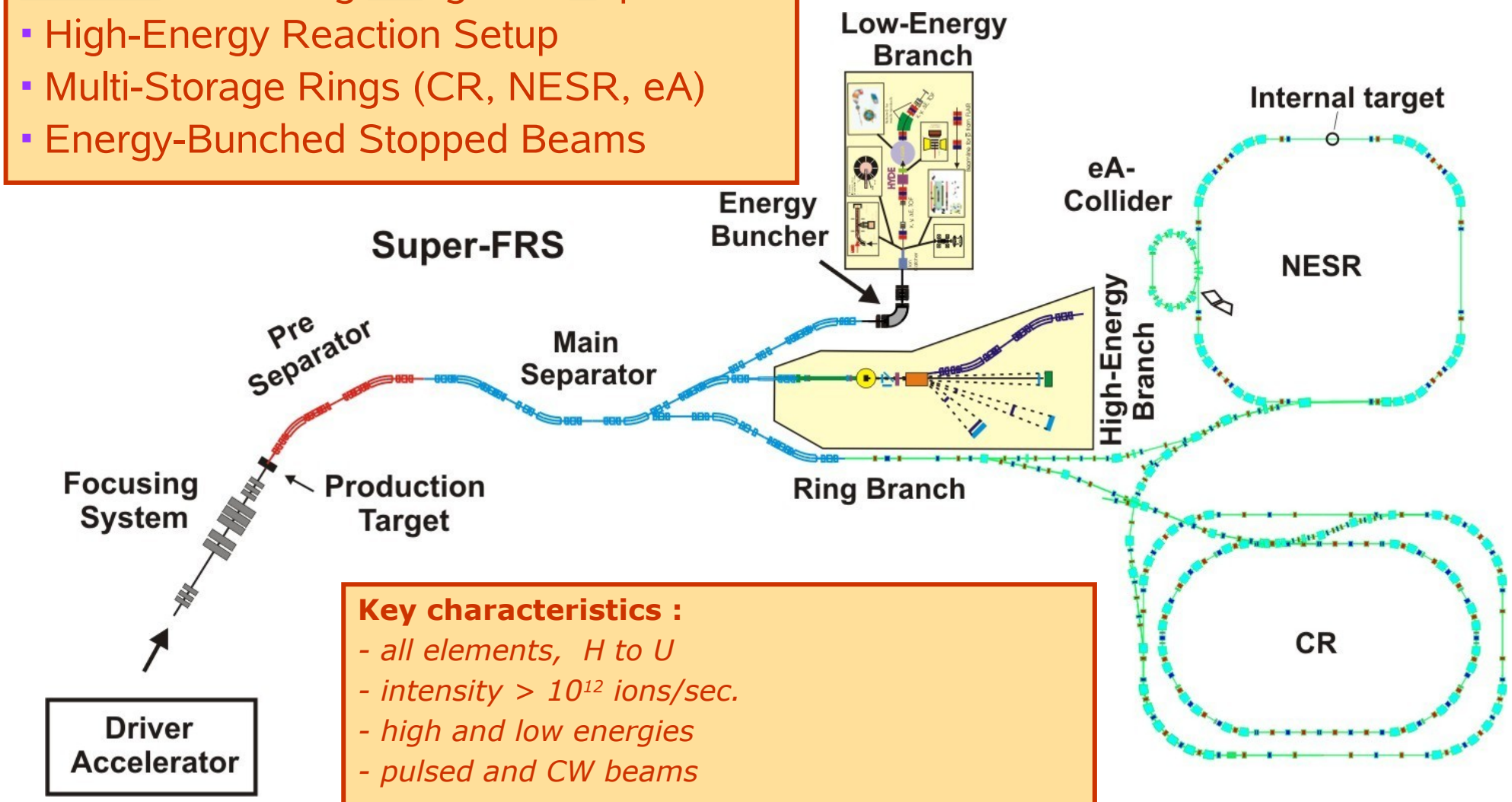
How Are Elements Made ?

- Structure of exotic nuclei far off stability
- Nuclear synthesis in stars and star explosions
- Fundamental interactions and symmetries

NUSTAR - Super Fragment Separator

SUPERconducting **FR**agment **S**eparator

- 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.

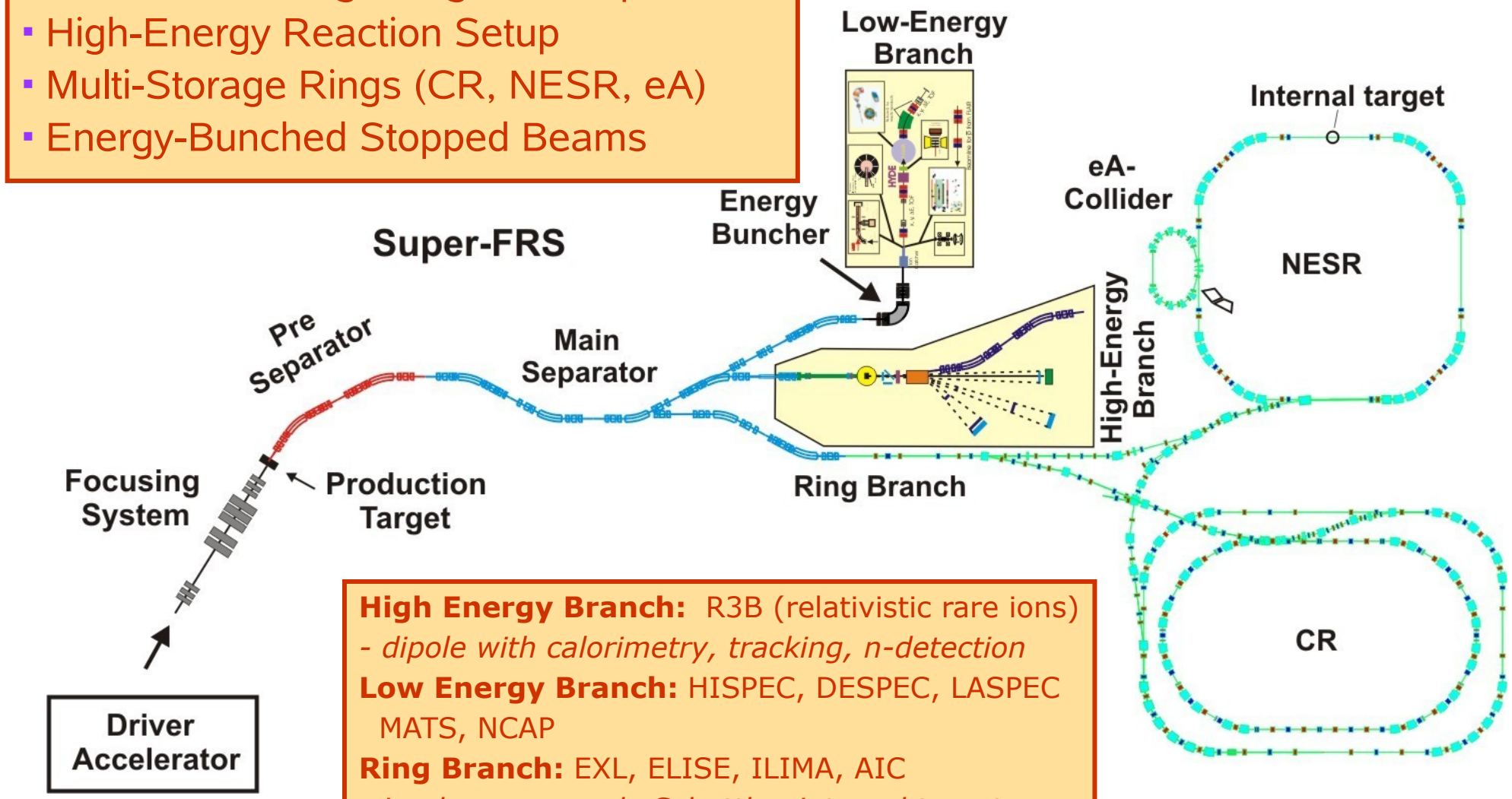
- high and low energies

- pulsed and CW beams

NUSTAR - Super Fragment Separator

SUPERconducting **FR**agment **S**eparator

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



High Energy Branch: R3B (relativistic rare ions)
- dipole with calorimetry, tracking, n-detection
Low Energy Branch: HISPEC, DESPEC, LASPEC
MATS, NCAP
Ring Branch: EXL, ELISE, ILIMA, AIC
- isochronous mode Schottky, internal targets

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 ($\bar{p}$He, $\bar{p}$p), anti-hydrogen
- **Gravitation of anti-matter**
  - Trapped and laser-cooled anti-hydrogen
- **Atomic Collisions**
  - Ionization, energy loss, anti-matter-matter
- **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
- **Medical application: Tumor therapy**

High-brilliant Low energy beams

USR

DC beam, rare ions

Higher energies

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

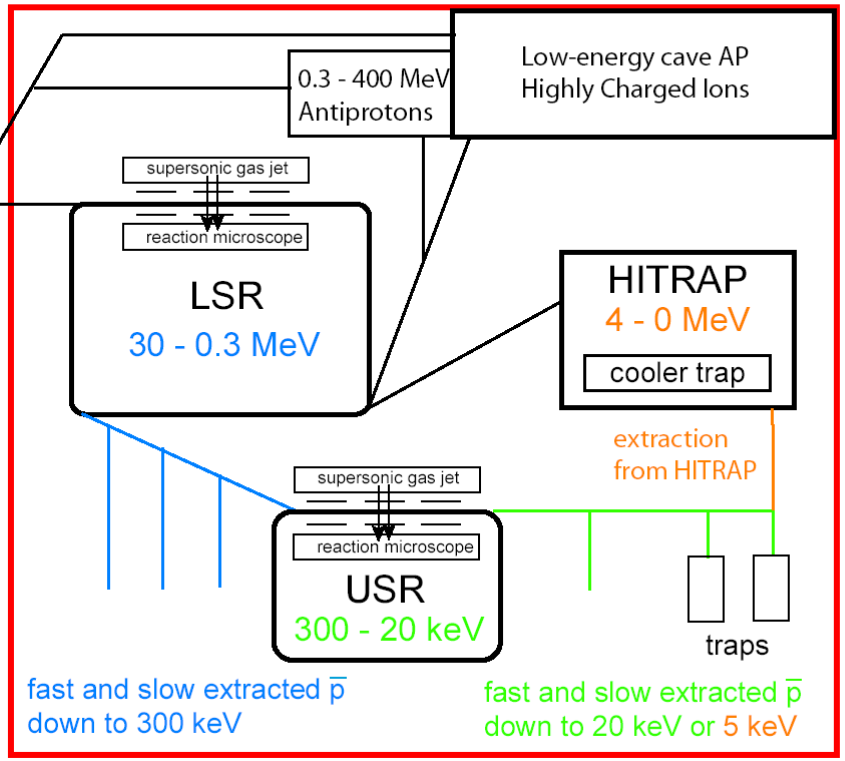
NESR
min. 30 MeV

CRYRING

Challenge! new
MPI-K HD

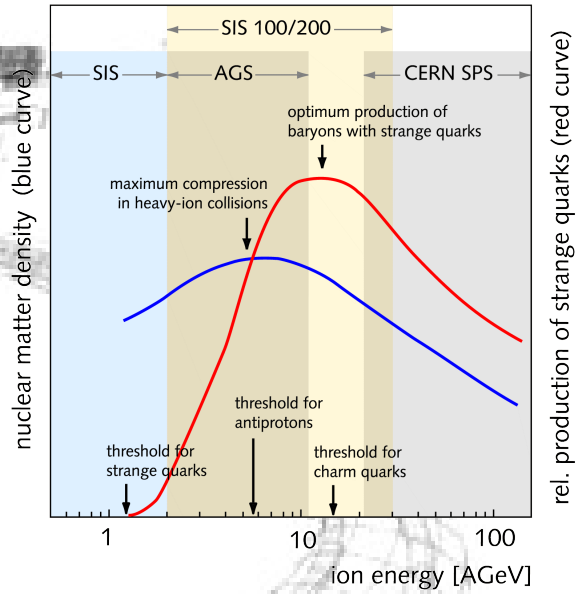
In construction for
ESR @ GSI
with Hall A
of CDR

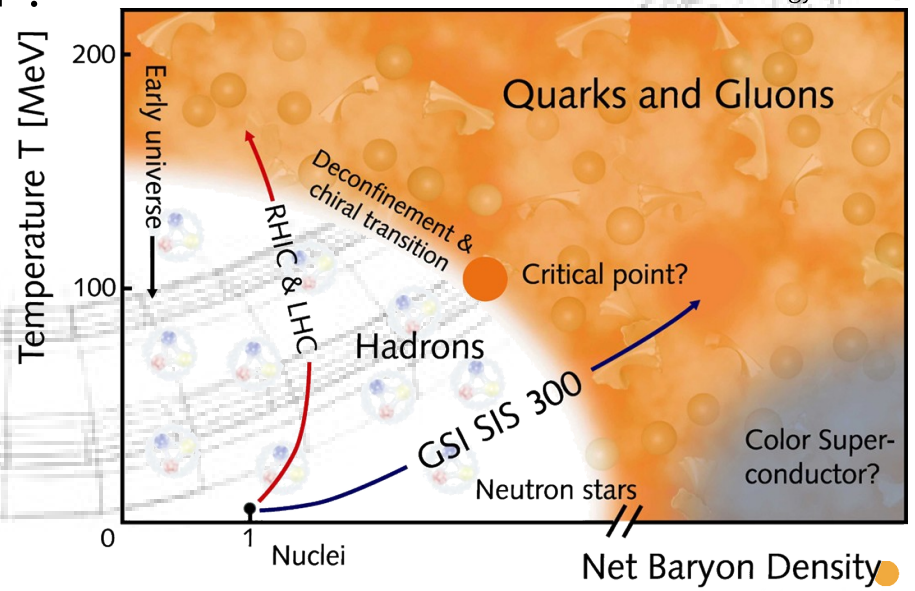
New low-energy antiproton and ion facility



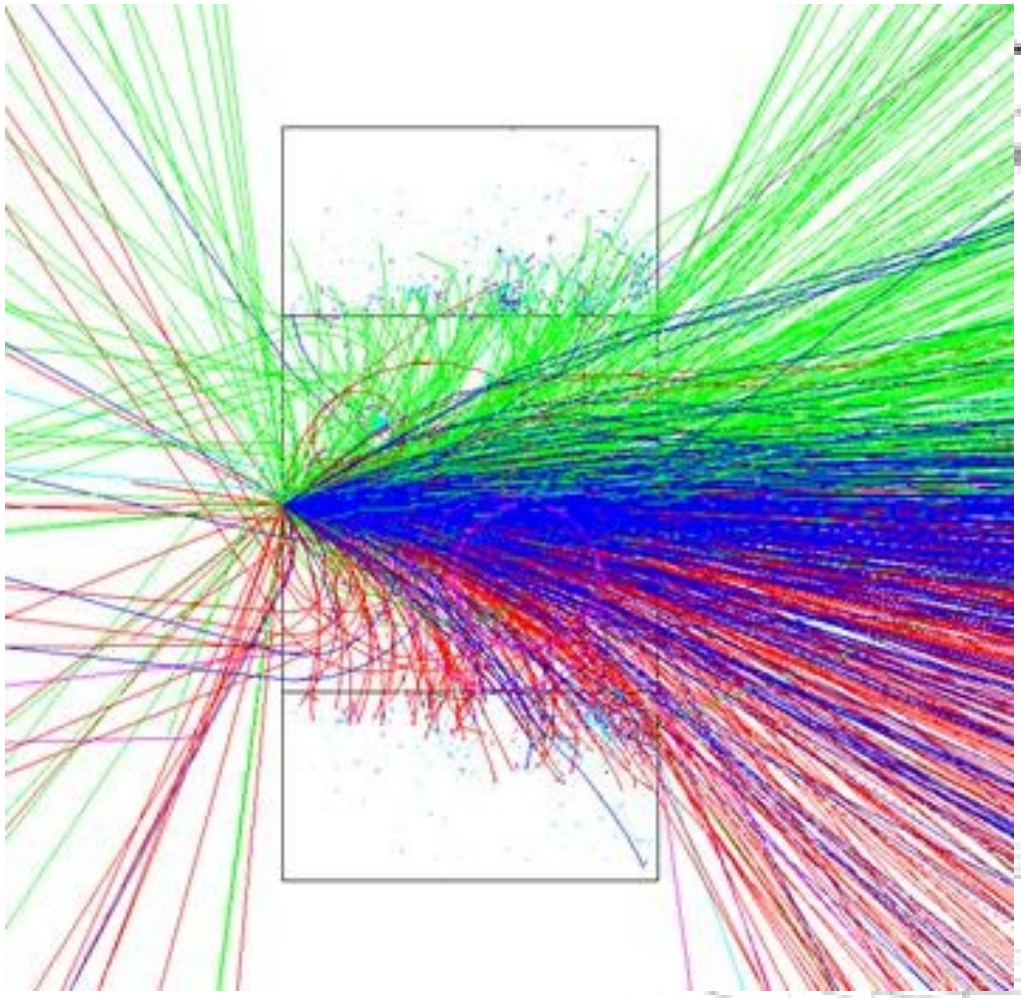
CBM - Compressed Baryonic Matter

- **In-medium modifications of hadrons**
  - onset of chiral symmetry restoration at high ρ_B
  - measure: ρ, ω, ϕ → e^+e^- and open charm
- **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 170 n

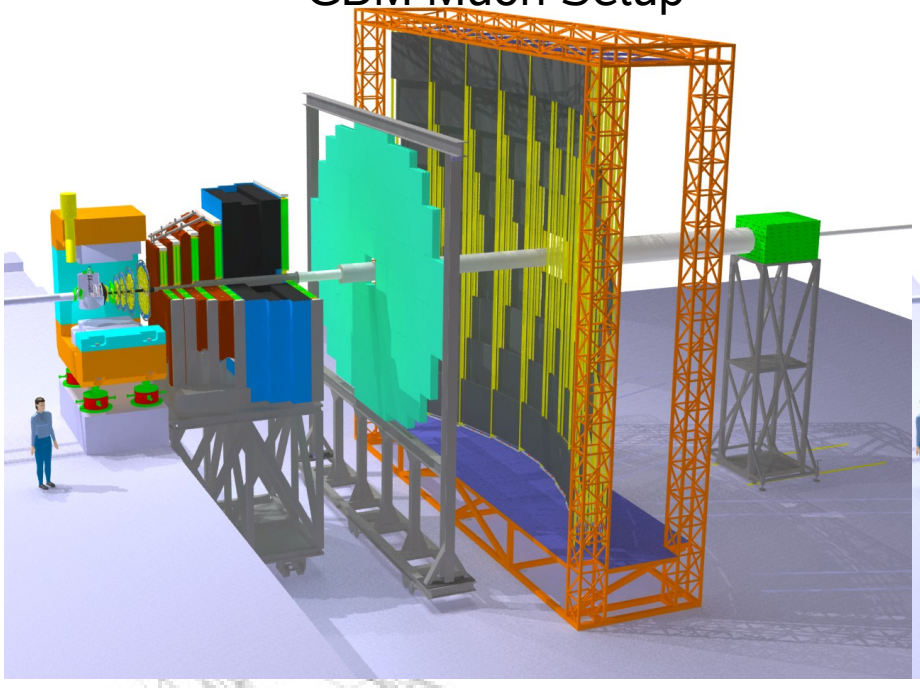
360 π^- 330 π^+ 360 π^0

41 K^+ 13 K^- 42 K^0

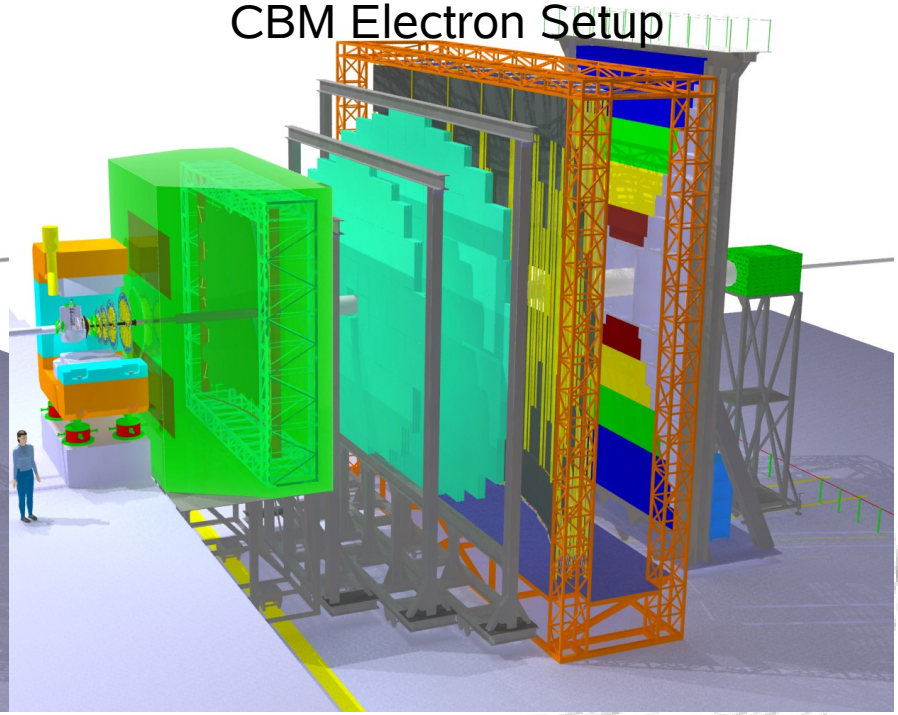
- 10^7 Au+Au interactions/sec
- 10^9 tracks/sec to reconstruct for first level event selection
- Find D vertices displaced by few 100 µm

CBM - Apparatus

CBM Muon Setup



CBM Electron Setup



- Radiation hard Silicon (pixel/strip) Tracking System in dipole
- **Muon setup:** iron absorbers and GEM detectors
- **Electron setup:** RICH & TRD & ECAL: $\pi/e < 10^{-4}$
- Measurement of photons, π, η, and muons: ECAL
- Hadron identification: TOF-RPC
- High speed data acquisition and trigger system

PANDA - Hadron Physics with Antiprotons

Structure & Dynamics of Hadrons in the transition regime of QCD

Why don't we observe free quarks?

- Charmonium spectroscopy
  → Quark confinement

How are color neutral states formed?

- Hadrons (qqq or $q\bar{q}$)
- Gluonic excitations
- Multi-quark systems
  → QCD predictions

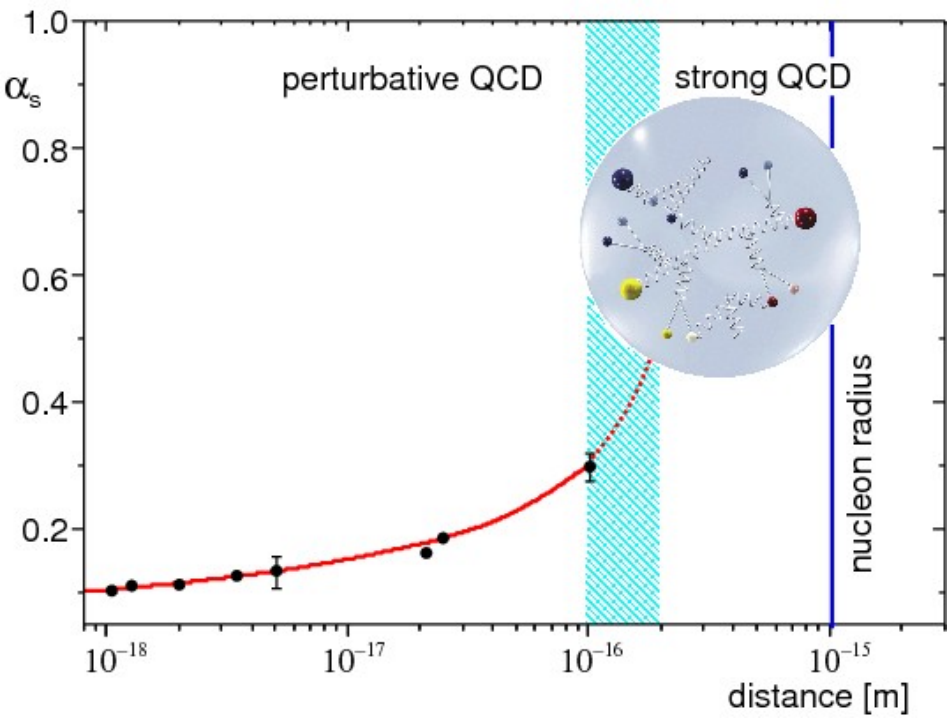
How do hadrons obtain mass?

- $\bar{p}$-A interactions
- Meson properties in nuclear medium
  → Restoration of chiral symmetry

What is the structure of the nucleon?

- Hard scattering processes & soft fragmentation
  → From partons to hadrons

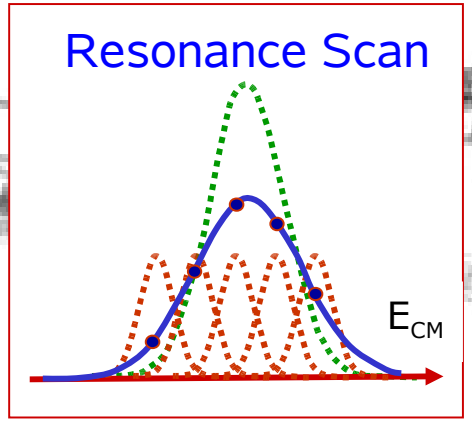
Strong coupling constant vs R



High Energy Storage Ring

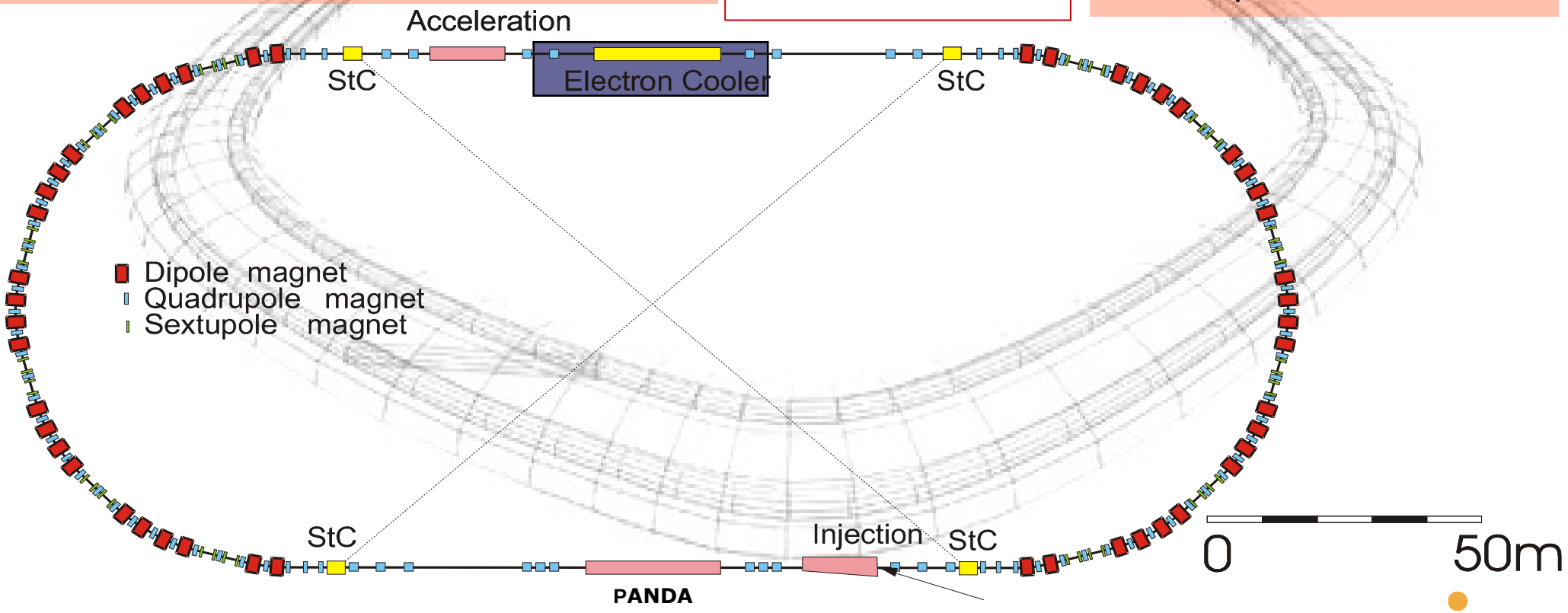
HESR Parameters

- Injection of $\bar{p}$ at 3.7 GeV
- Slow synchrotron (1.5-15 GeV/c)
- Storage ring for internal target
- Luminosity up to L~ $2x10^{32}$ $cm^{-2}s^{-1}$
- Beam cooling (stochastic & electron)

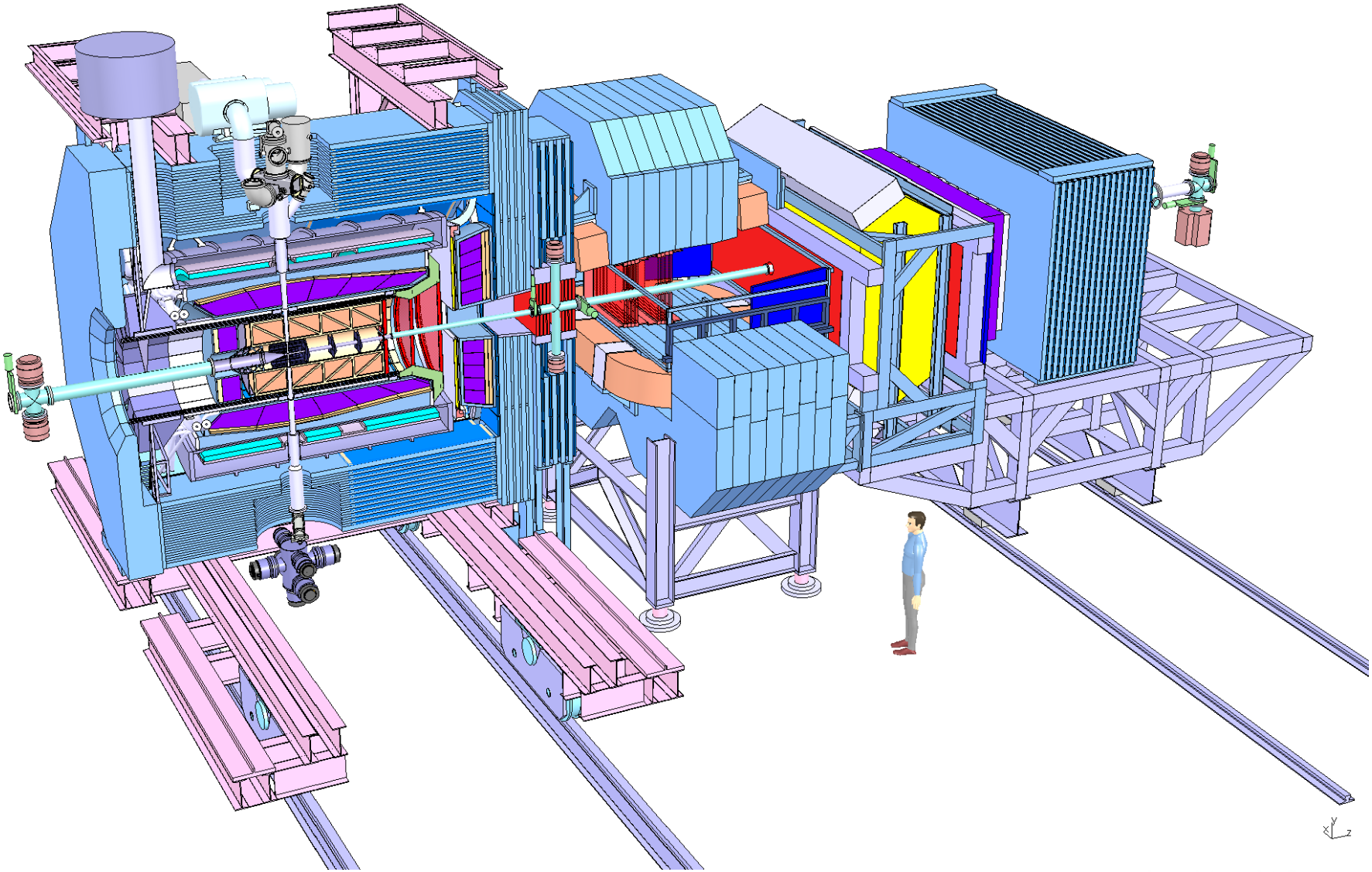


Resonance scan

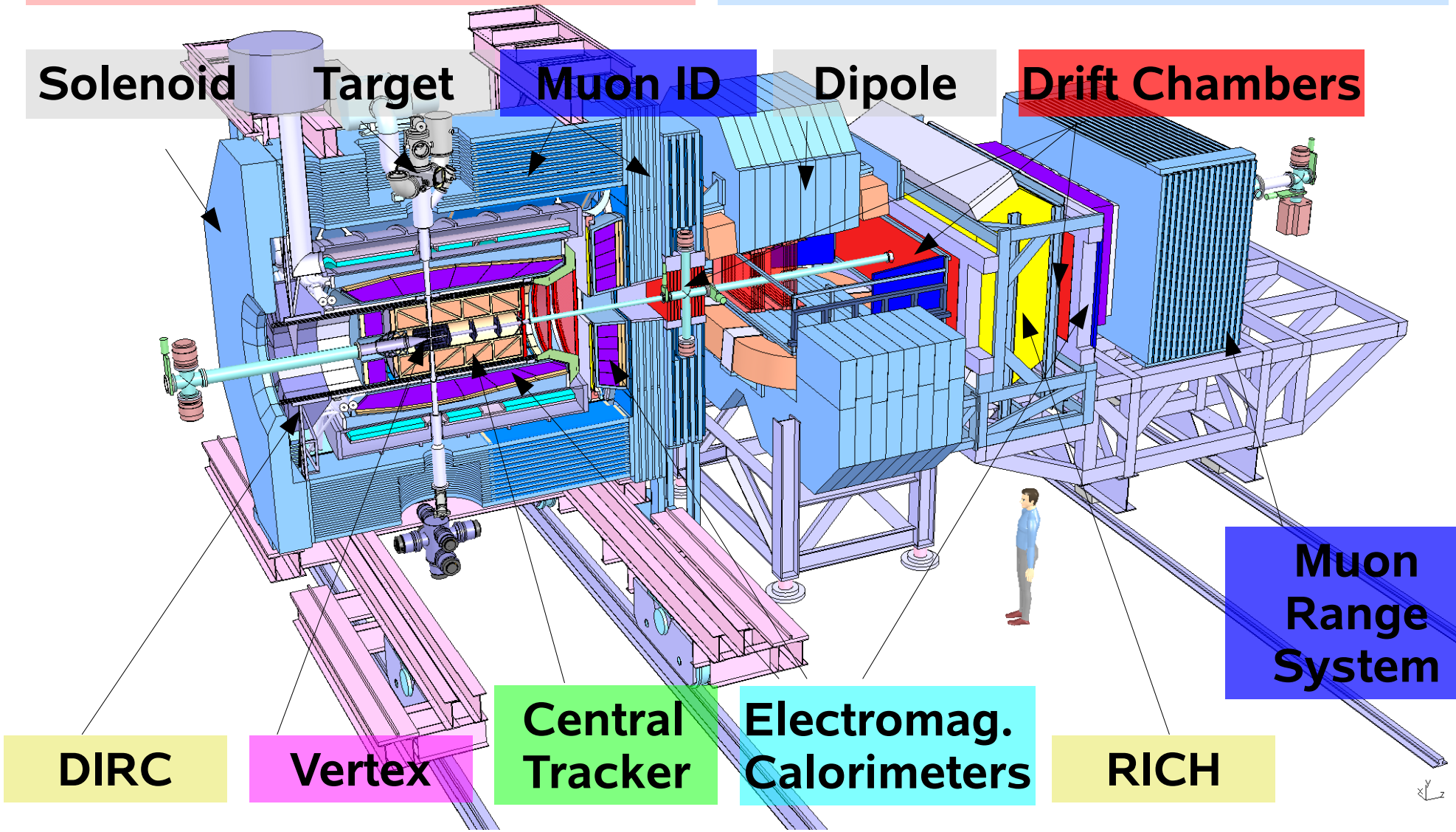
- Energy resolution ~50 keV
- Tune E_{CM} to probe resonance
- Get precise m and Γ



PANDA Spectrometer



PANDA Spectrometer



Summary & Outlook

- FAIR will be a major facility in fundamental physics research
  - World class RIB facility
  - Heavy ion program complementary to RHIC and LHC
  - Hadron physics with antiprotons unique
  - Atomic physics with ions and antiprotons
  - Plasma research with laser and ion beams
- The next important steps:
  - Founding of the FAIR company in summer 2009
  - Planning and building permits until end 2009
  - Begin of civil construction in 2010
  - 36 months for all buildings and tunnels
- First physics in 2013/14