The **F**acility for **A**ntiproton and **I**on **R**esearch

A New Large-Scale International Lab.

Signing of the **FAIR Convention** by representatives of the founding countries
Finland, France, Germany, India, Poland, Romania, Russia, Slovenia, Sweden
in Wiesbaden on **4/10/2010**

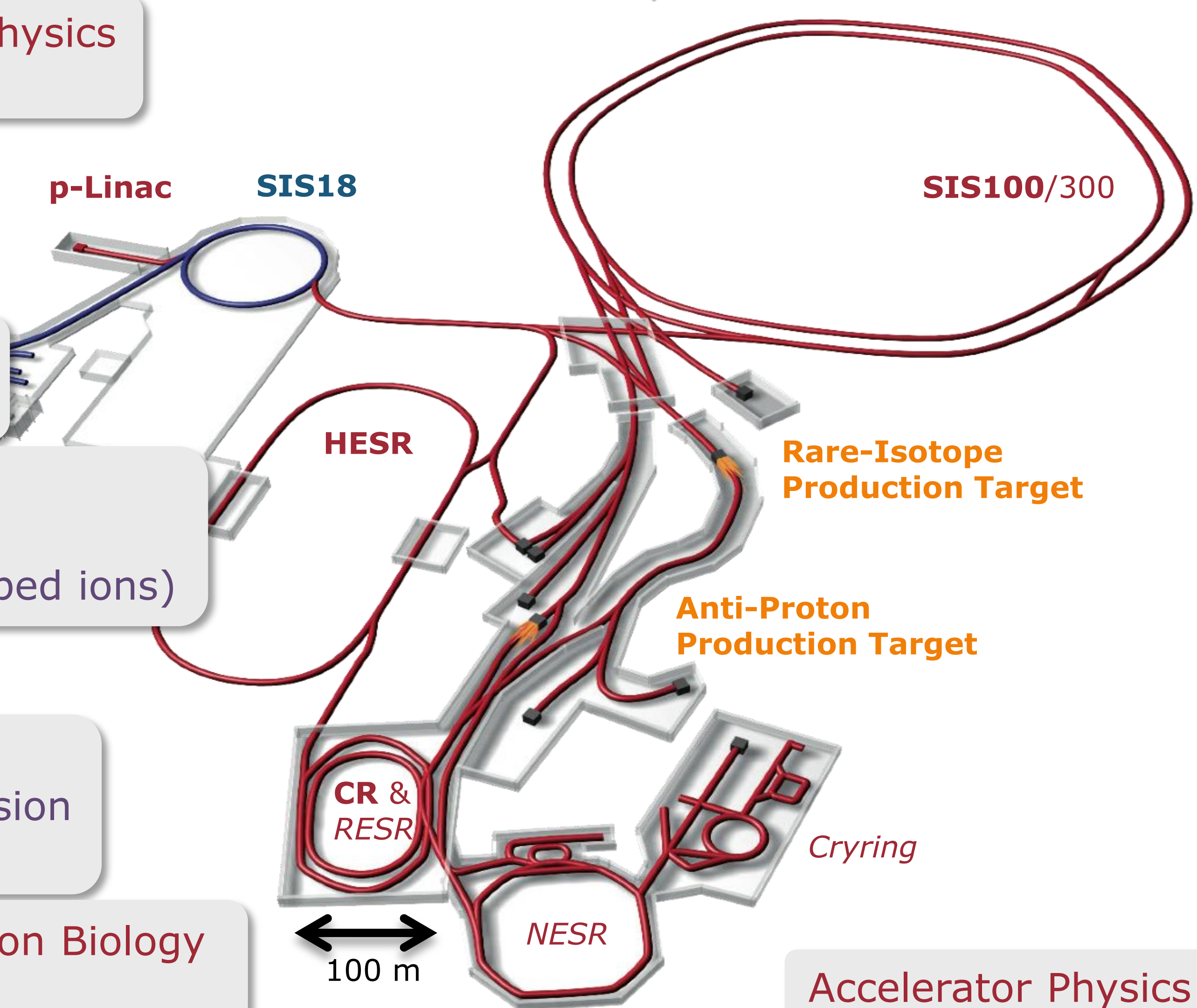
Facility for Antiproton & Ion Research

Nuclear Structure & Astrophysics
(Rare-isotope beams)

Hadron Physics
(Stored and cooled
14 GeV/c anti-protons)

QCD-Phase Diagram
(HI beams 2 to 45 GeV/u)

Fundamental Symmetries
& Ultra-High EM Fields
(Antiprotons & highly stripped ions)



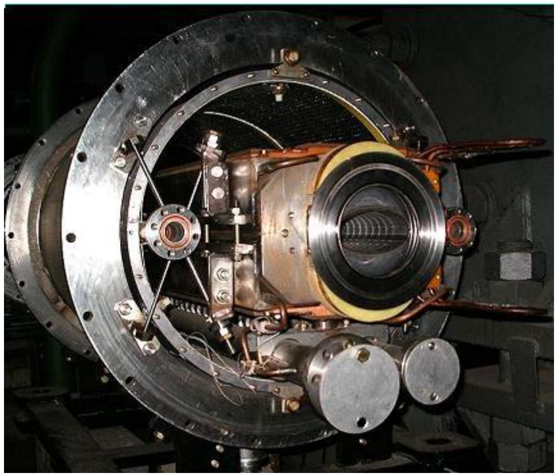
Dense Bulk Plasmas
(Ion-beam bunch compression
& petawatt-laser)

Materials Science & Radiation Biology
(Ion & antiproton beams)

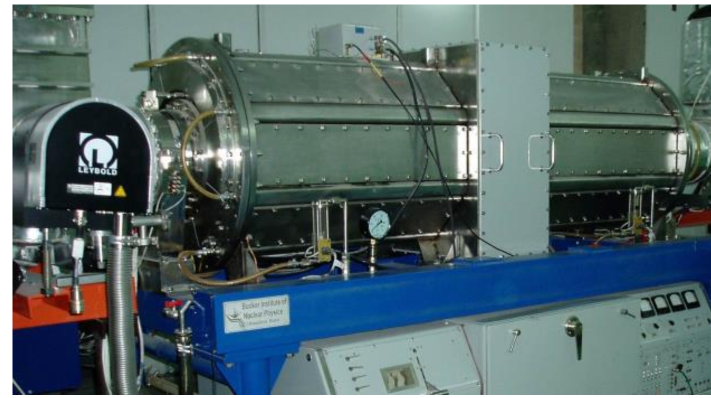
Accelerator Physics

Accelerator Challenges

Compact & cost effective accelerators
Fast cycling superconducting magnets
dB/dt ~ 4T/s



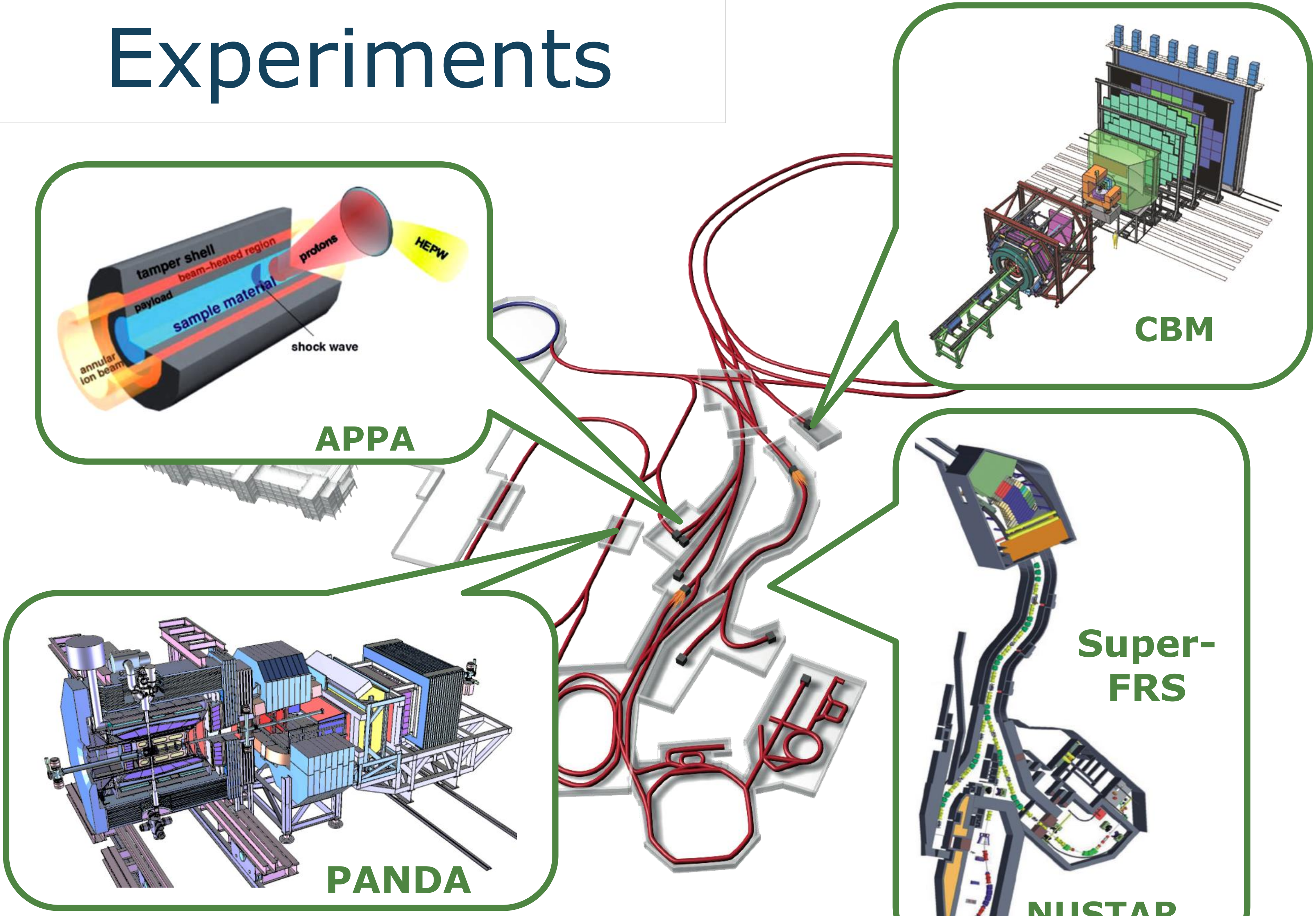
Fast acceleration
High gradient, variable frequency
Ferrite & MA loaded cavities



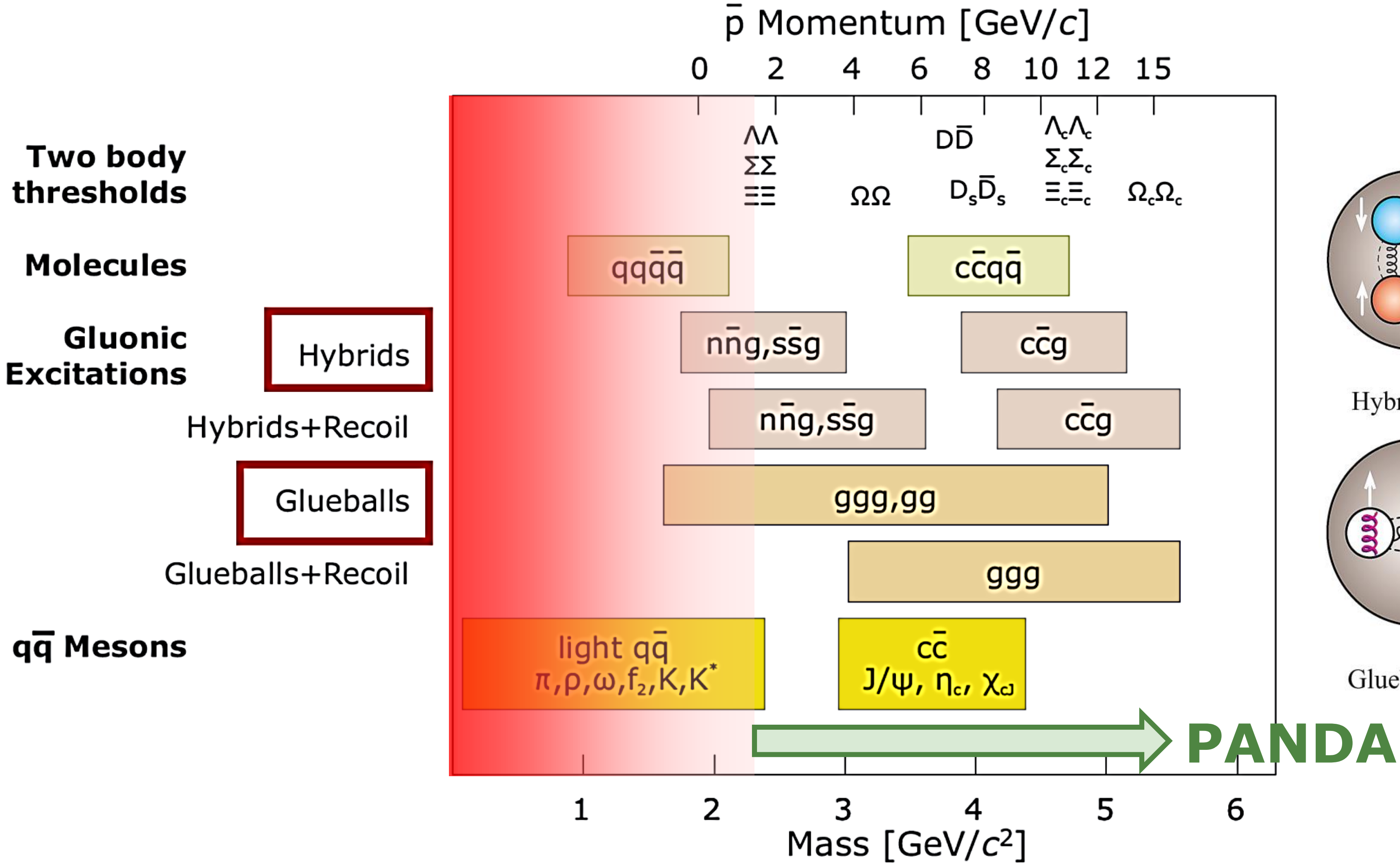
XHV @ high beam intensities
Extremely high vacuum ~10^{-12} mbar

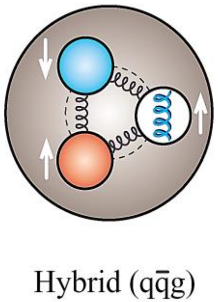
Precision beams
Electron & stochastic cooling

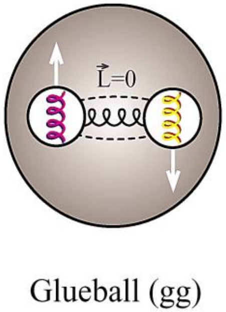
Experiments



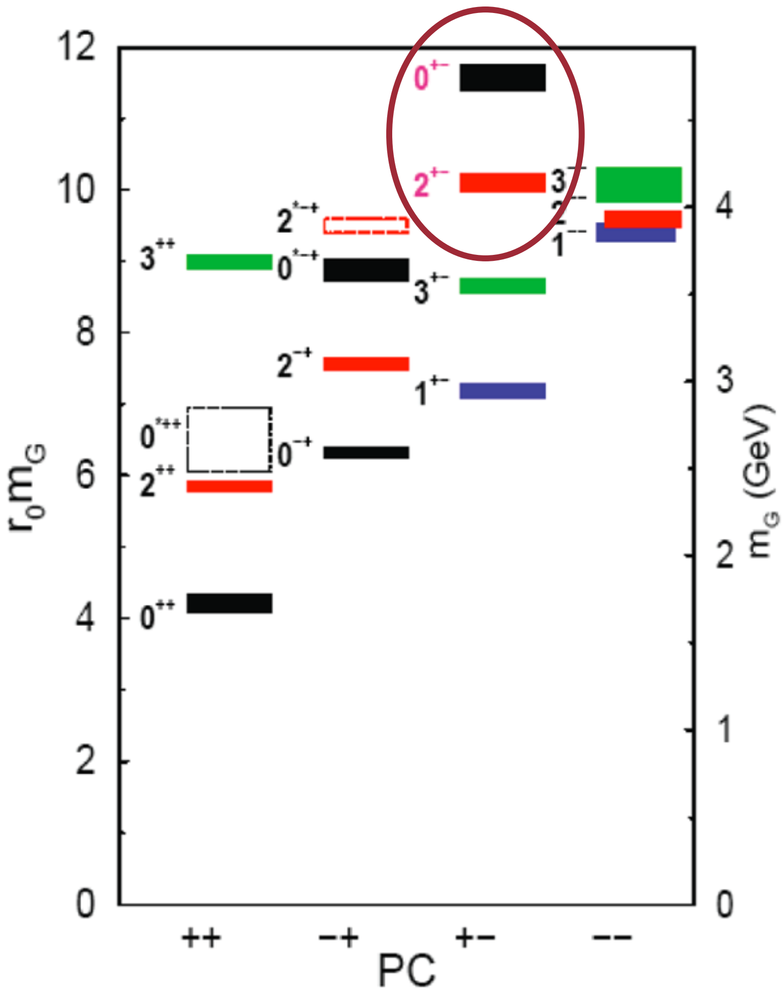
Anti-**P**roton **An**nihilation @ **DA**







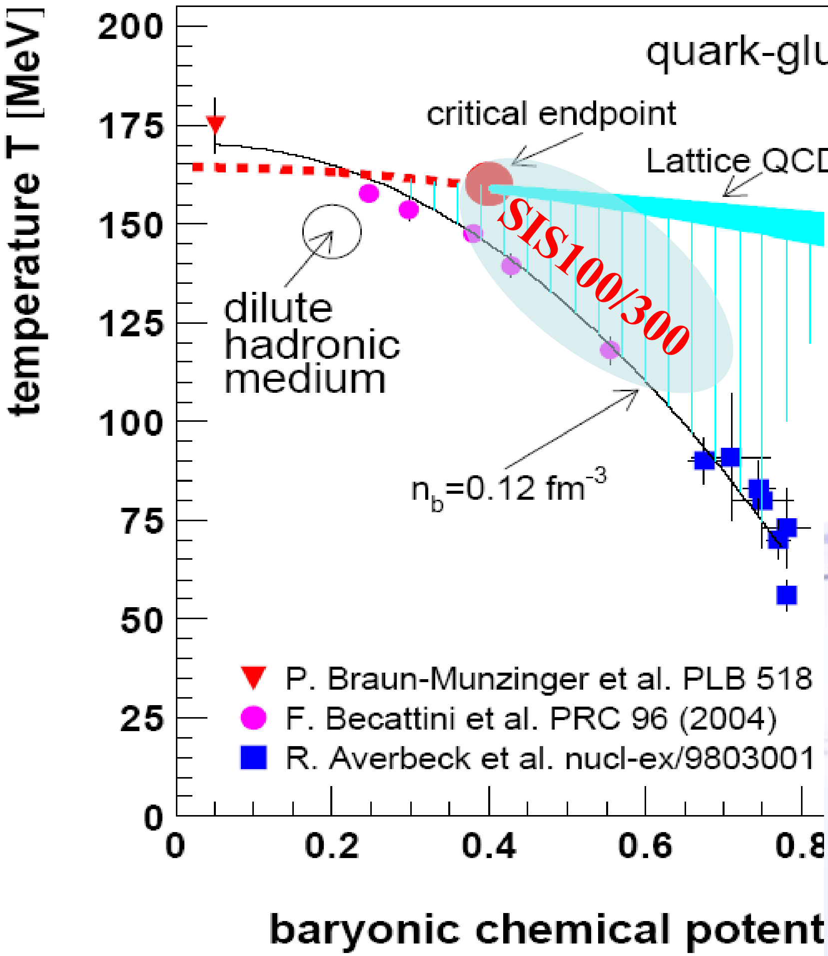
Search for Heavy Glueballs

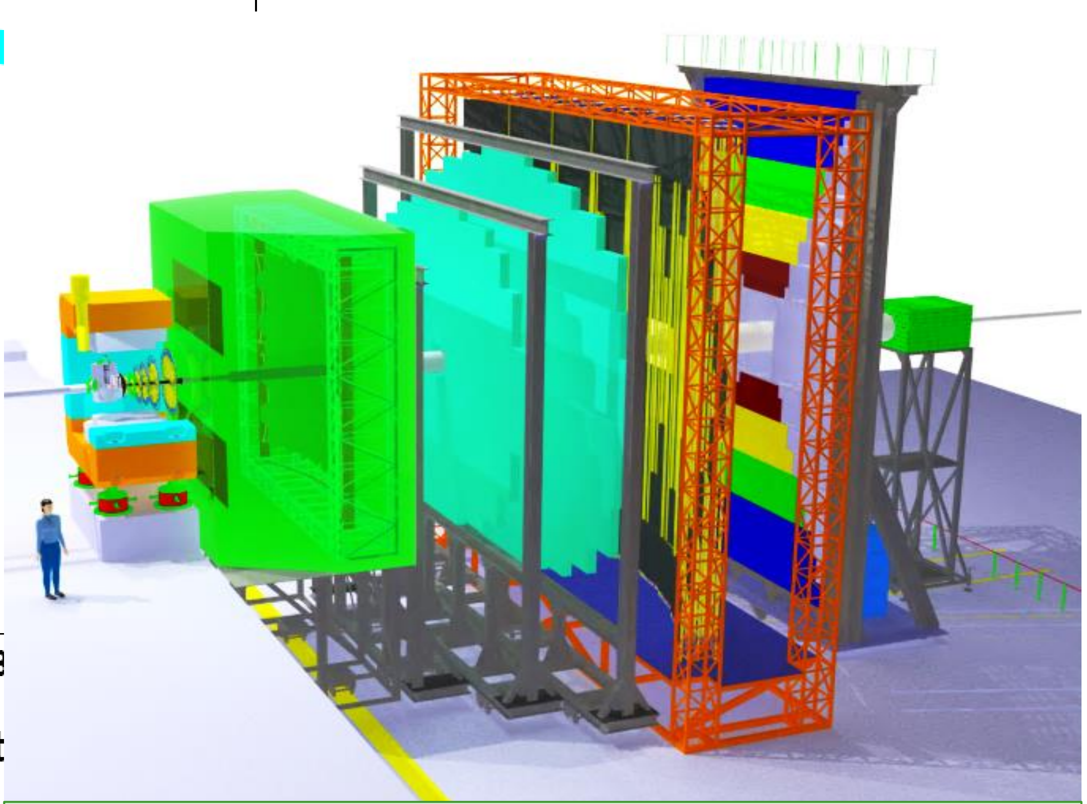


Morningstar & Peardon, PRD60(1999)34509
Morningstar & Peardon, PRD56(1997)4043

- Charmed glueballs
  - flavour blind decays
    - charmed final states
  - only a few charmed mesons around 3 - 4 MeV/c^2
    - less mixing
- Exotic glueballs: “oddballs” = no mixing!
  - m(2^{+-}) = 4140(50)(200) MeV
  - m(0^{+-}) = 4740(70)(230) MeV
    - decay modes $\phi\phi$, $\phi\eta$, $J/\psi\eta$, $J/\psi\phi$
    - Narrow widths predicted

Compressed Baryonic Matter





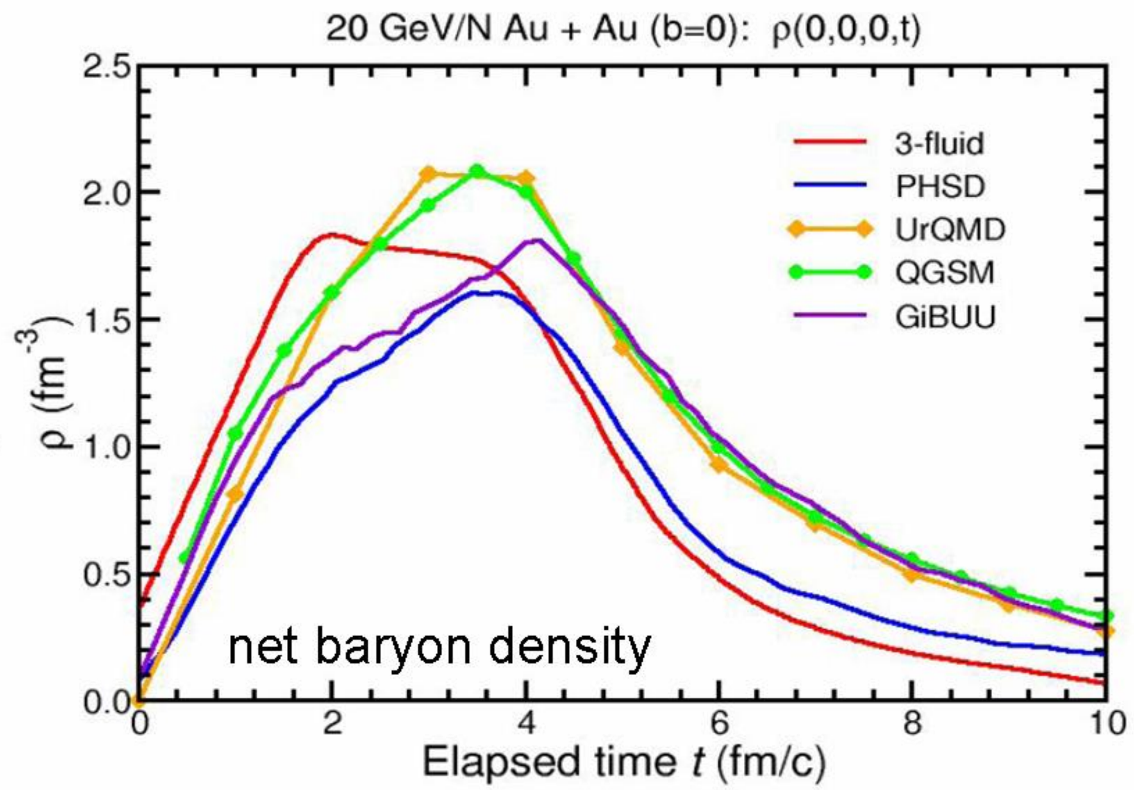
CBM @ FAIR

High Baryon Density @ **CBM**

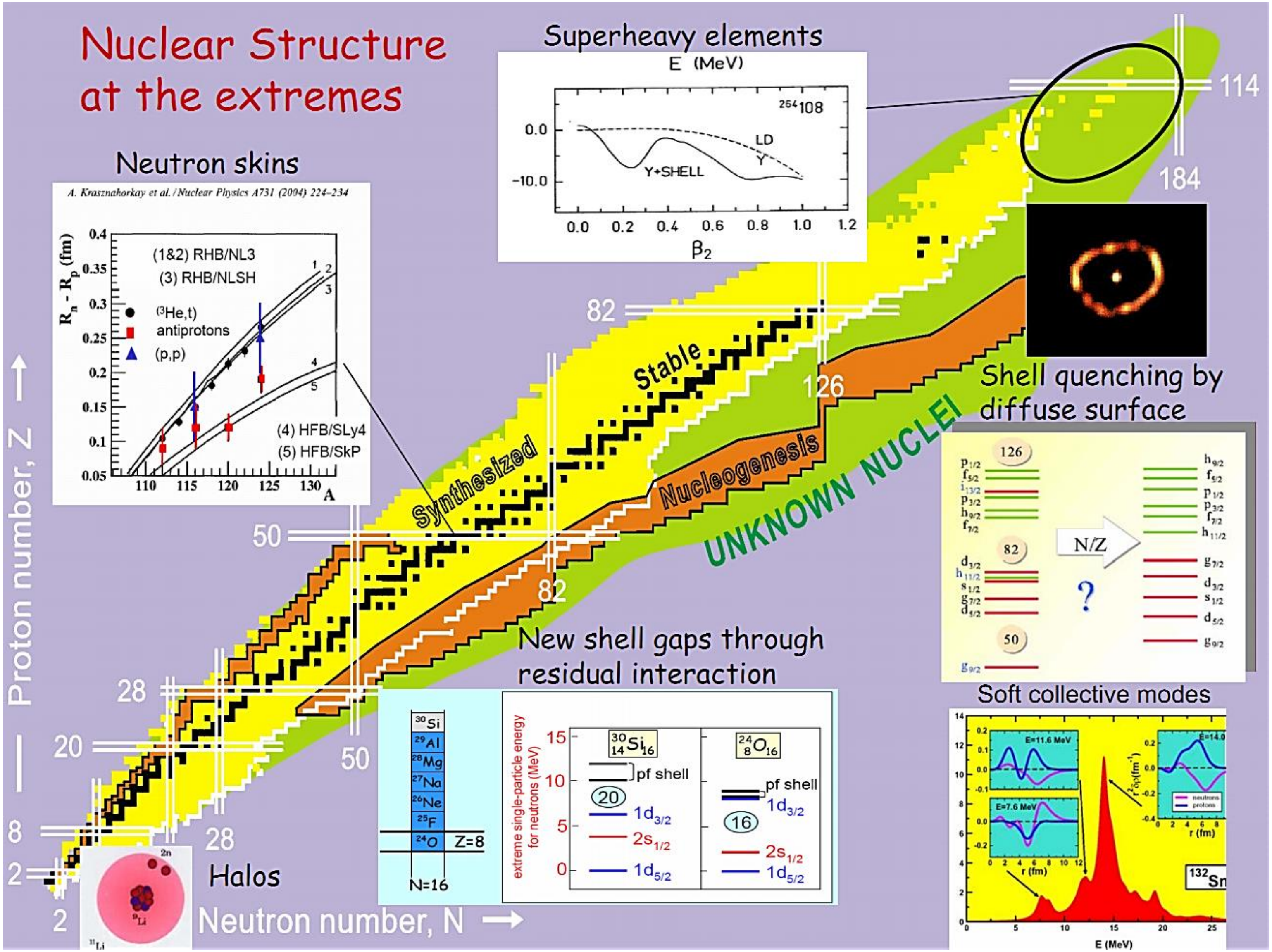
- high baryon and energy densities created in central Au+Au collisions
- max. net baryon densities from 5 - 40 AGeV ~ 1 - 2 fm^{-3} ~ (6 – 12) ρ_0

ρ = 1 fm^{-3}

~ 6 times normal nuclear matter density



NUSTAR



Nuclear Structure at the extremes
Superheavy elements
Neutron skins
A. Krasznahorkay et al. / Nuclear Physics A731 (2004) 224–234
(1&2) RHB/NL3
(3) RHB/NLSH
(³He,t)
antiprotons
(p,p)
(4) HFB/SLy4
(5) HFB/SkP
Stable
Synthesized
Nucleogenesis
UNKNOWN NUCLEI
Shell quenching by diffuse surface
N/Z
New shell gaps through residual interaction
pf shell
Soft collective modes
Halos
Proton number, Z
Neutron number, N

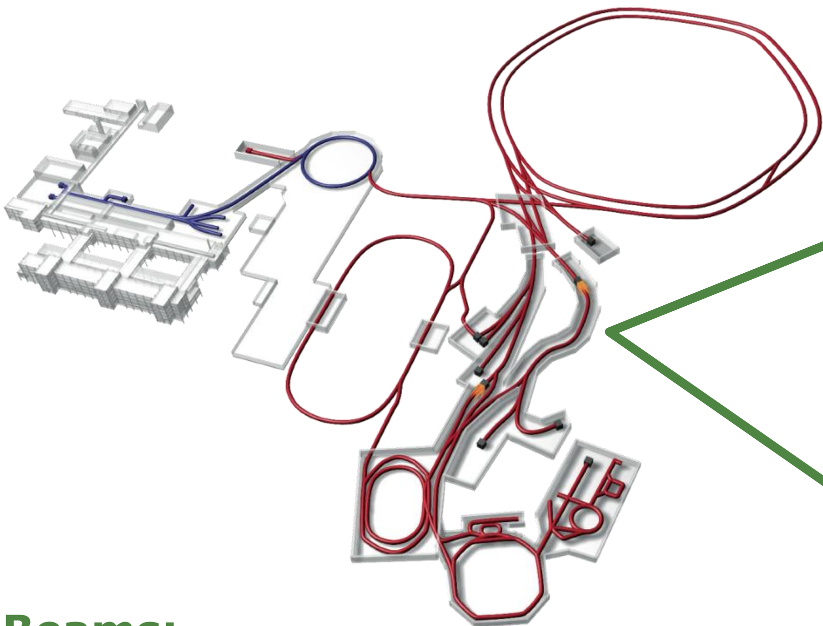
NUSTAR

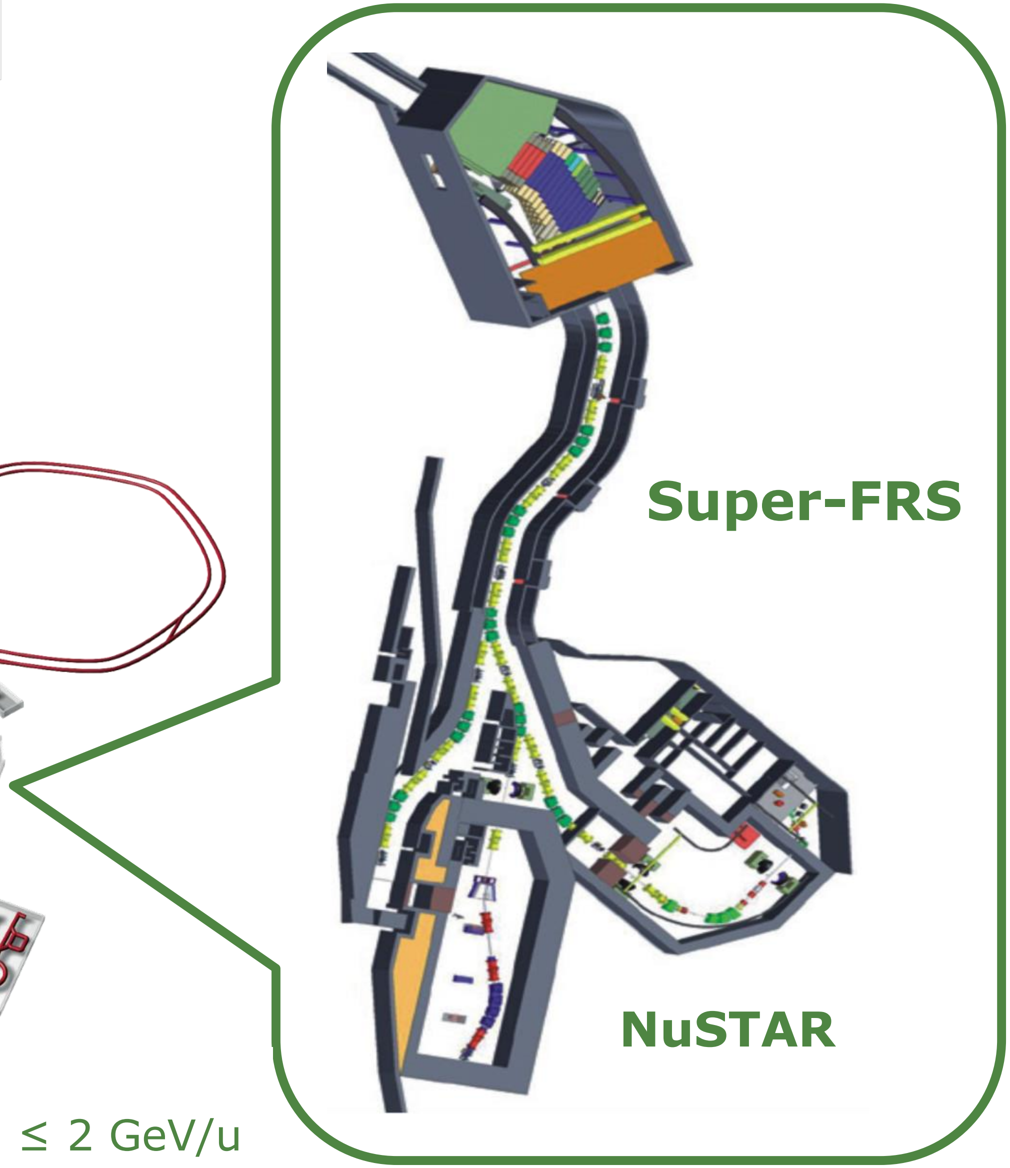
Primary HI Beams:

- $^{40}Ar^{18+}$ $2 x 10^{12}/s$ @ 1 – 2 GeV/u
- $^{238}U^{28+}$: $5 x 10^{11}/s$ @ 1 – 2 GeV/u

- $^{40}Ar^{18+}$ $2 x 10^{10}/s$ @ 1 – 45 GeV/u
- $^{238}U^{92+}$: $1 x 10^{10}/s$ @ 1 – 35 GeV/u

100 x 1000 times current intensity

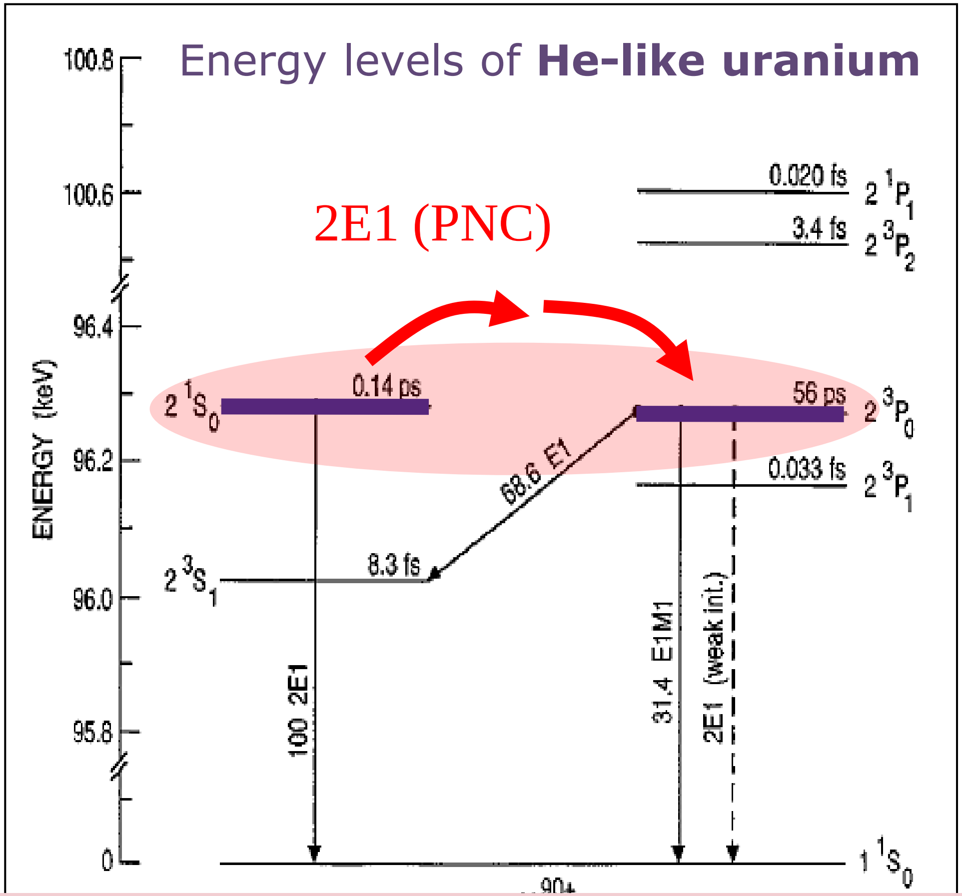




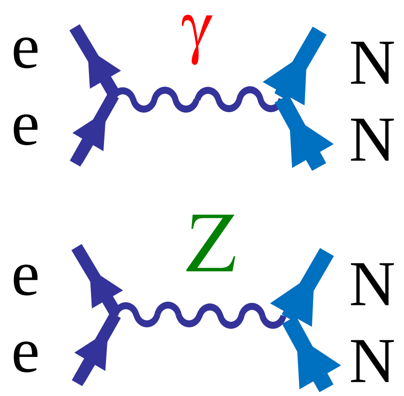
Secondary Beams:

- Broad range of radioactive ion beams ≤ 2 GeV/u
- **RI- Intensities up to 10 000 over present**

APPA: Parity-Violation



To "compete" with spontaneous decay channels, one needs to induce a two-photon PNC transition by polarised light with intensity 10^{20} W/cm^2



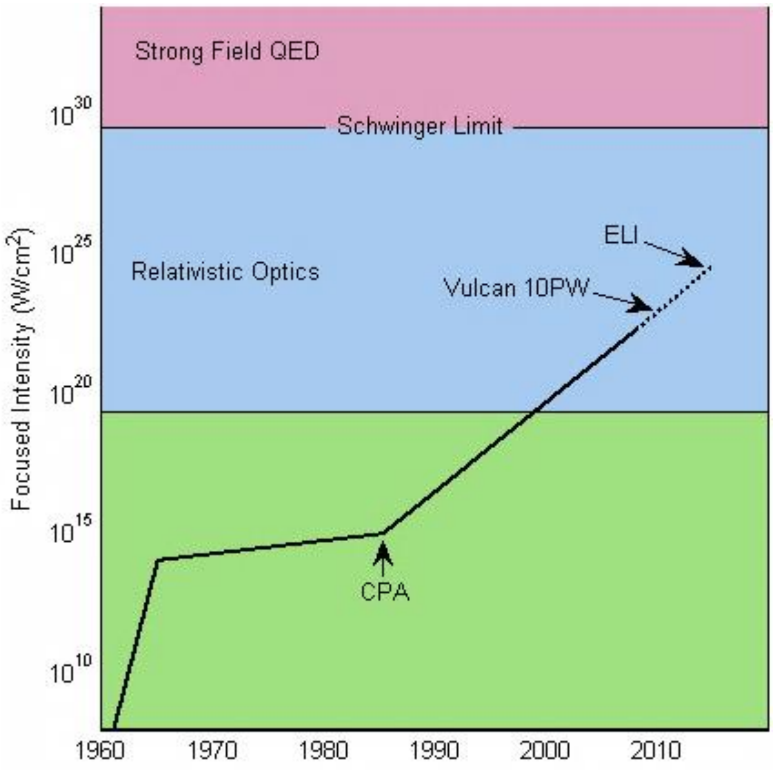
Mixing coefficient for states with opposite parities:

$$\eta = \frac{\left\langle \Psi_S \middle| G_F / 2\sqrt{2}\, Q_W\, \rho_N\, \gamma_5 \middle| \Psi_P \right\rangle}{E_S - E_P}$$

Select case with small splitting!

APPA: Large EM Fields

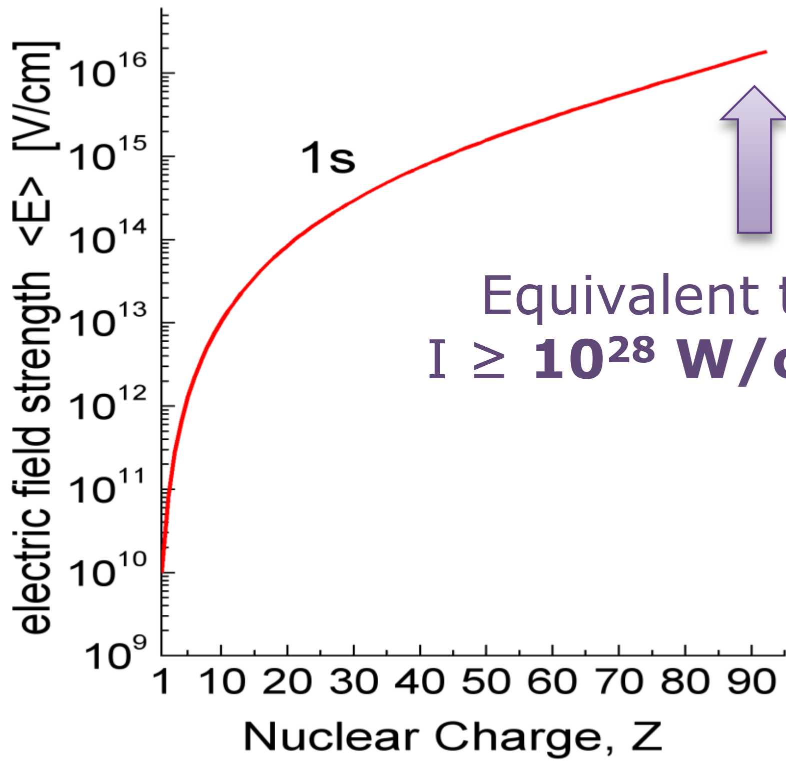
Lasers



(adapted from Mourou, Tajima, Bulanov, RMP **78**, 2006)

Sub-fs pulses

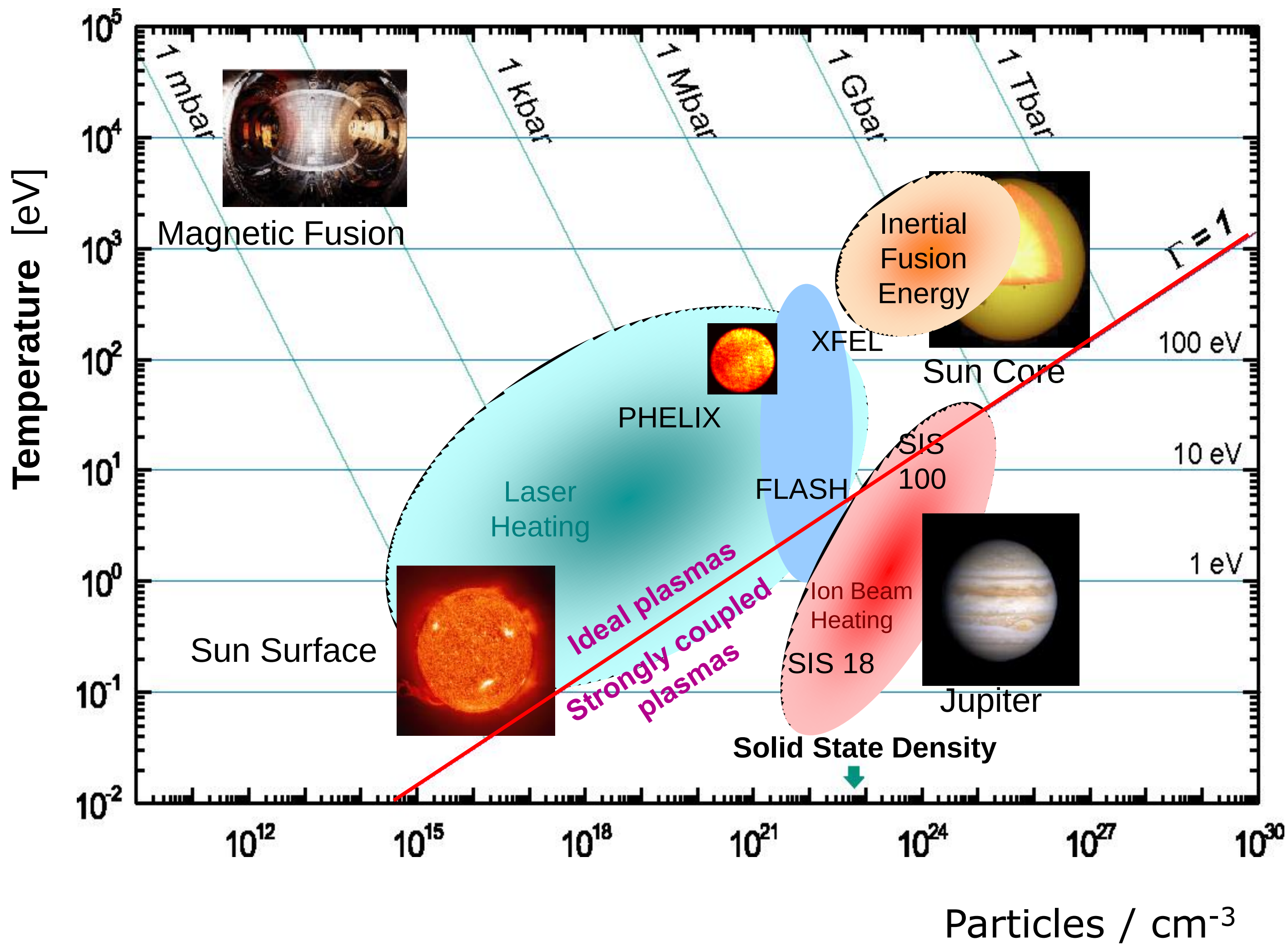
Heavy ions



Equivalent to
I ≥ $\mathbf{10^{28}}$ **W/cm²**

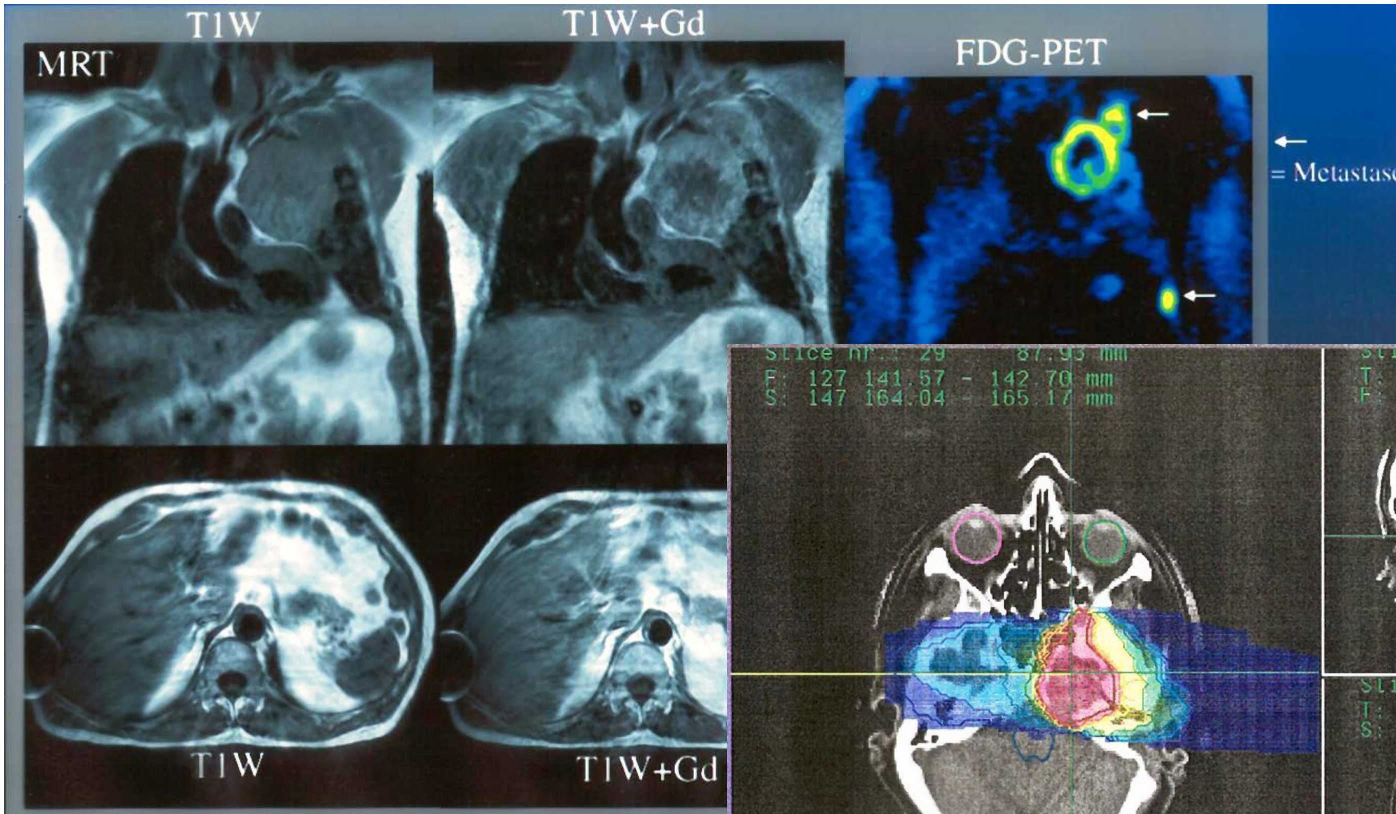
Large EM fields, zs pulses

APPA: Plasmas

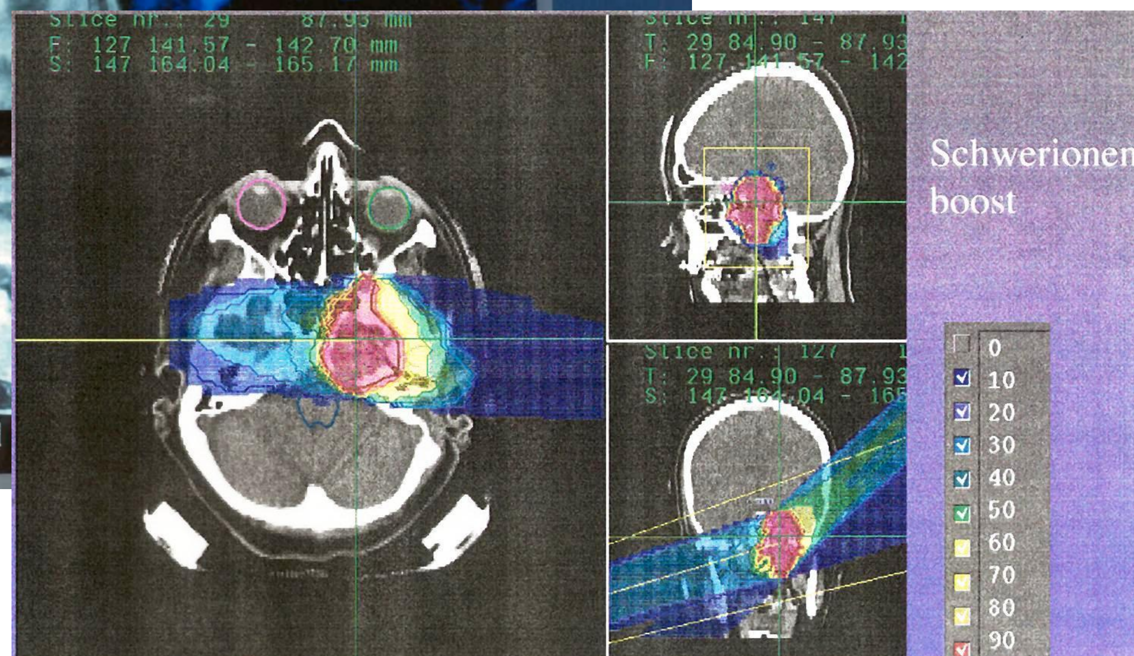


APPA: Nuclear Medicine

Small cell lung carcinoma



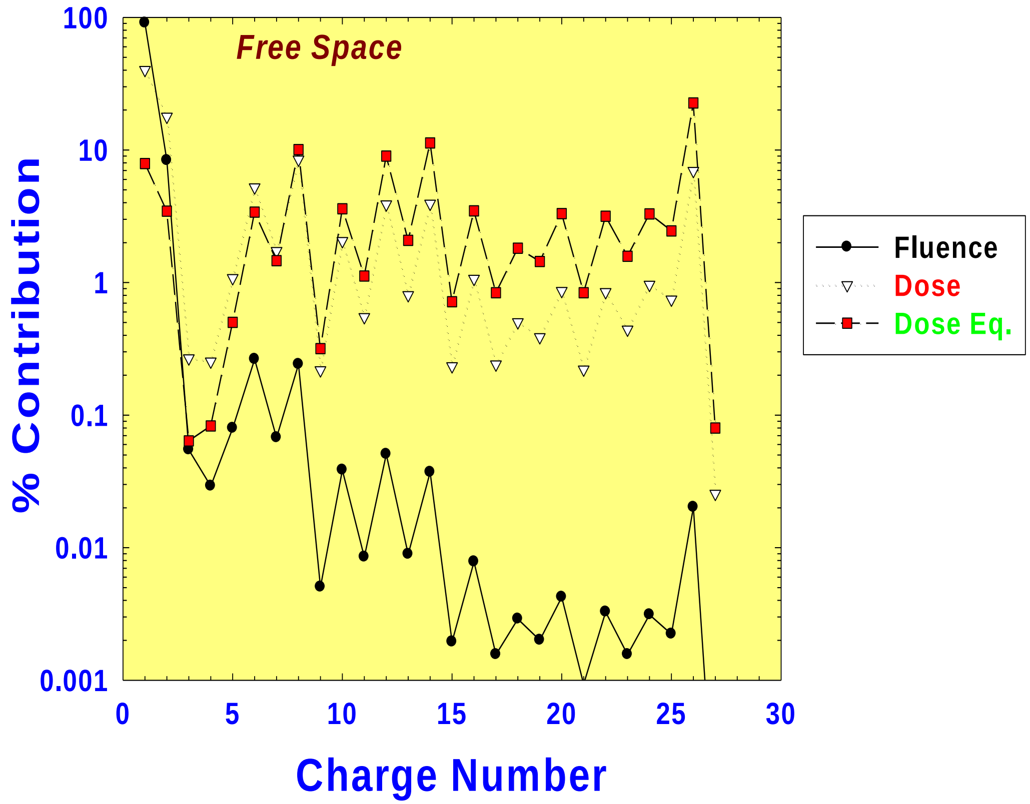
^{12}C
Therapy
@ GSI



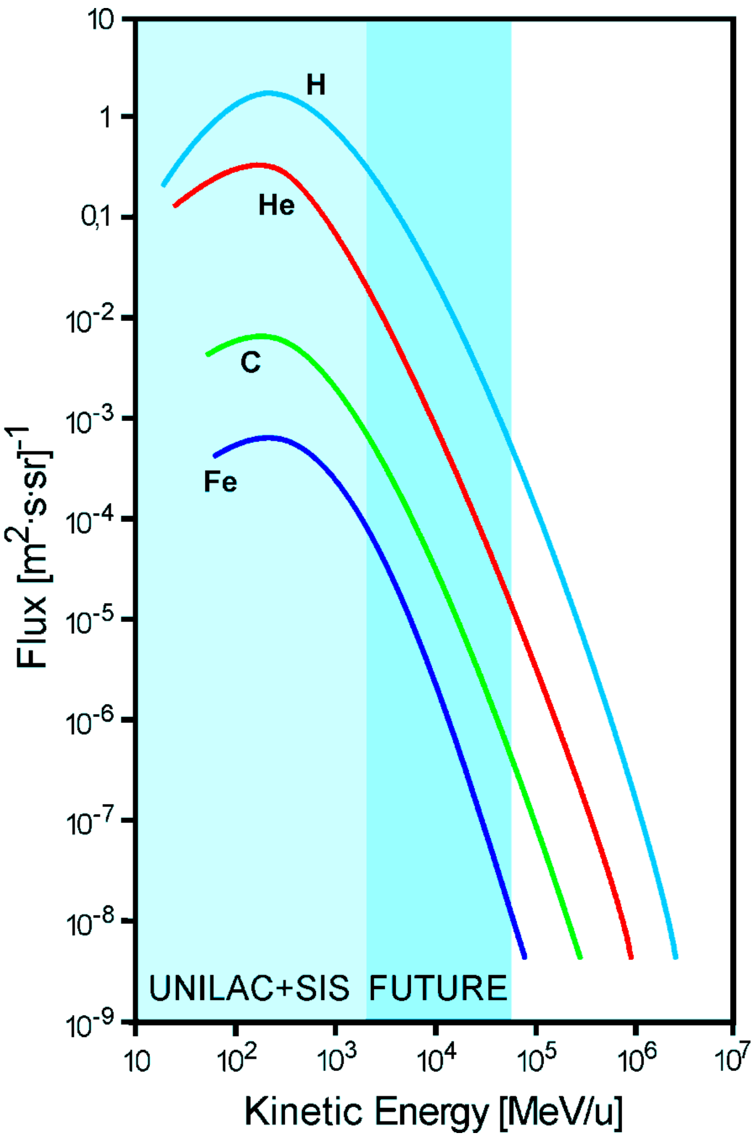
Adenoid cystic ca.

ESA @ GSI & FAIR

GCR Charge Contributions



Durante & Cucinotta, *Nature Rev. Cancer* (2008)

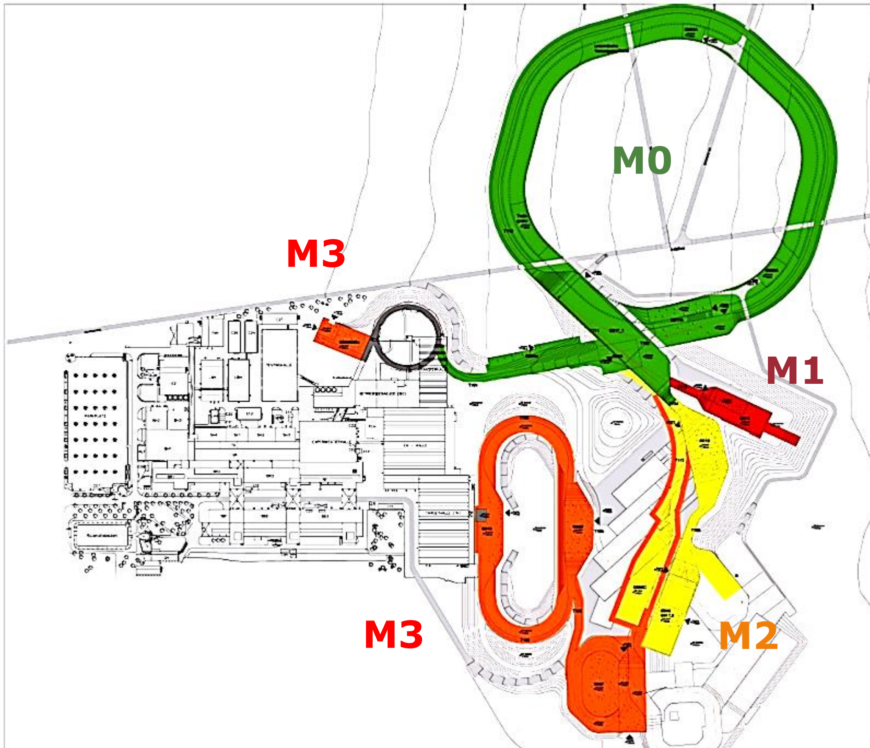


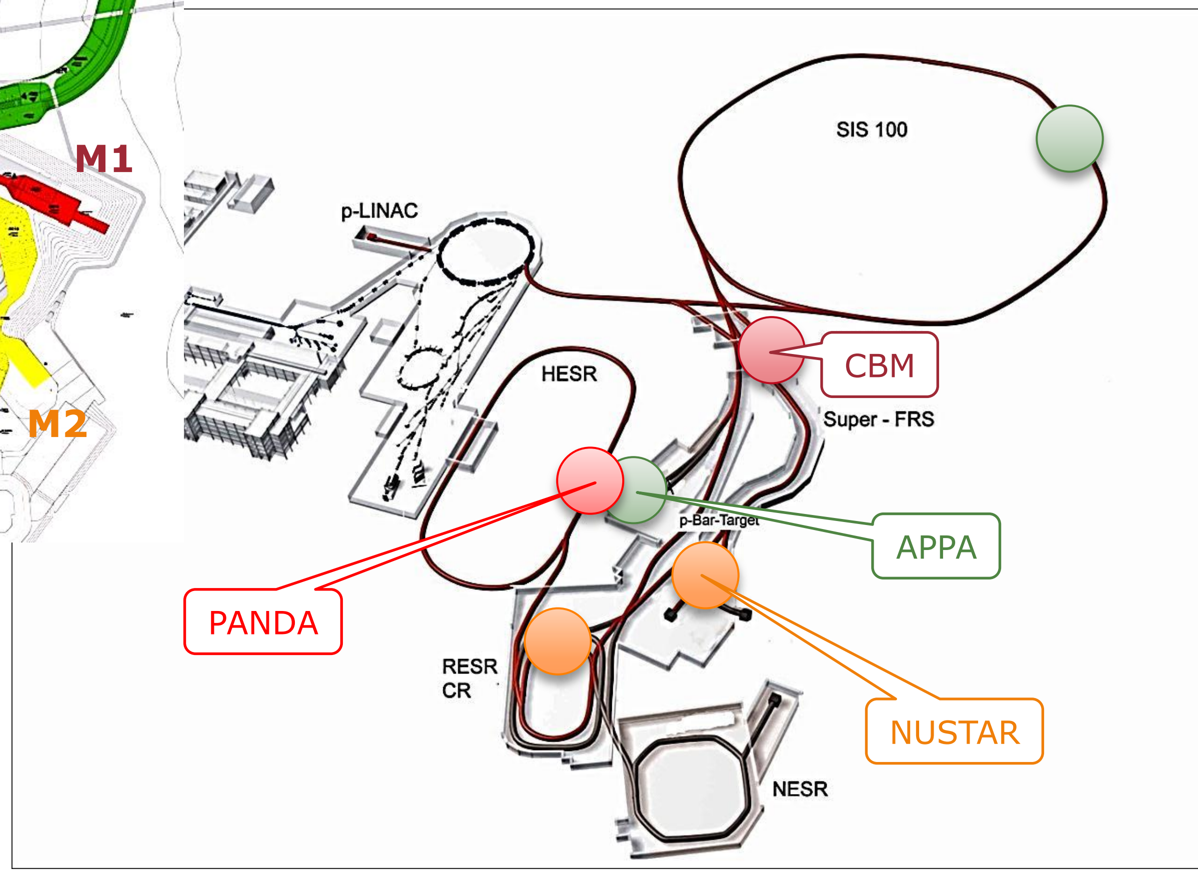
Staging

<table>
<tr><td colspan="6">Start Version Phase A
(SIS100)</td><td rowspan="4">Phase B
(SIS300)</td></tr>
<tr><td colspan="4">Modularised Start Version</td><td colspan="2"></td></tr>
<tr><td>Module 0</td><td>Module 1</td><td>Module 2</td><td>Module 3</td><td>Module 4</td><td>Module 5</td></tr>
<tr><td>SIS100</td><td>Exp. halls
CBM & APPA</td><td>Super-FRS
NuSTAR</td><td>Antiproton Facility
PANDA & options NuSTAR</td><td>LEB, NESR, FLAIR
NuSTAR & APPA</td><td>RESR
PANDA, NuSTAR & APPA</td></tr>
</table>

2018

Modularised Start Version





Experiments

M0: APPA
M1: CBM
M2: NUSTAR
M3: PANDA

Costs

Accelerators and personnel (including Super-FRS)	502 M€
Civil construction (excluding site related costs)	400 M€
FAIR contribution to experimental end stations *	78 M€
FAIR GmbH personnel & running until 2018 (>8 years)	47 M€
Grand Total MSV, Modules 0 - 3	1027 M€

in 2005 €
(inflation escalation until 2018: ca. **+50%**)

* Total experimental end stations (excluding Super-FRS): ca. 210 M€ (2005) = 315 M€ (2018)

FAIR Member States

Contracting Party	Contribution (in 2005 M€)
Finland	5.00
France	27.00
Germany	705.00
India	36.00
Poland	23.74
Romania	11.87
Russia	178.05
Slovenia	12.00
Sweden	10.00
Total	**1.008,66**

- **All numbers in 2005 €** (escalation until 2018 ca. **+50%**)
- UK Associate Member since 3/5/13
- Spain expected to join soon as a full member
- Talks with China on Associate FAIR Member status
- Talks with Italy
- Additional contributions to experiments by many countries

UK – Associate Partner 3/5/2013

Licences

- Radiation protection licences
  - 13 applications submitted to **Hessian Environmental Minister** end of 2011
    - 3 approved in **June 2012**
    - Rest by 2013

Civil Construction Grants

- **526 M€** German contribution to civil construction
  - largest BMBF grant ever
  - approved in July 2012

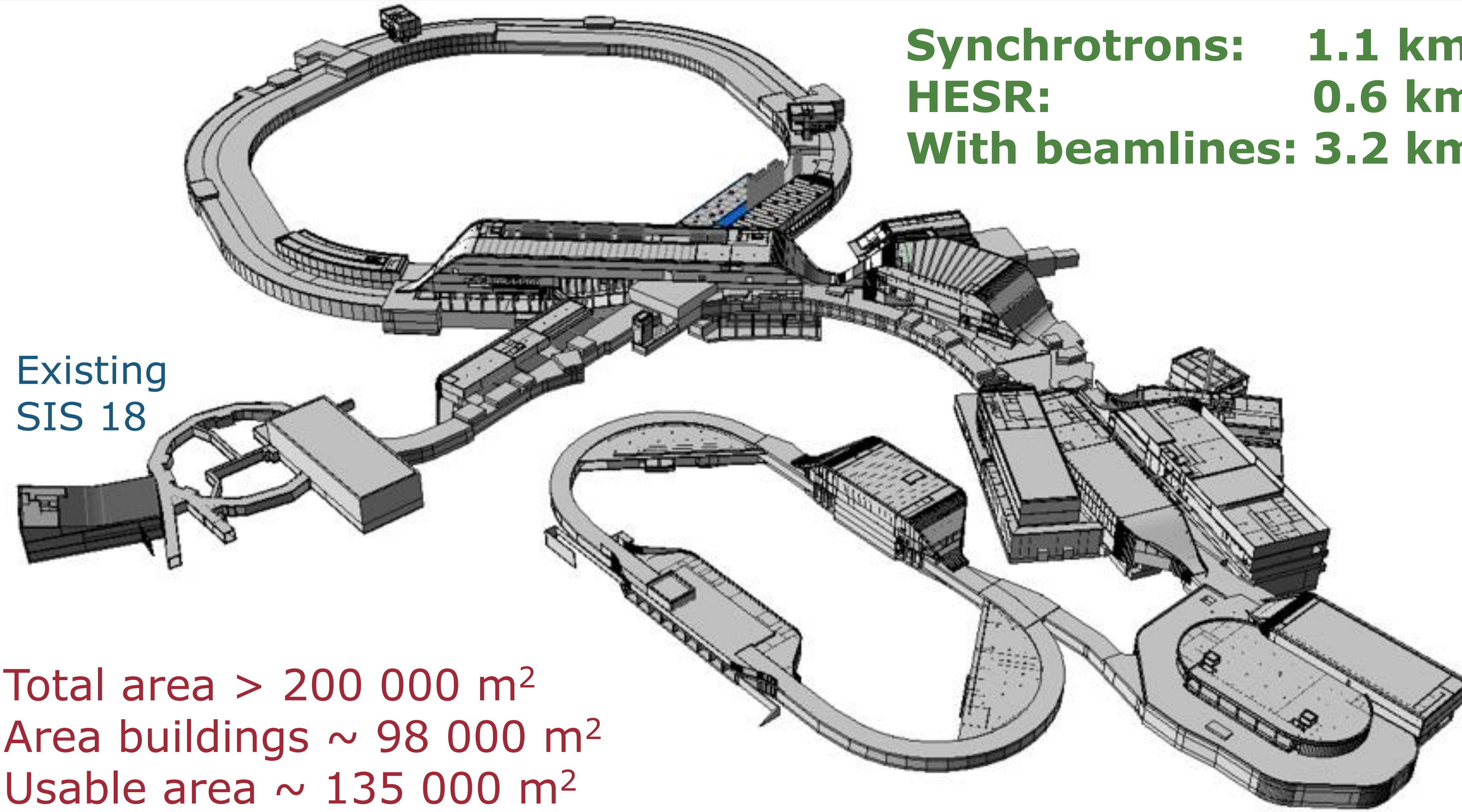
Building Permit

Submission of **771 folders** building application to Darmstadt's civil construction authority in Aug. 2011

Darmstadt Councilor Brigitte Lindscheid handing over the FAIR building permit (**21 folders**) to FAIR management at the end of Oct. 2012

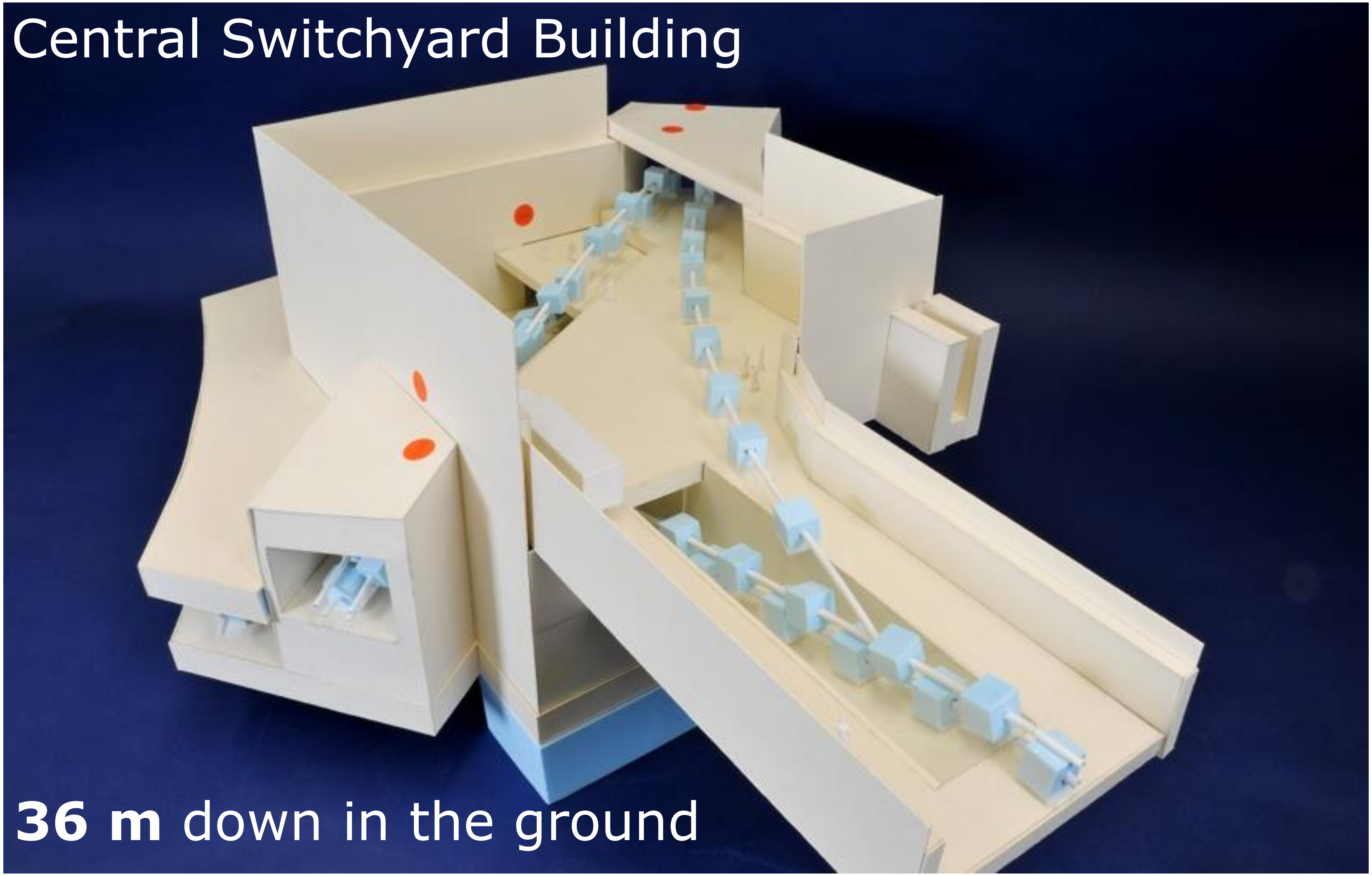
Civil Construction

Synchrotrons: 1.1 km
HESR: 0.6 km
With beamlines: 3.2 km



Total area > 200 000 m^2
Area buildings ~ 98 000 m^2
Usable area ~ 135 000 m^2
Volume of buildings ~ 1 049 000 m^3
Substructure:~ 1500 pillars, up to 65 m deep

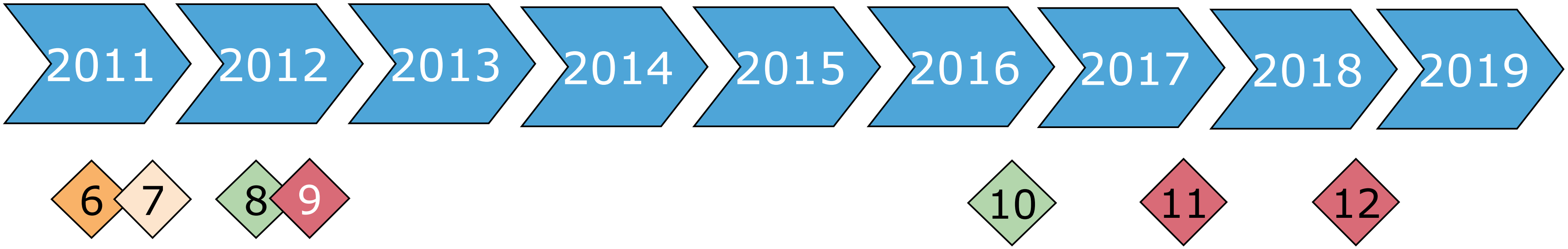
...with complex interior



Bird’s View

...closing in

Timeline



- 6 Submission building permits
- 7 Site preparation
- 8 Civil construction contracts
- 9 Building of accelerator & detector components
- 10 Completion of civil construction work
- 11 Installation & commissioning of accelerators and detectors
- 12 Start data taking

Thank you very much