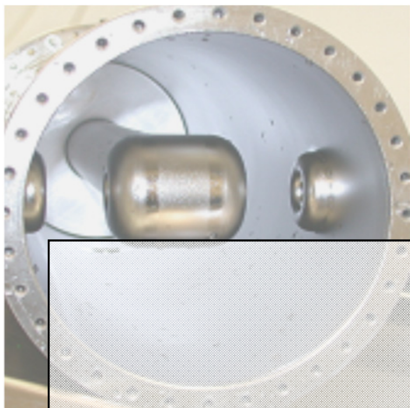
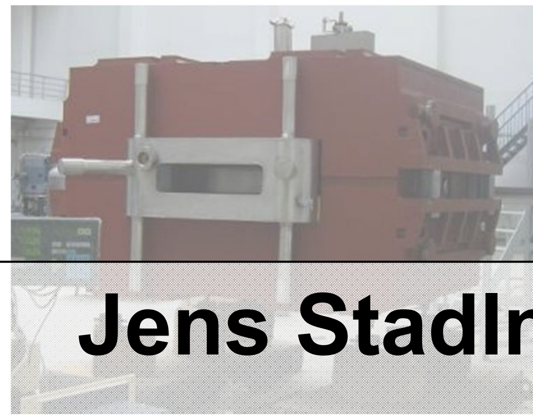
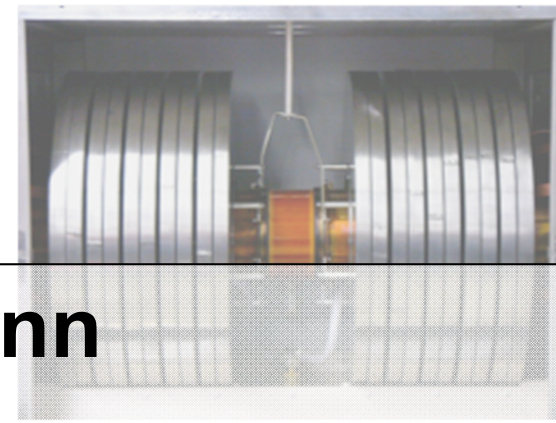
Future accelerators for Secondary particle production

Jens Stadlmann

GSI Helmholtzzentrum für Schwerionenforschung



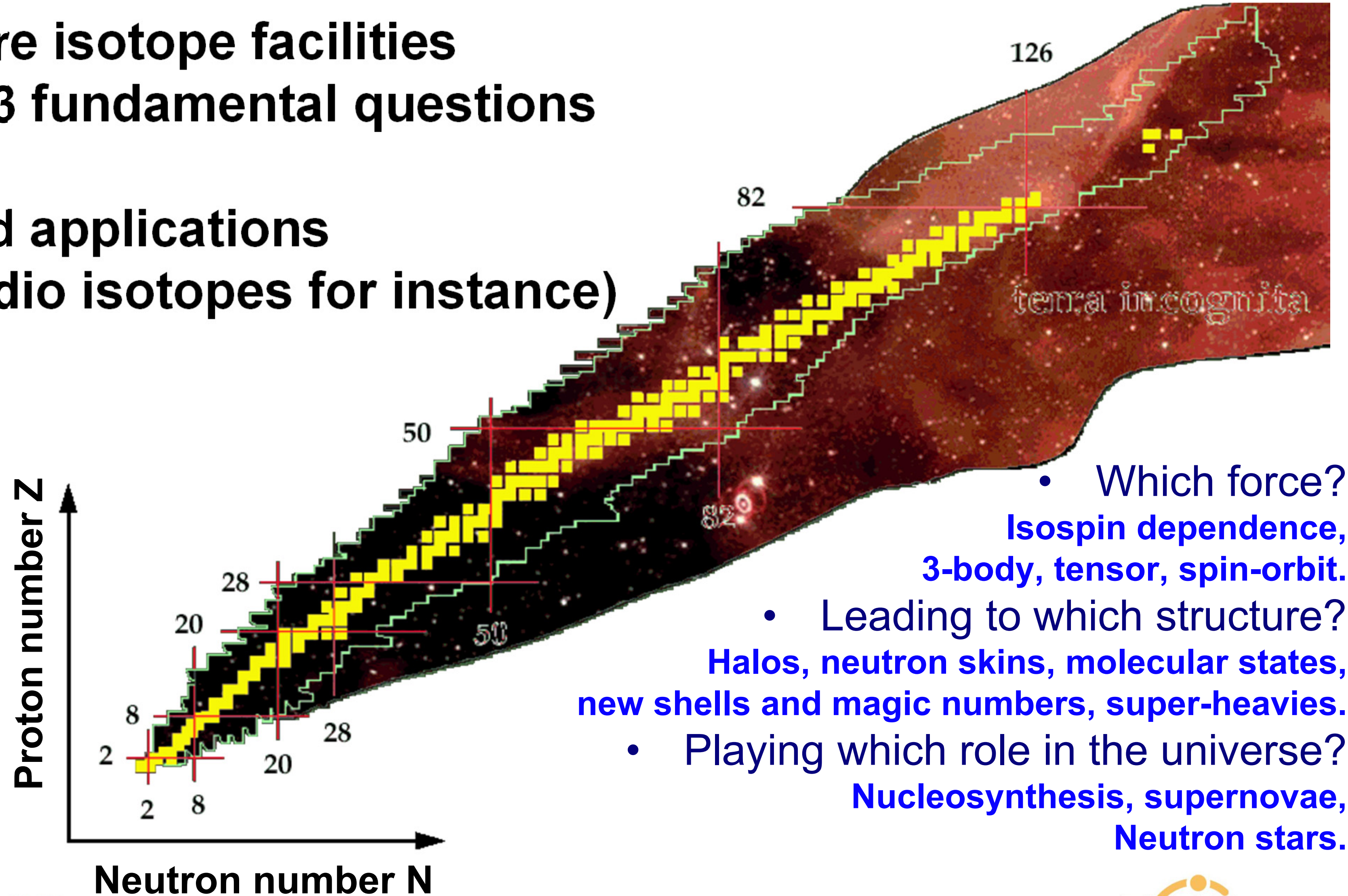
Outline

- Motivation: "Rare isotope production"
- Advances and technical developments for rare isotope accelerators
  - Application of Superconductivity
  - Radiation resistant materials and targets
  - Vacuum technology, rf-systems
- Technologies and the link to industry

Motivation: Physics with rare isotopes

Rare isotope facilities
→ 3 fundamental questions

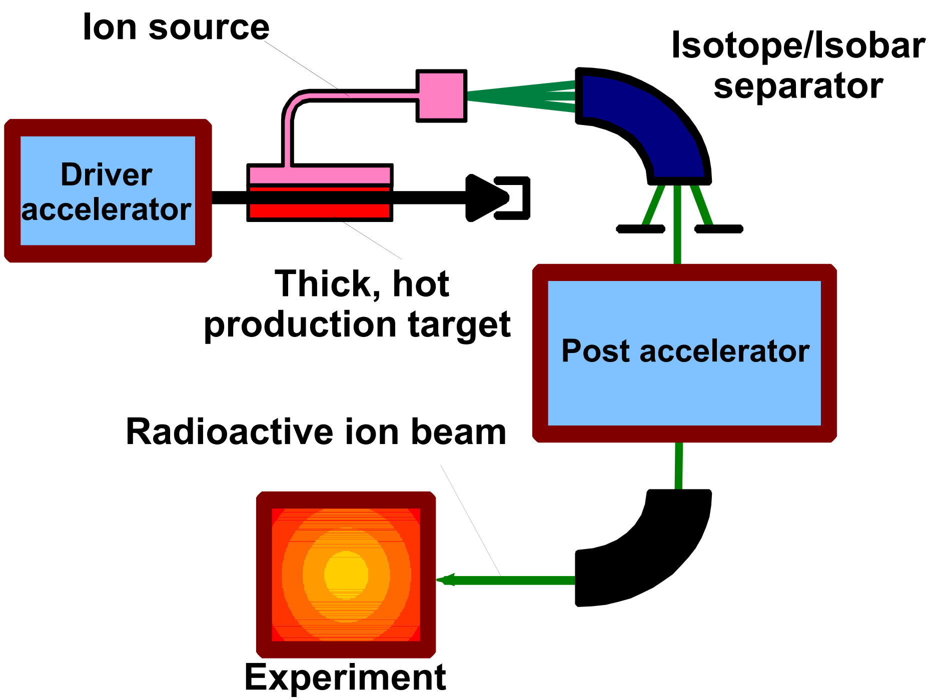
and applications
(radio isotopes for instance)



- Which force?
  Isospin dependence, 3-body, tensor, spin-orbit.
- Leading to which structure?
  Halos, neutron skins, molecular states, new shells and magic numbers, super-heavies.
- Playing which role in the universe?
  Nucleosynthesis, supernovae, Neutron stars.

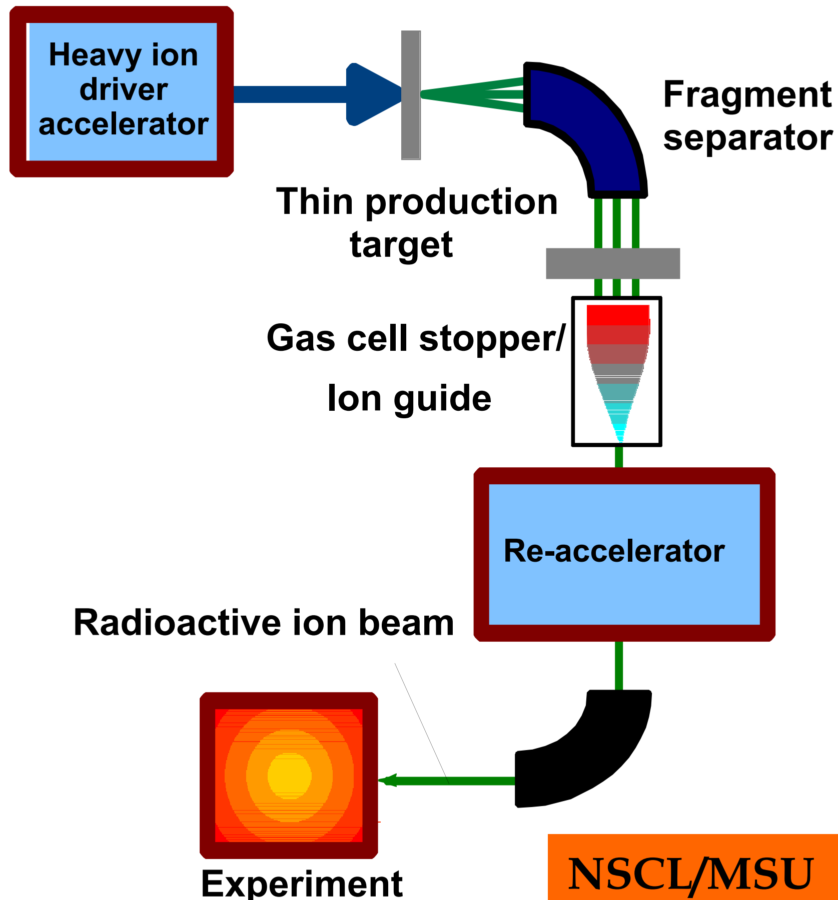
Production of rare isotopes:

ISOL



ISOLDE (CERN)
TRIUMF
GANIL

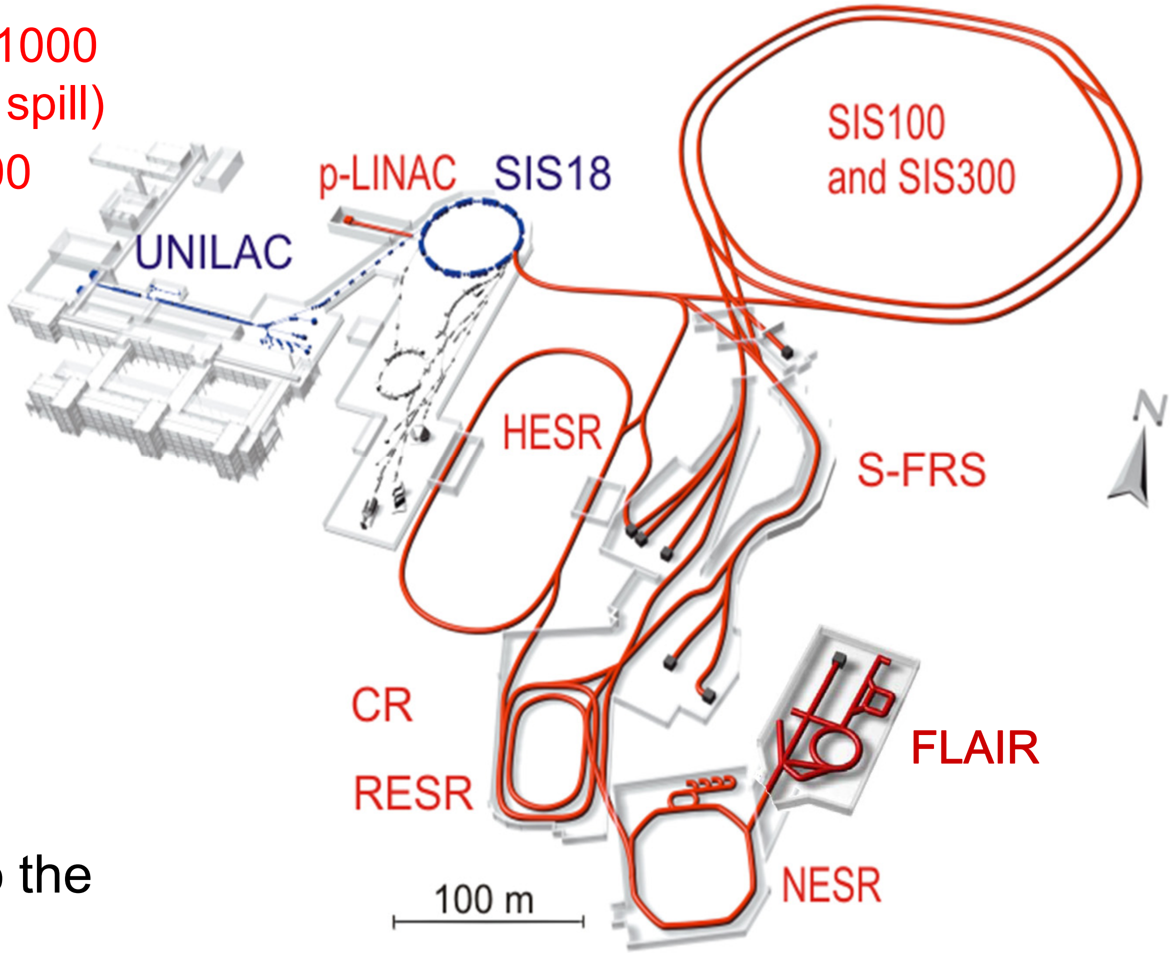
Projectile Fragmentation (PF) and stopped beams



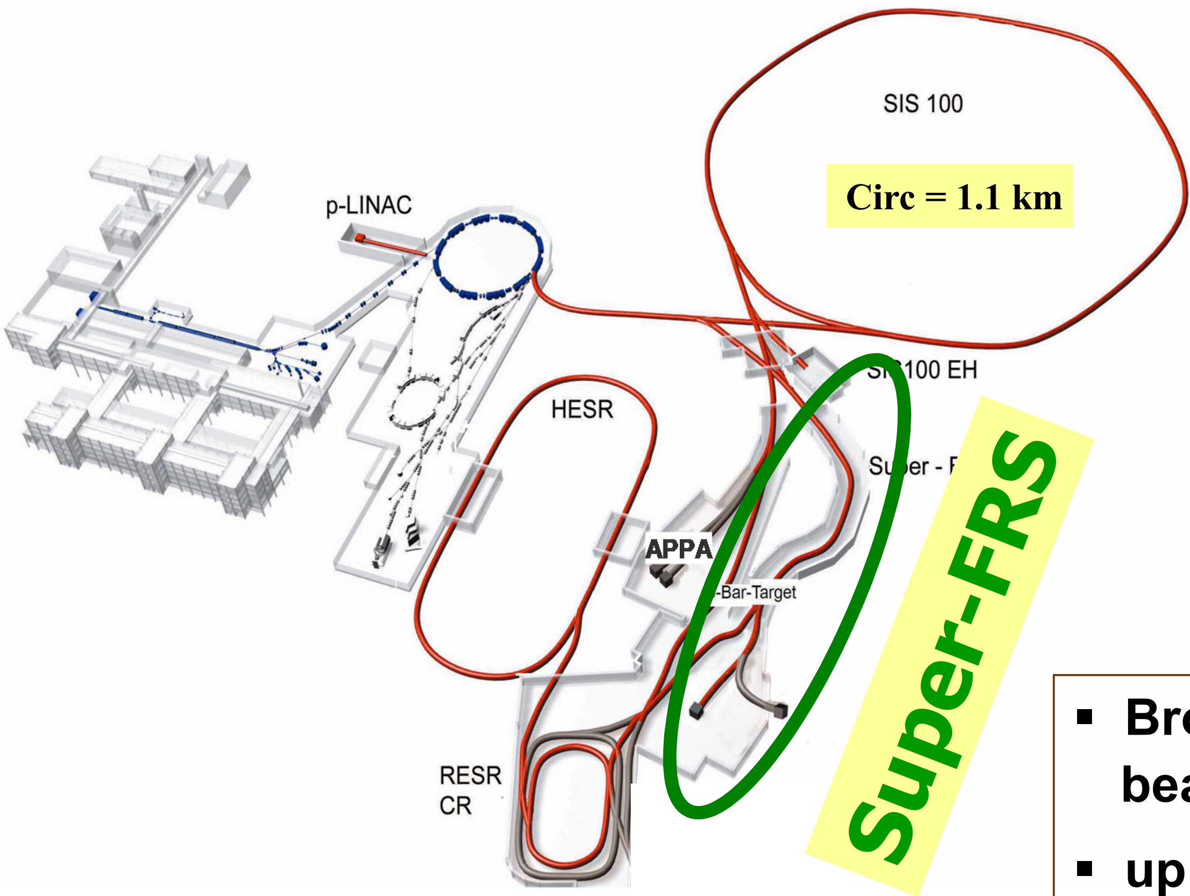
NSCL/MSU
GSI, RIKEN

The Facility for Antiproton and Ion Research (FAIR)

- Beam intensity increase:
  - Primary beams: x 100 – x 1000 (7.5*10^{11} uranium ions per spill)
  - Secondary beams: x 10.000
- Beams:
  - Anti protons
  - Protons to uranium, RIBs
- Beam quality:
  - Cooled anti proton beams
  - Cooled, intense RIBs
- Beam pulse structure:
  extreme short pulses to quasi continuous
- 1.5 GeV/u ^{238}U beams to the S-FRS for instance



Super-FRS at FAIR



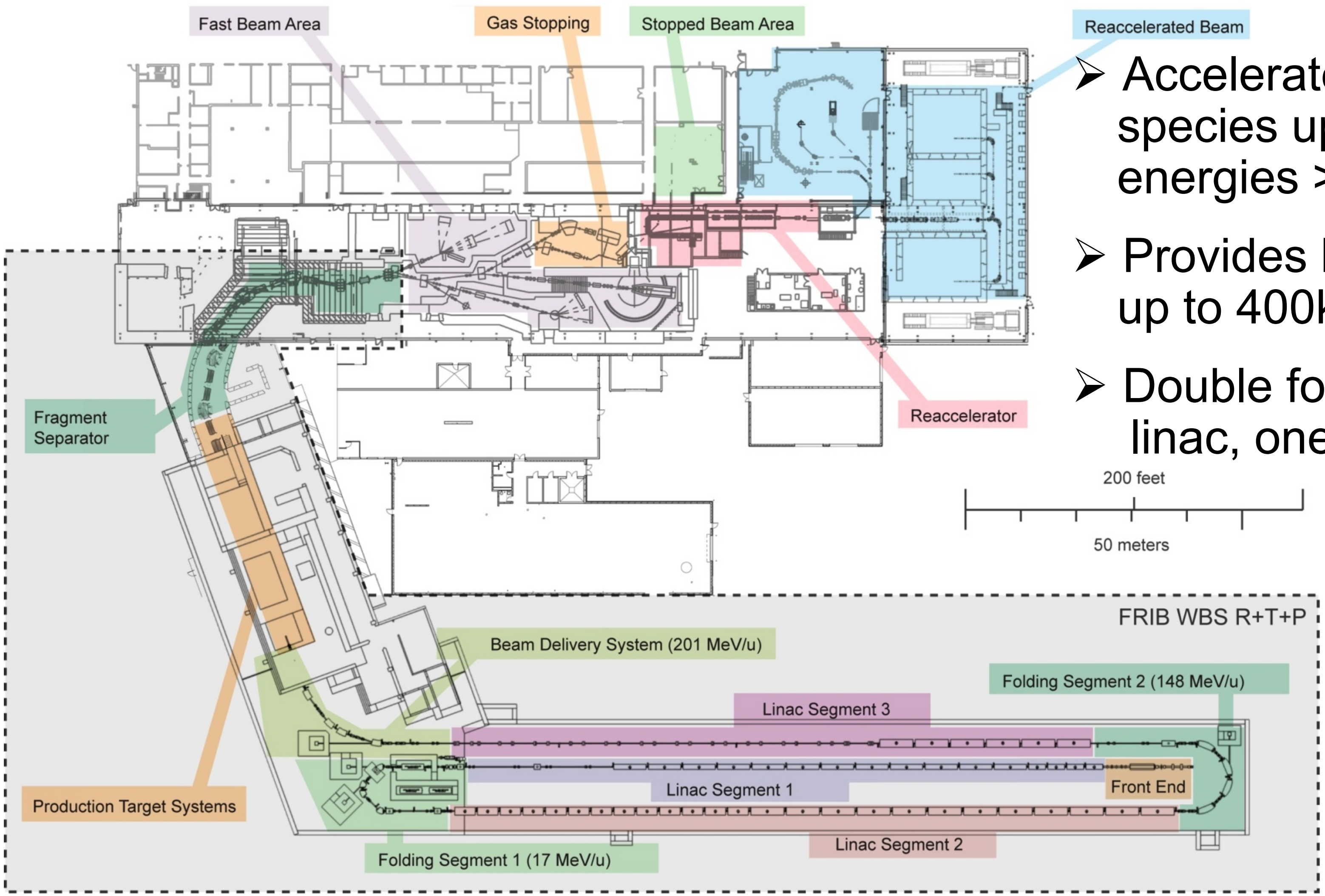
Primary Beams

- $3 \cdot 10^{11}$ $^{238}U^{28+}$/s (Slow extr.) @ 1.5 GeV/u
- $4 \cdot 10^{11}$ $^{238}U^{28+}$ (pulsed) @ 1 GeV/u
- factor 100 in intensity over present

Secondary Beams

- Broad range of radioactive beams up to 1.5 GeV/u
- up to factor 10 000 in intensity over present

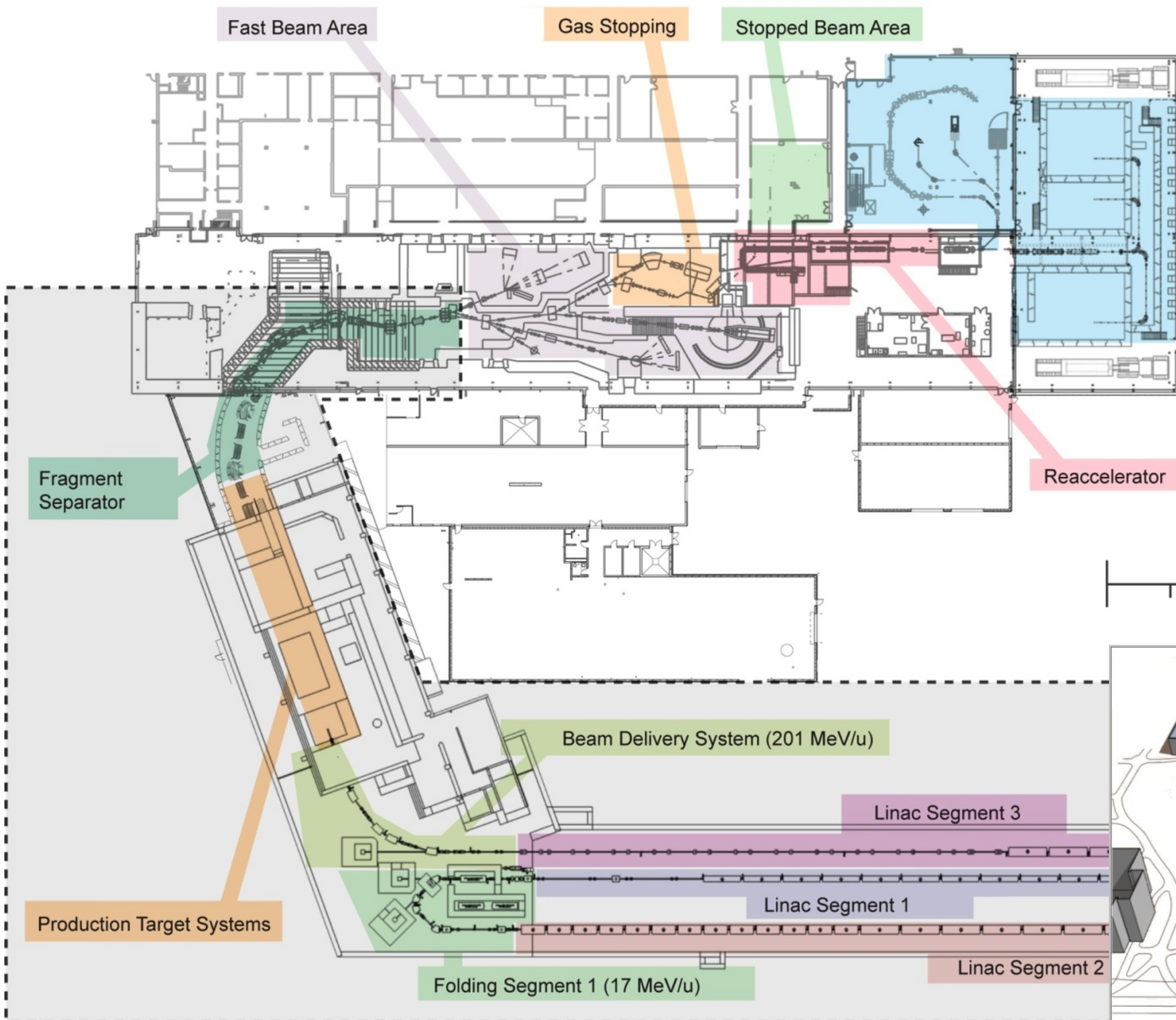
Facility for rare ion beams (FRIB) at MSU



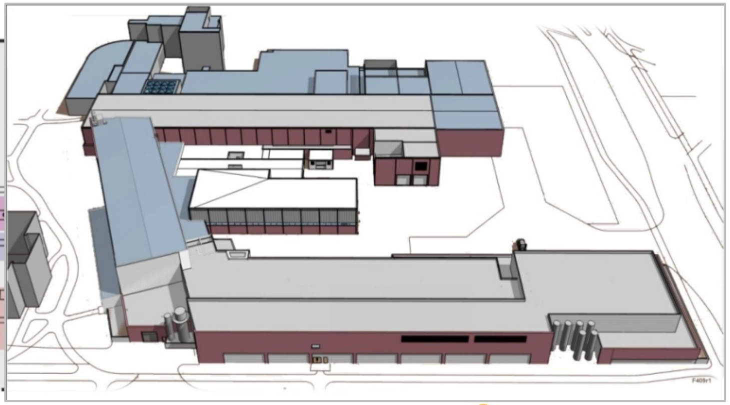
- Accelerates ion species up to ^{238}U with energies > 200 MeV/u
- Provides beam power up to 400kW on target
- Double folded driver linac, one stripper

J. Wei, G. Bollen

Facility for rare ion beams (FRIB) at MSU

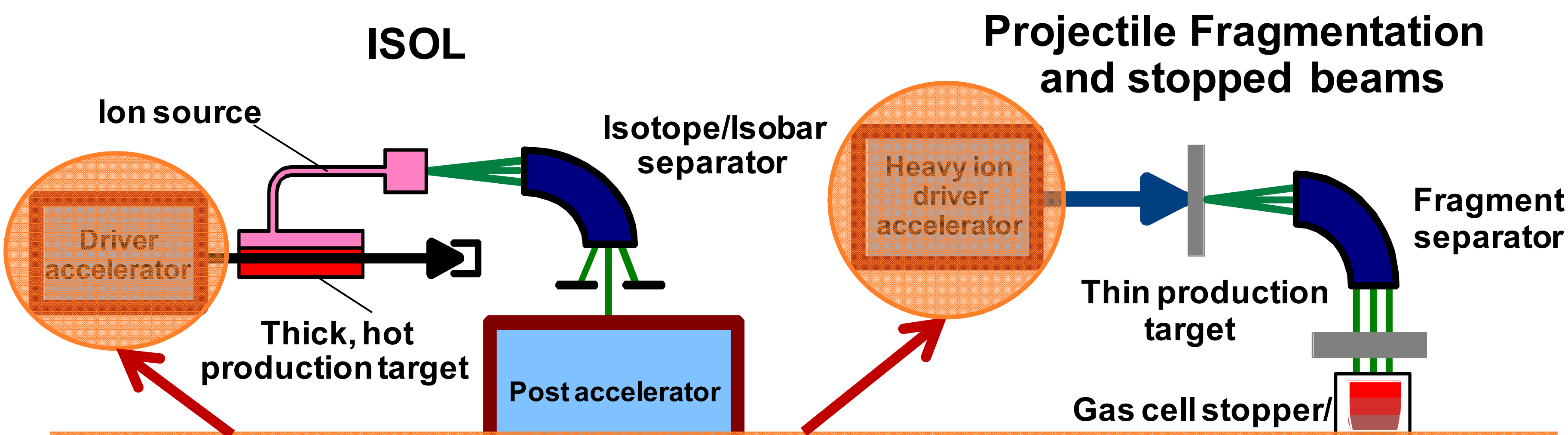


- Accelerates ion species up to ^{238}U with energies > 200 MeV/u
- Provides beam power up to 400kW on target
- Double folded driver linac, one stripper



J. Wei, G. Bollen

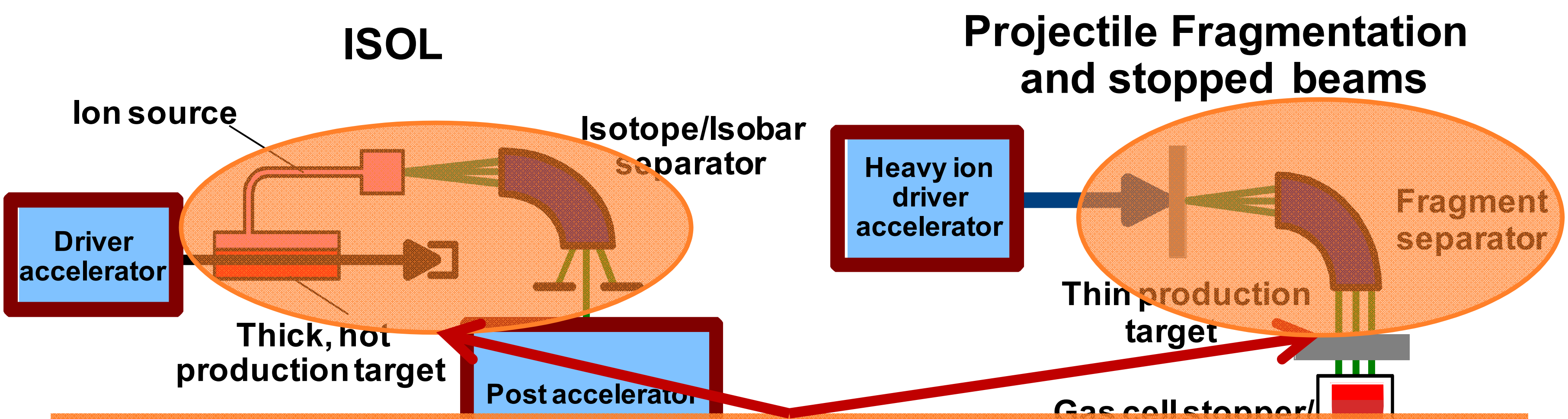
Driver accelerator challenges



→ **High beam intensities, high duty cycles**

- **Ion sources, Low energy beam transport (LEBT),**
- **Cavities (high duty cycle) → superconducting RF**
- **Charge state stripper**
- **Quality of magnets in ring machines**
- **Highest intensities in ring machines (resonances)**
- **beam diagnostics and machine protection**
- **Beam losses and activation**

Target and separator challenges



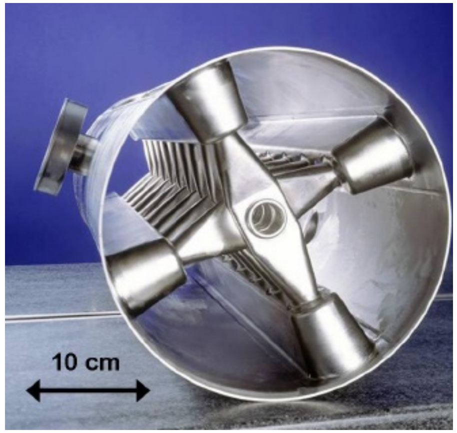
Targets:

- ➢ Beam power deposition in the targets and lifetime of the targets (similar to charge state stripper)
- ➢ Activation and target handling

Separators

- ➢ Phase space acceptance, resolution → Magnet size
- ➢ Activation of components, Suppression of background contamination

Superconducting rf-cavities (SRF)



- E-Beam welding, Nb
- Sufficient lHe cooling
- High gradients → surface preparation and processing BCE, HPR, EP, degassing (high T)

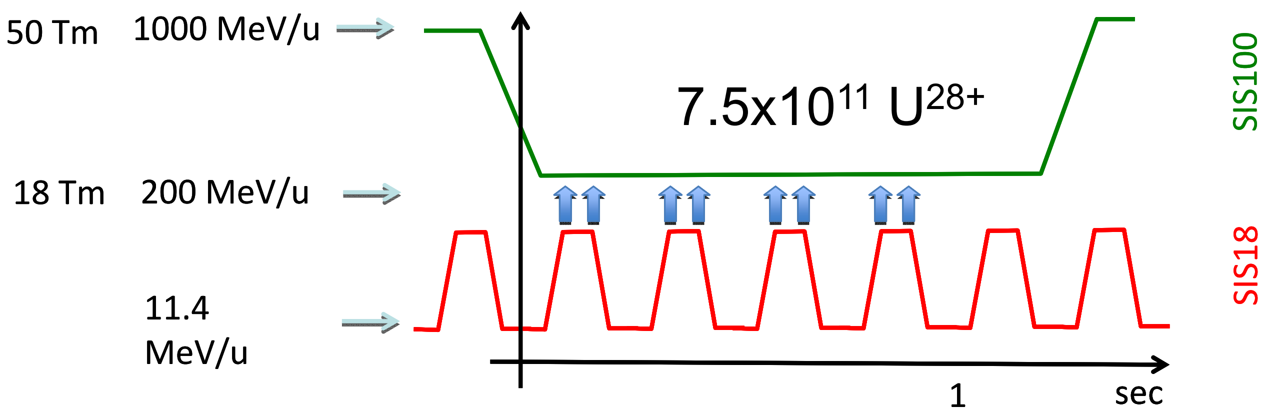
Typical for driver and post accelerators (TRIUMF, MSU,CERN,GANIL…)

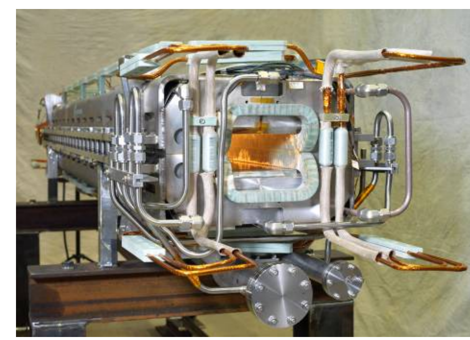
- Quarter and half wave resonators (QWR/HWR)
- single and multi spokes cavities
- Cross bar (CH) structure
- Elliptical cavities

Challenges of the SC-magnets development for SIS100

Fast ramped magnets (synchrotrons)

- Dynamic load and AC heat losses (Synchrotron magnets)
  Bρ= 100 Tm - Bmax= 1.9 T - dB/dt= 4 T/s
- High field quality, low multipole strength





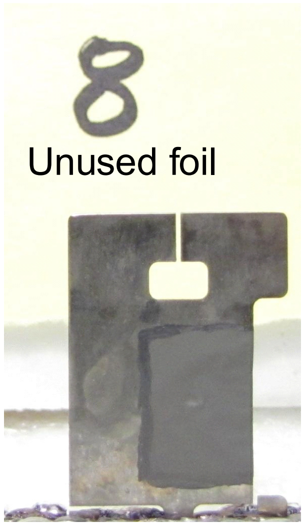
R&D Goals

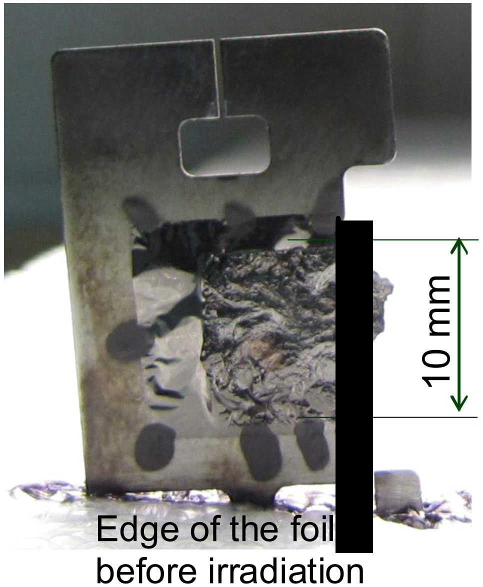
- Reduction of eddy / persistent current effects

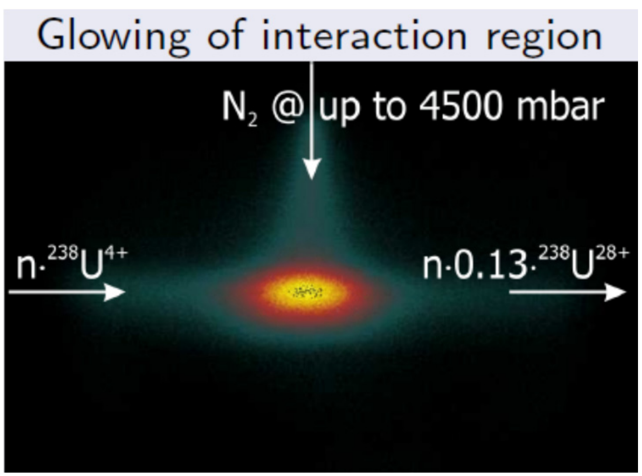
- Guarantee of long term mechanical stability (≥ $2*10^8$ cycles)

(mechanical stress →coil restraint)

Charge state stripper for intense heavy ion beams





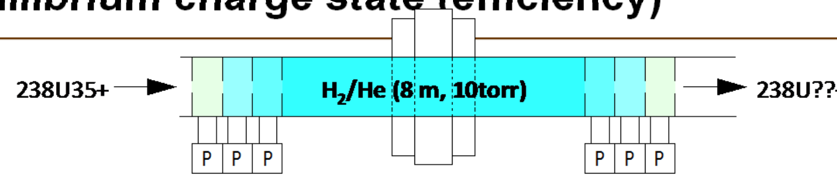


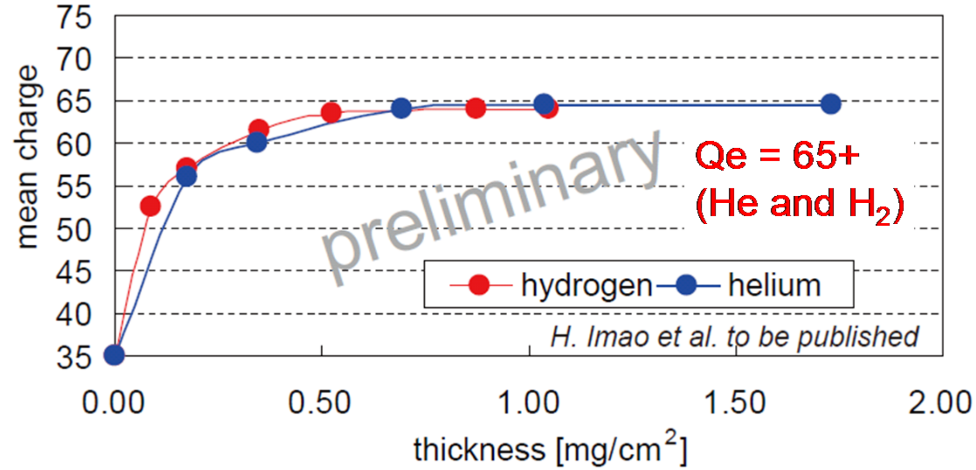
C-foil stripper

- short lifetime at highest intensities, but highest charge states

gas stripper

- High intensity capabilities, but lower charge states
- Equilibrium charge state (efficiency)

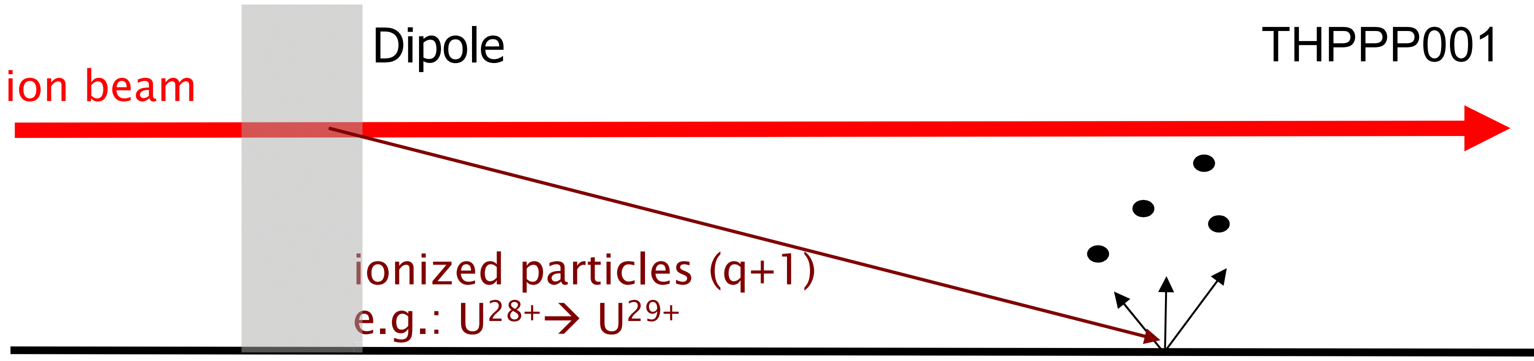


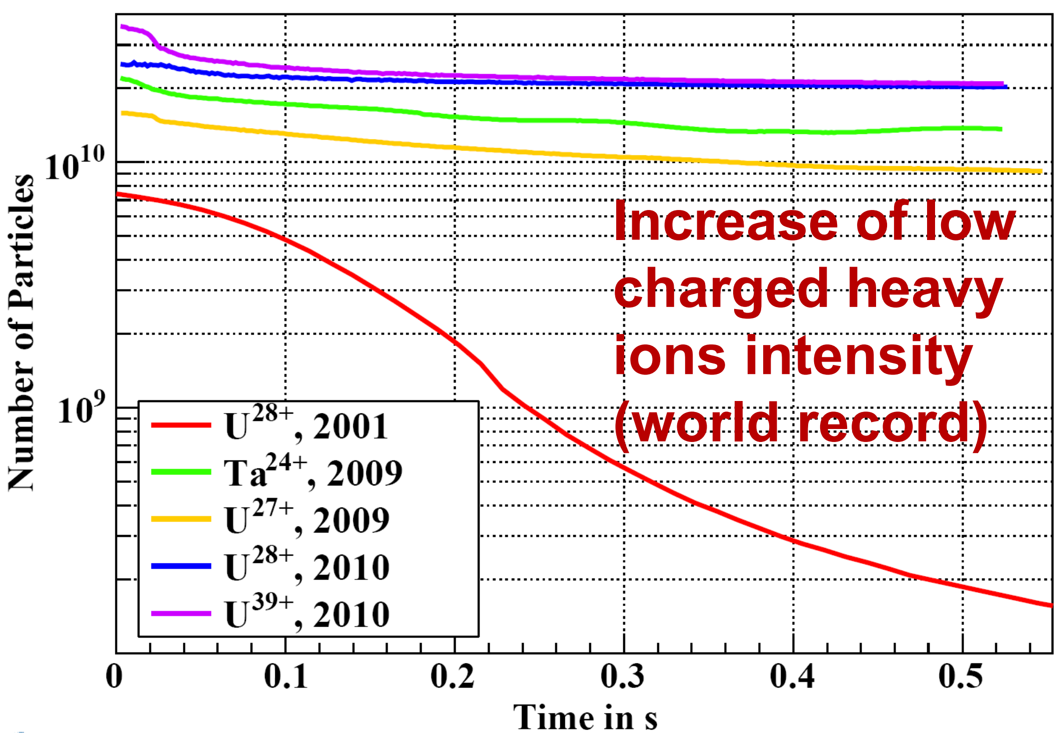


HELMHOLTZ GEMEINSCHAFT

FAIR GSI

Lifetime of Heavy ions in a synchrotron

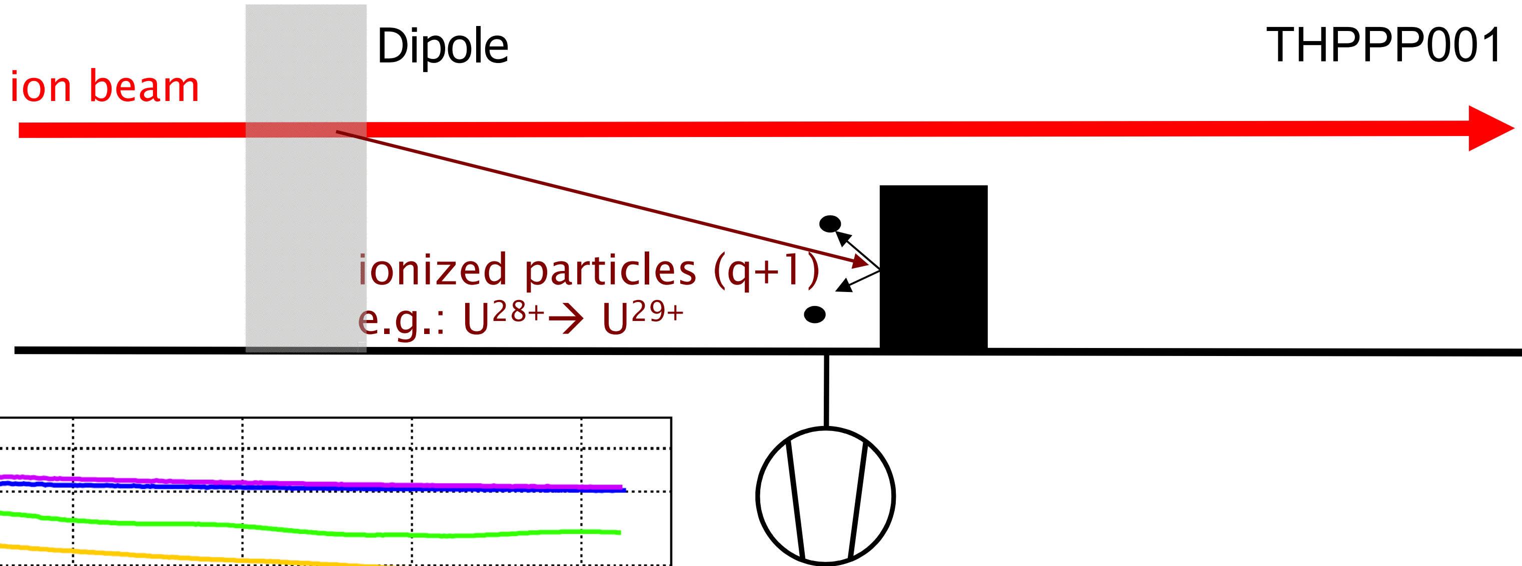


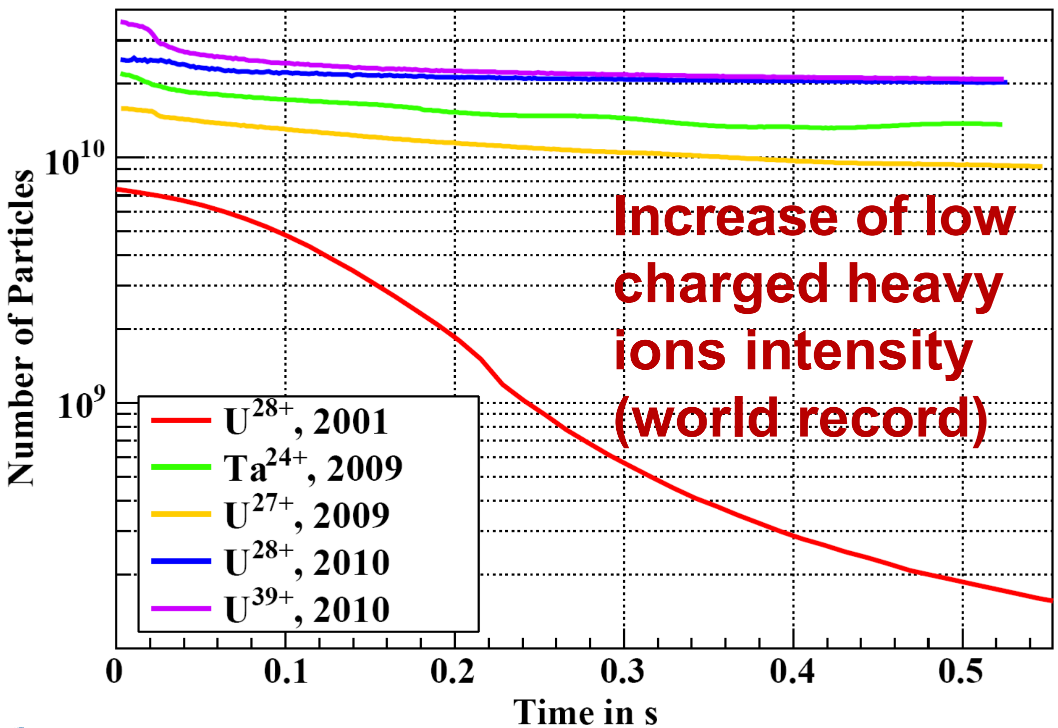


- Charge changing reactions due to rest gas atoms
- Losses induce pressure bumps
- Define location for losses with high pumping capacity
- Low desorbing material

Lifetime of Heavy ions in a synchrotron

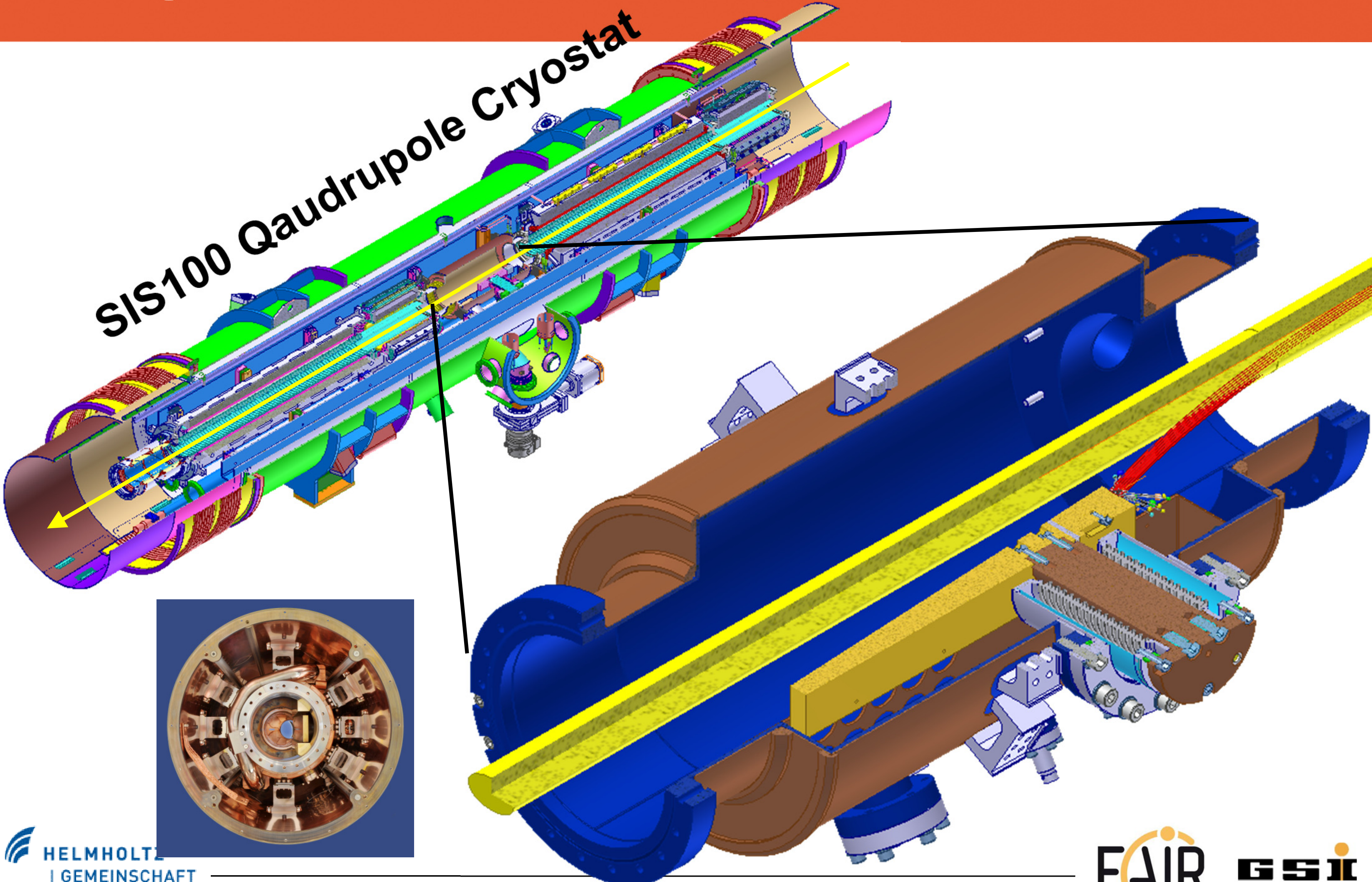
THPPP001





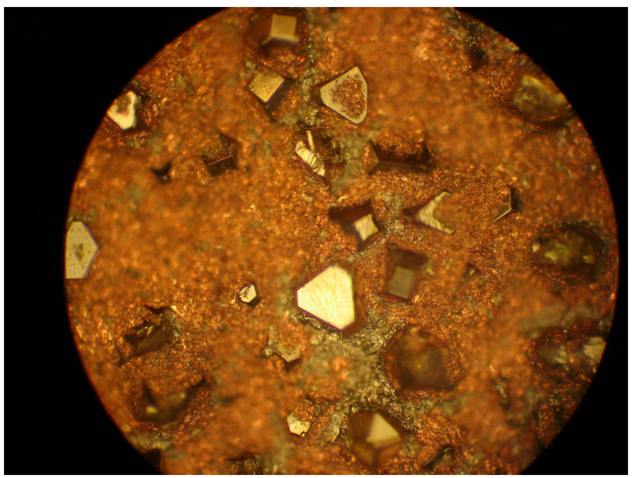
- Charge changing reactions due to rest gas atoms
- Losses induce pressure bumps
- Define location for losses with high pumping capacity
- Low desorbing material

Cryocatcher in Quadrupole Module

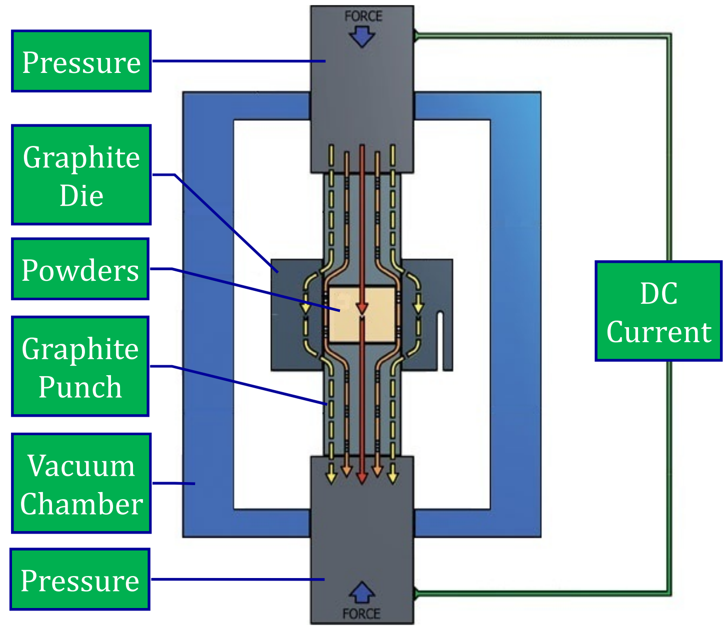


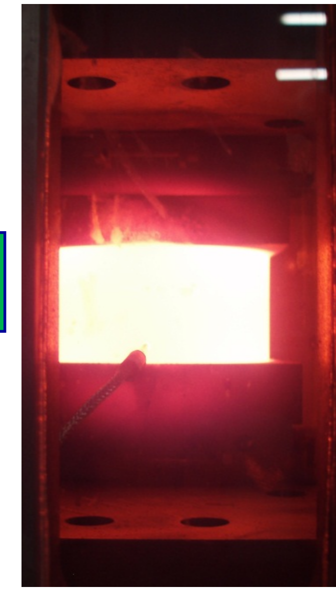
Exotic Materials for Accelerators

Metal-diamond composites:
- High thermal and electrical conductivity
- Mechanical an thermal robustness

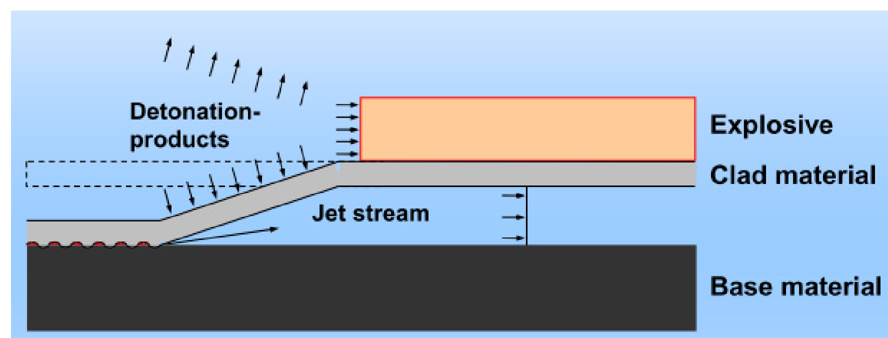


(WEPPD028)





Explosive plating:
Copper onto stainless steel
For FAIR cryocatcher



(THEPPB004)

Summary

- The nuclear frontier is determined by the availability of intense rare isotope beams
- There are key development towards the new facilities FRIB, ARIEL, FAIR, SPIRAL2, HIE-ISOLDE and EURISOL
- The high experimental challenge requires newest state of the art technologies.
- Industry benefits by delivering high technology into RIB projects and thus acquiring expertise for new products.

Additional slides

Expected reach for ^{132}Sn

heaviest stable

115

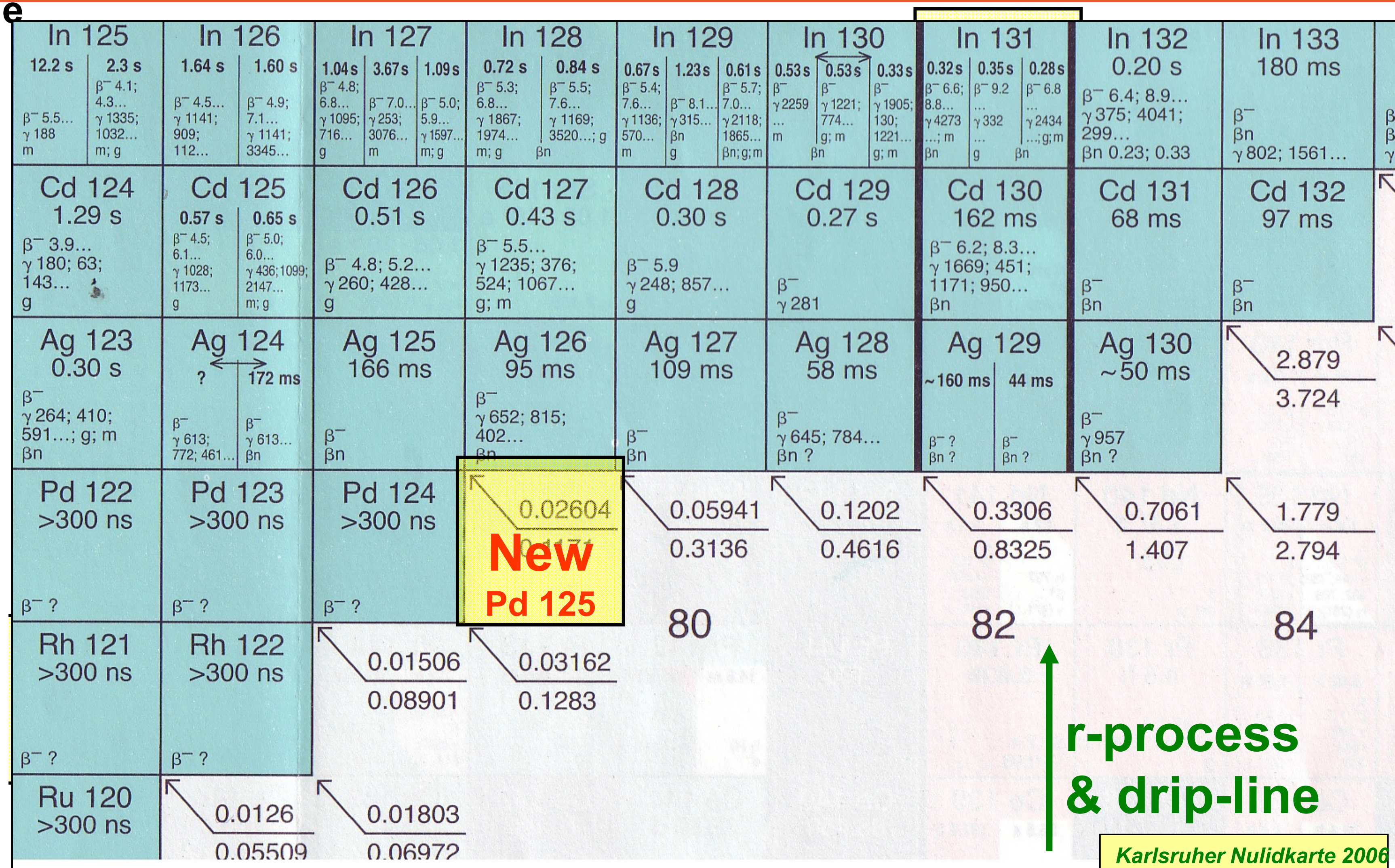
116

109

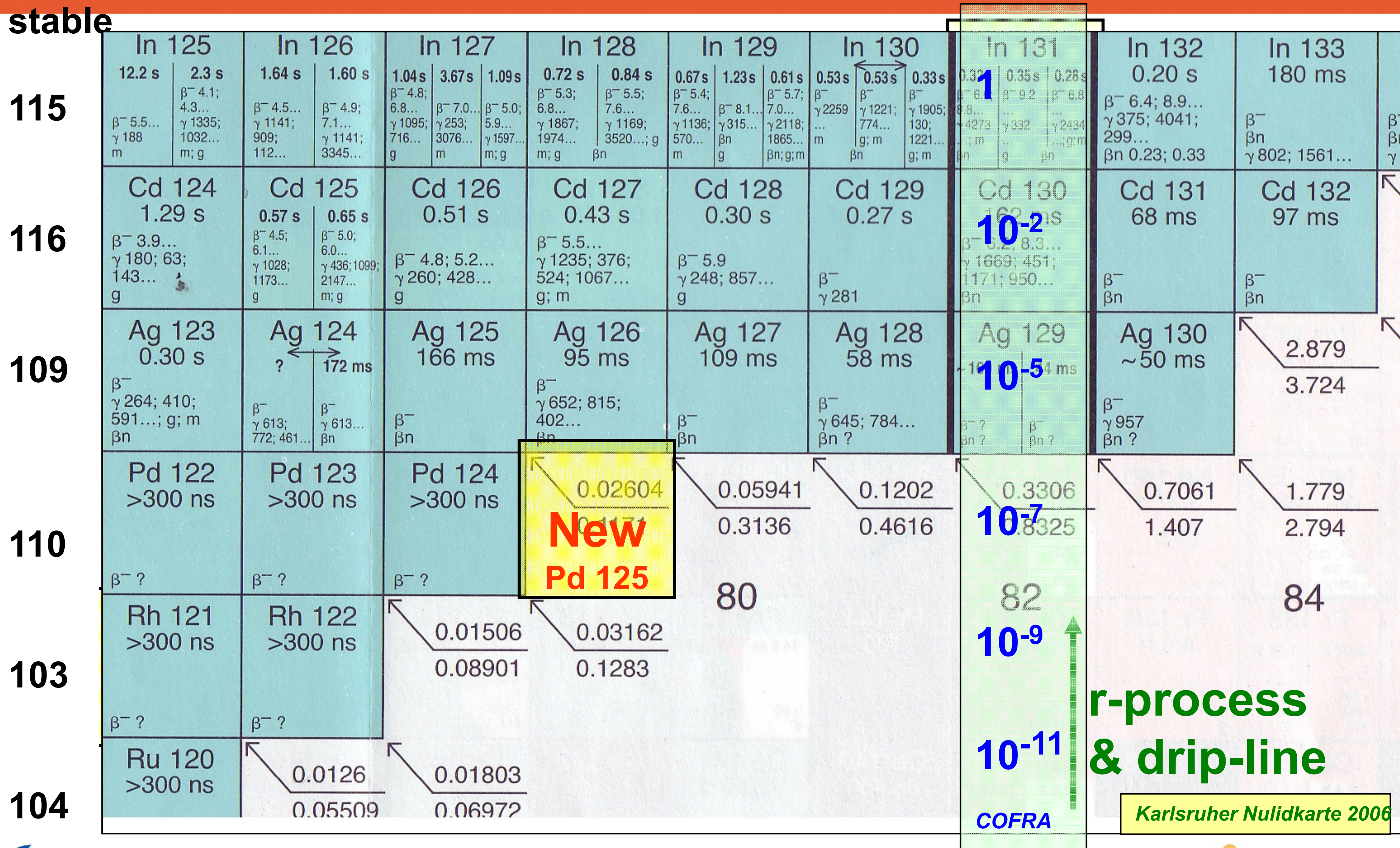
110

103

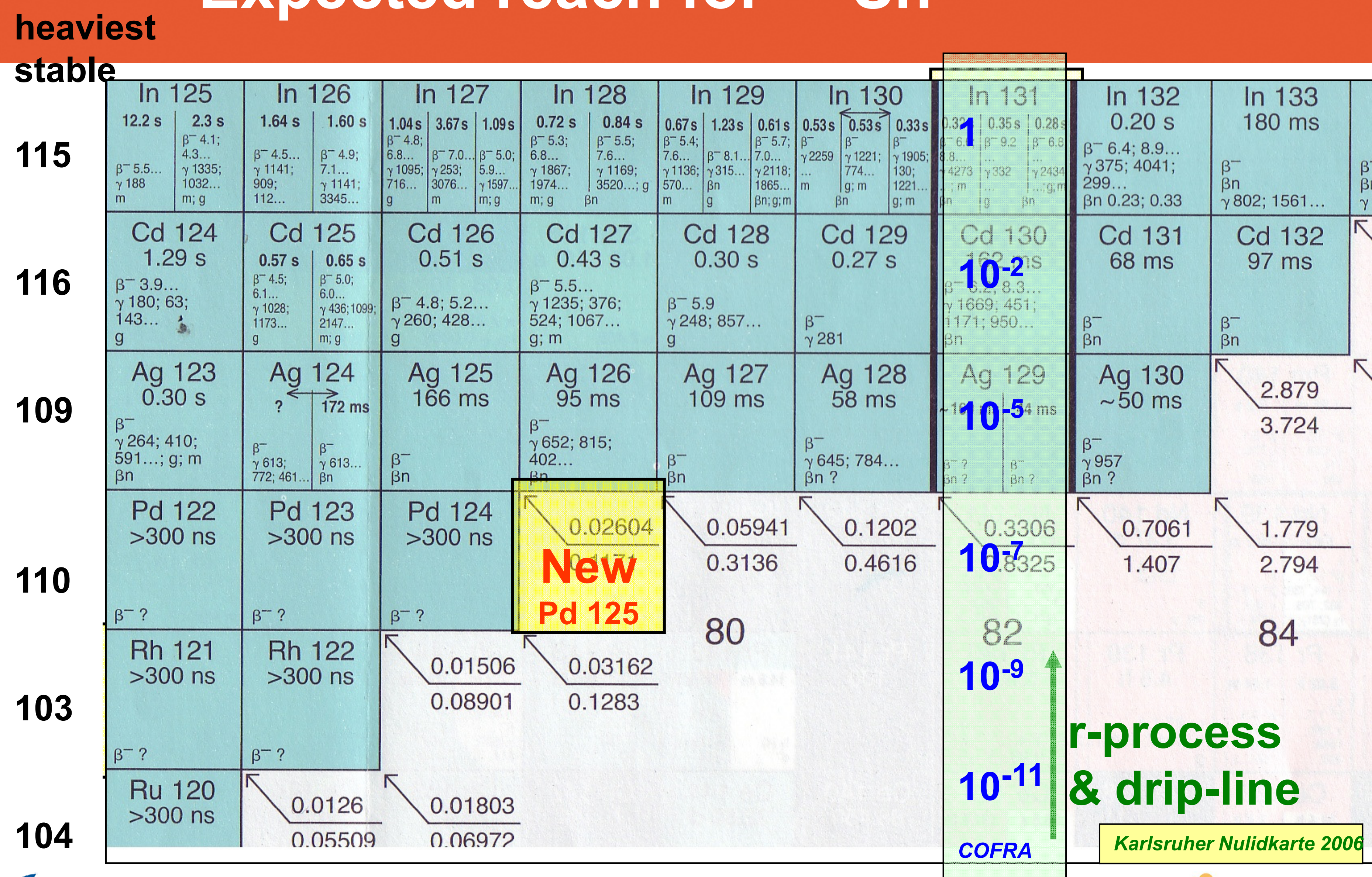
104



Expected reach for ^{132}Sn



Expected reach for ^{132}Sn



^{132}Sn: GSI present: 10^{3}/s FAIR, FRIB: 10^{8}/s EURISOL: 10^{12}/s

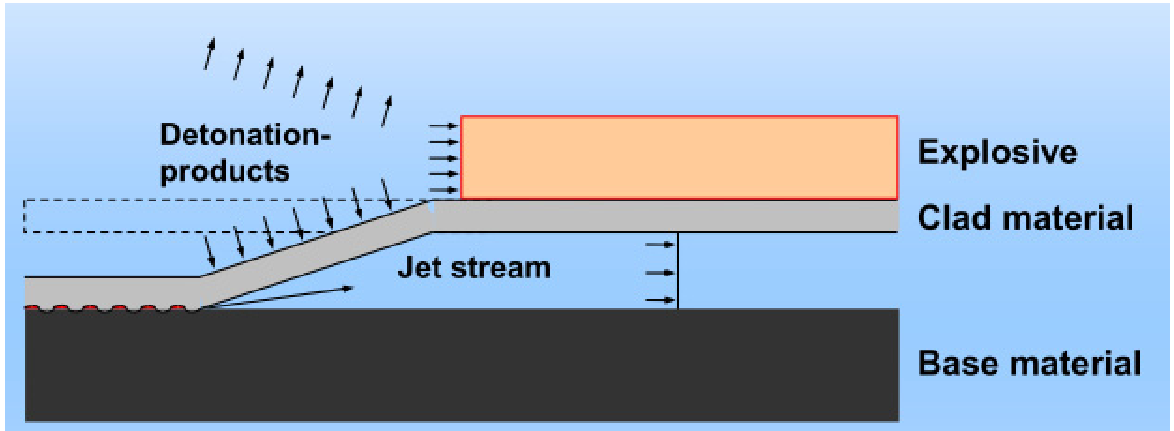
Challenges

- **Driver accelerators:**
  Ion sources, LEBT, cavities (SRF), magnets,
  beam diagnostics, machine protection
  highest intensities in ring machines

- **Targets, stripper and separators:**
  Beam power deposition, lifetime, acceptance, resolution, activation, beam dumps

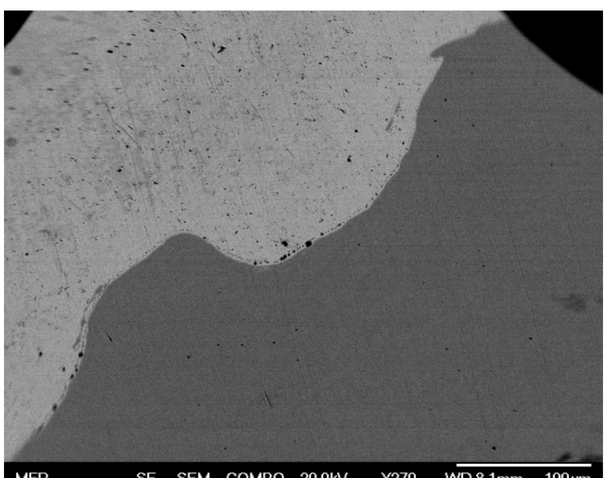
- **Post acceleration:**
  Beam stopping (PF), charge breeding, beam diagnostics, cavities

Explosive plating – Copper onto stainless steel



Dynaplat, 2010

- Chamber will be coated with copper
- Cryo-tests were performed with test-sample



(L.Bozyk, GSI)

Reuter, 2010

Cu-CD Composite

(Alessandro Bertarelli – CERN)

- Developed by **RHP-Technology** (Austria)
- Produced by Rapid Hot Pressing (**RHP**).
- 60% Diamond, 40% Cu

↑ No diamond degradation (in reducing atmosphere graphitisation starts at **~ 1300 °C**)

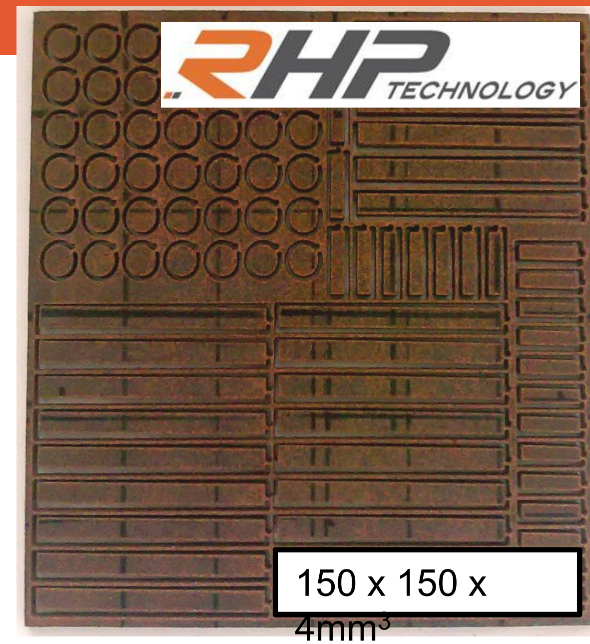
↑ Good thermal (**~490 W/mK**) and electrical conductivity (**~12.6 MS/m**).

↓ No direct interface between Cu and CD (lack of affinity). Limited bonding surface assured by Boron Carbides hampers mechanical strength (**~120 MPa**).

↓ BC brittleness adversely affects material toughness.

↓ Cu low melting point (**1083 °C**) limits Cu-CD applications for highly energetic accidents.

↓ CTE increases significantly with T due to high Cu content (from ~**6 ppmK^{-1} at RT** up to **~12ppmK^{-1} at 900 °C**)

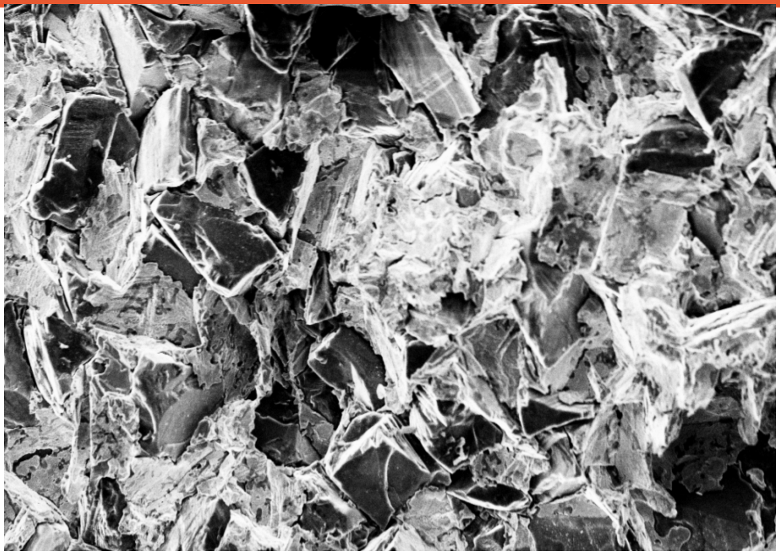


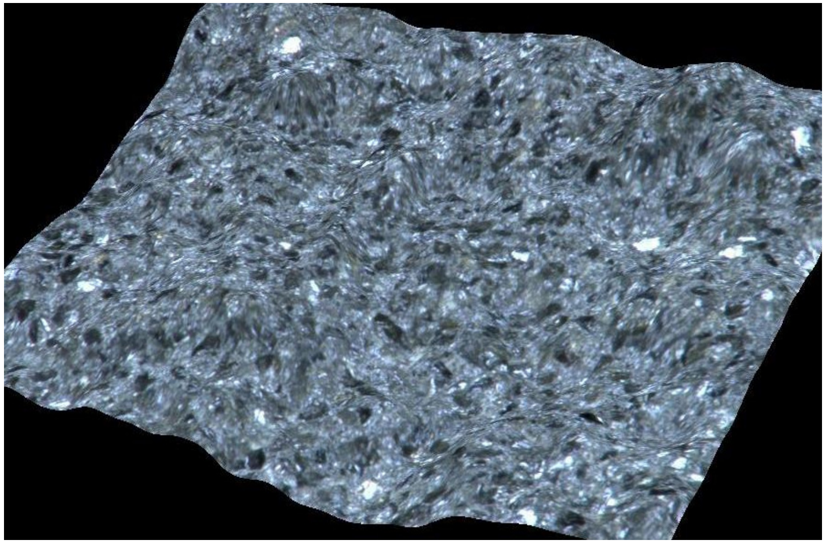
Ag-CD Composite

(Alessandro Bertarelli – CERN)

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

- Developed by **EPFL**, Switzerland.
- Manufactured by Liquid Infiltration
- ~60% Diamond**,** **~**40% Ag-Si alloy





- ↑ Excellent bonding between Ag and CD assured by SiC formation on diamond.
- ↑ High Flexural Strength (**~500 MPa**) and toughness.
- ↑ High Electrical Conductivity.
- ↓ Max $T_{Service}$ limited by low-melting eutectic phase Ag-Si (**840 °C**).
- ↓ Hard to manufacture large components (>100 mm)
- ↓ Material non homogeneities induced by liquid metal infiltration intrinsic limitations.

Mo-CD Composites

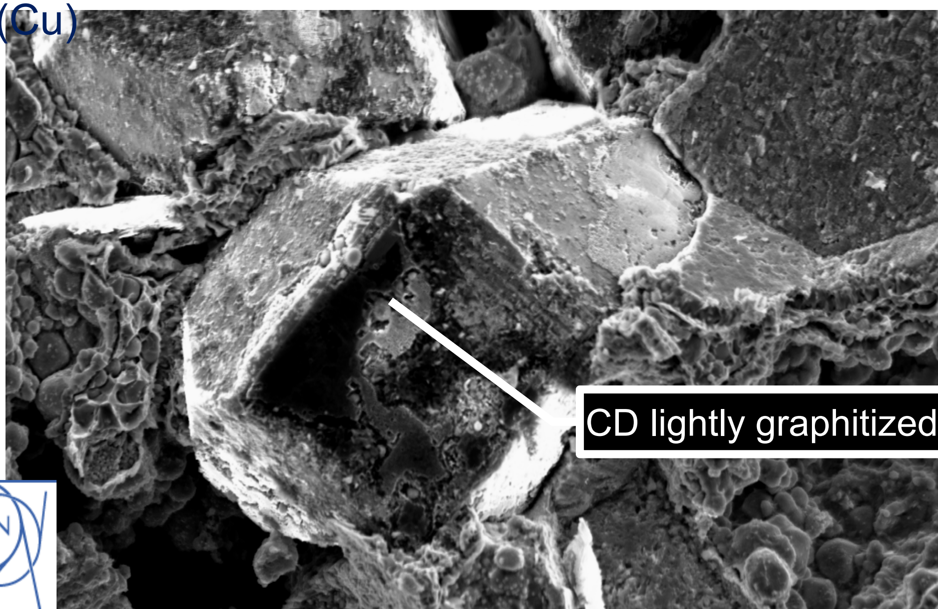
- Co-developed by **CERN** and a SME, **Brevetti Bizz**, Verona, Italy
- High sintering T of Mo (~**1700 °C**) leads to diamond graphitisation. 2 alternative processes:
  Liquid Phase Sintering (**LPS**) or **Assisted Solid-state Sintering** (**ASS**)

LPS

↑ Addition of low-melting phase (Cu) to fill in the pores between Mo and CD

↑ Good mechanical strength (400+ MPa) and fair Thermal Conductivity (185 W/mK)

↓ Max $T_{Service}$ limited by low-melting phase (Cu)



ASS

↑ Addition of activating elements (Ni, Pd) enhances Mo sintering at low T (~1300 °C)

↑ Absence of low-melting phase increases $T_{Service}$ up to ~2600 °C

↓ Large diamond particles interfere with Mo compaction.

↓ Diamond graphitization not fully avoided.