Position sensitive Focal plane Detectors for Heavy Ions Spectrometers

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- What for?
- Detector features
- Present status
- CVD-diamond detectors: an option for the future?

Atomic Physics with relativistic Highly Charged Ions

Atomic Structure and Collision Dynamics studies using cold beams of

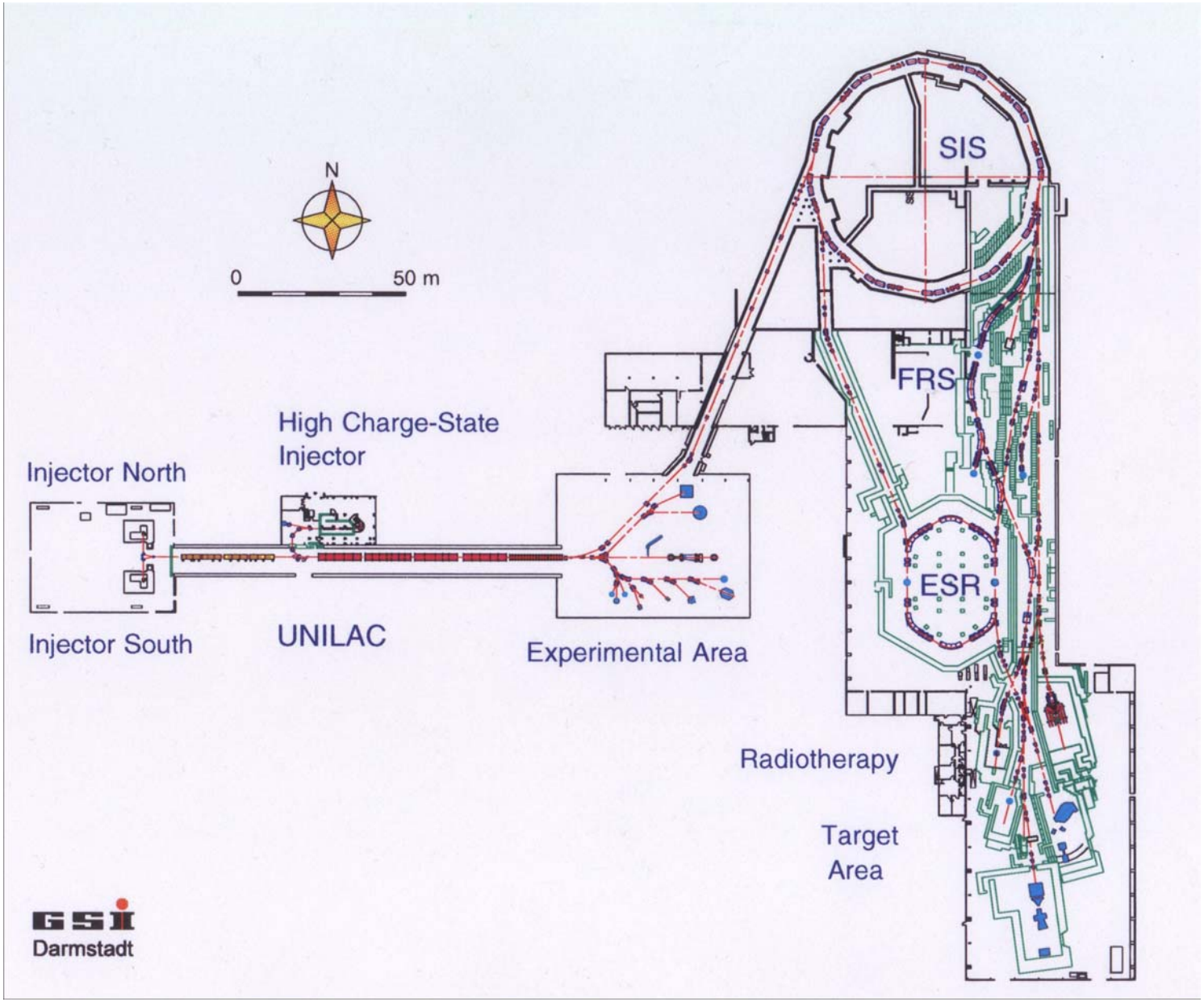
- few electrons heavy ions: H-like, He-like, Li-like,etc.
- relativistic energies: 10 MeV/u < E_{ion} < 400 MeV/u $\left(15\% \leq \frac{v_{ion}}{c} \leq 70\%\right)$

to determine

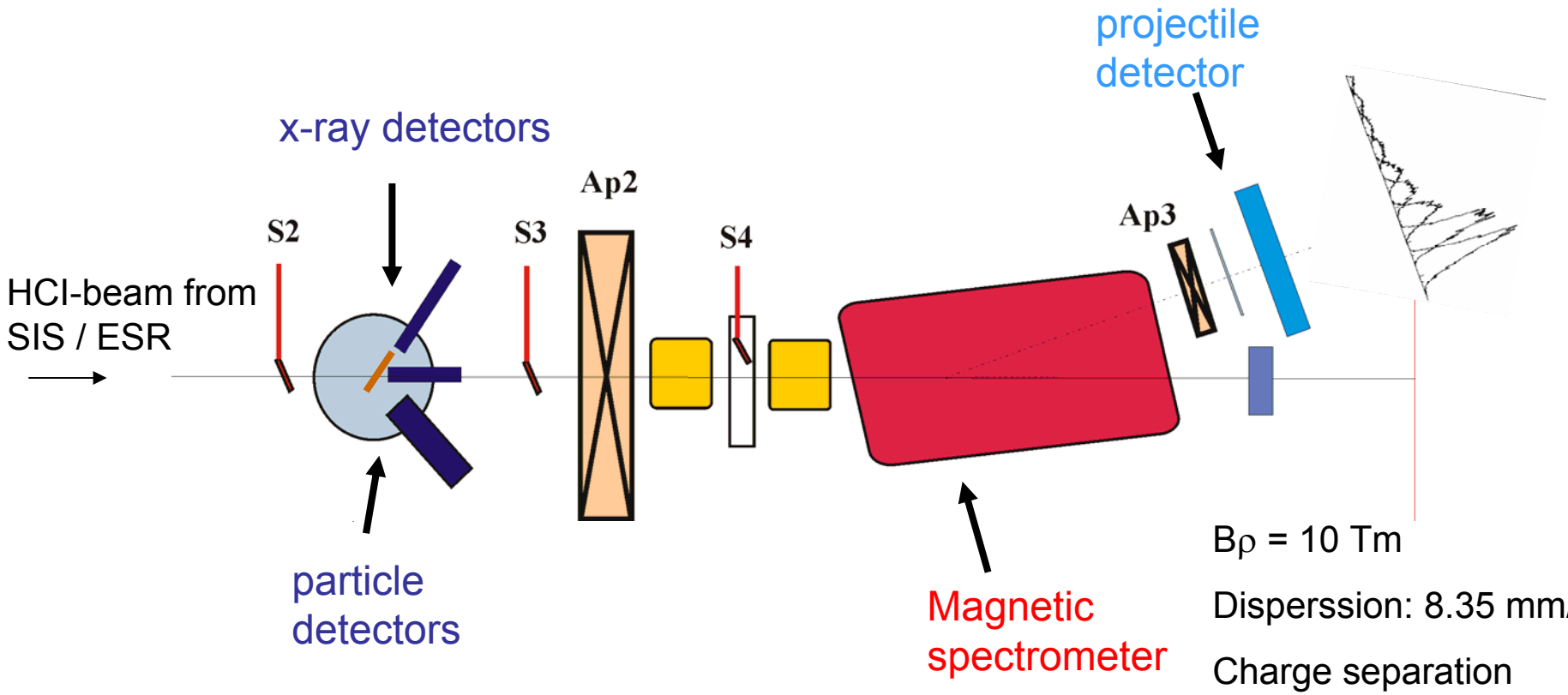
- total and differential cross sections for excitation / de-excitation, ionization / capture processes $\longleftrightarrow$ x-ray emission, charge exchange
- life time measurements of atomic states
- impact parameter dependent studies of atomic processes

via

- particle-particle coincidence
- x ray-particle coincidence
- charge state selection using
  - magnetic spectrometer
  - time-of-flight


N
0
50 m
SIS
FRS
ESR
High Charge-State
Injector
Injector North
Injector South
UNILAC
Experimental Area
Radiotherapy
Target
Area
GSI
Darmstadt

Vacancy transfer in inner shells of super heavy quasimolecules



Bρ = 10 Tm

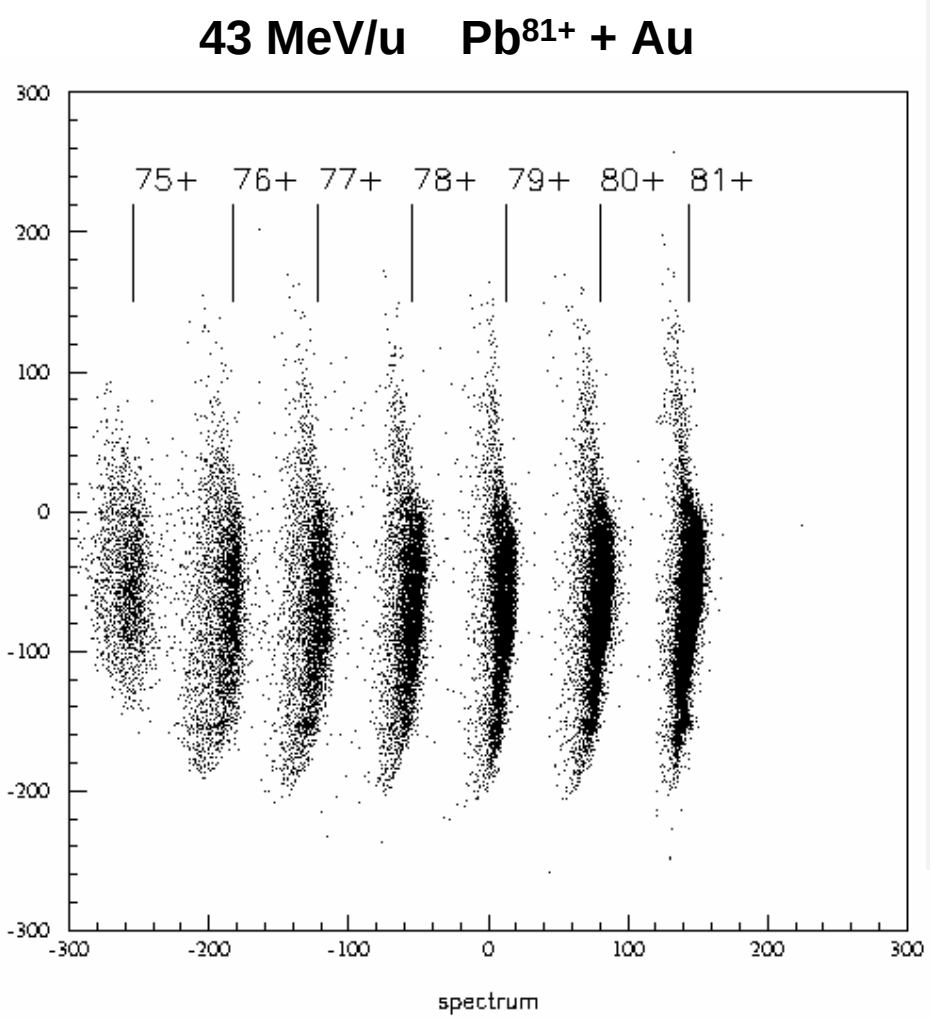
Disperssion: 8.35 mm/%

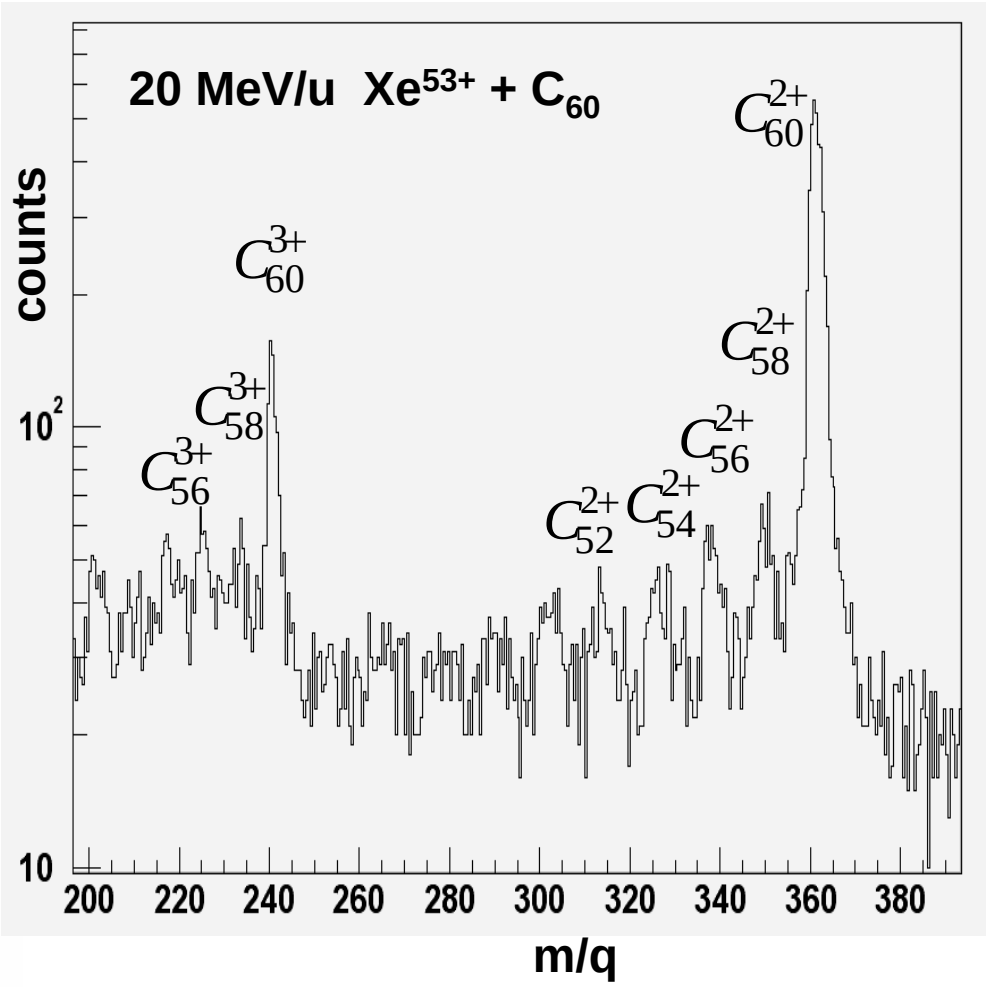
Charge separation

x = D Δq/q

for bare U is 9 mm

Two-dimensional Position Sensitive Heavy Ion Detection





Two-dimensional position sensitive Heavy Ion Detector

Detector capabilities:

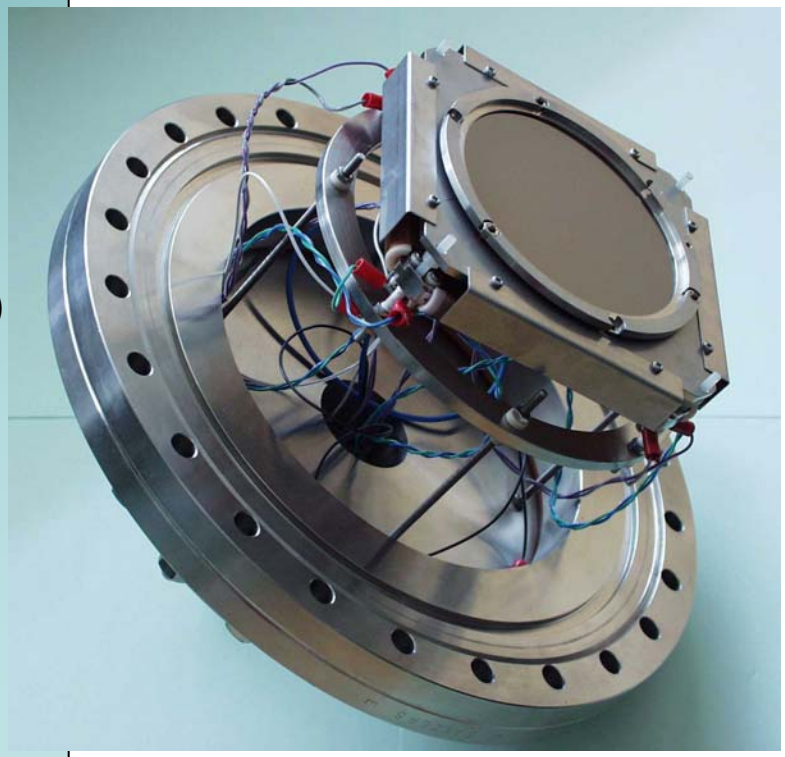
- position resolution: $\frac{\Delta x}{x} \cong 0.2\,\text{mm}$ and $\frac{\Delta y}{y} \cong 0.2\,\text{mm}$
- time resolution: $0.5ns \leq \frac{\Delta t}{t} \leq 1ns$
- count rate: up to 10^6 $s^{-1}mm^{-2}$ / 10^{10} s^{-1}
- active area: at least 80 mm x 40 mm
- radiation resistant
- UHV-compatible
- no window

comfortable handling and low cost

Two-dimensional position sensitive MCP-based Heavy Ion Detector

Detector Features

- ☺ multipurpose detector
- ☺ delay-line read out
- ☺ multi hit capability
- ☺ position resolution: $\frac{\Delta x}{x} \leq 0.2$ mm (0.075 mm)
- ☺ time resolution: $\frac{\Delta t}{t} \cong 0.5 ns$
- ☺ active area: 44.2 cm^2
- ☺ UHV-compatible
- ☺ no window



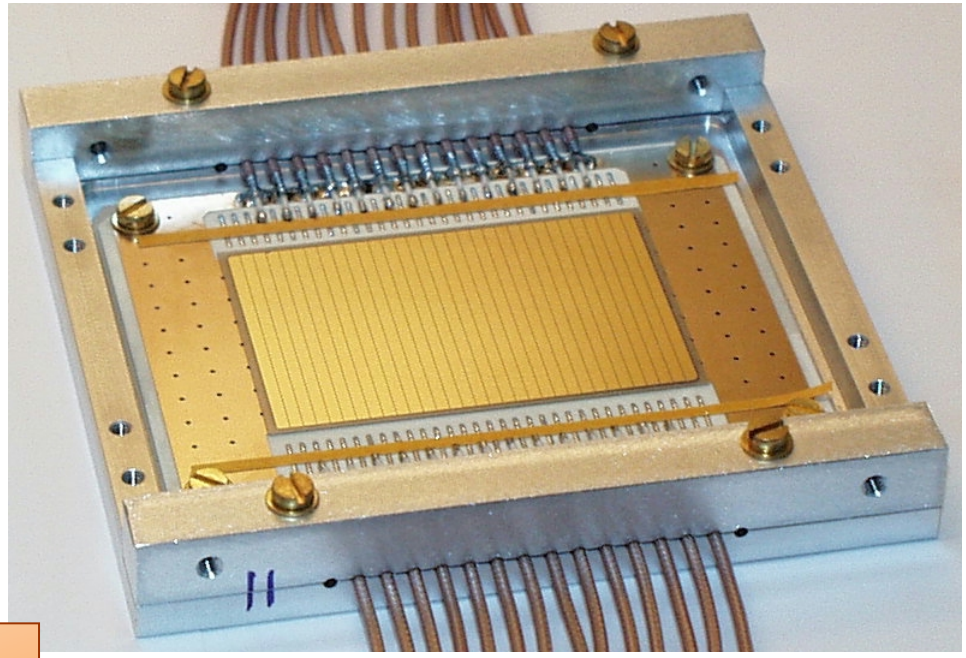
! count rate: 10^2 $s^{-1}mm^{-2}$ to 10^3 $s^{-1}mm^{-2}$

! life-time: < 10^4 U^{238} (20 MeV/u / micro channel)

Position sensitive CVD-Diamond Detector

Detector features:

- active area: 60 mm x 40 mm, 0.2 mm thick CVD-diamond
- one-dimensional sensitive: 32 Au stripes 1.8 mm width, 1.9 mm pitch, C=16.3 pF
- individual strip read-out



! only one dimensional

! low granularity

! not vacuum compatible

?

radiation hardness

Experimental investigations

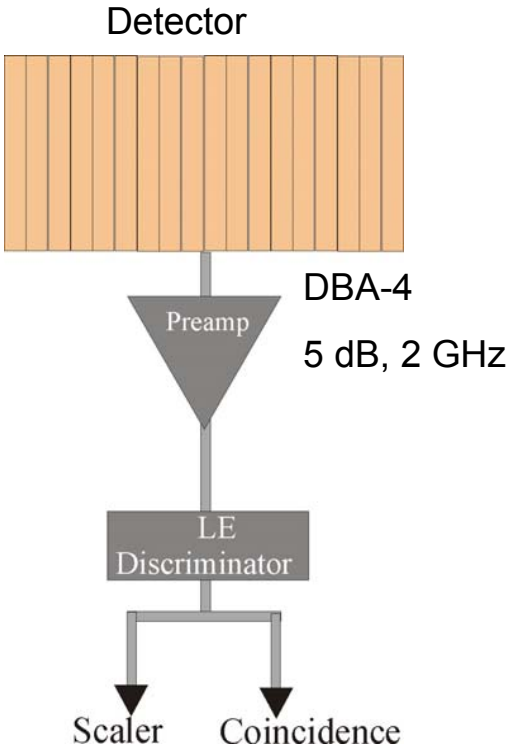
Byproduct of the atomic physics experiments

Four experiments:

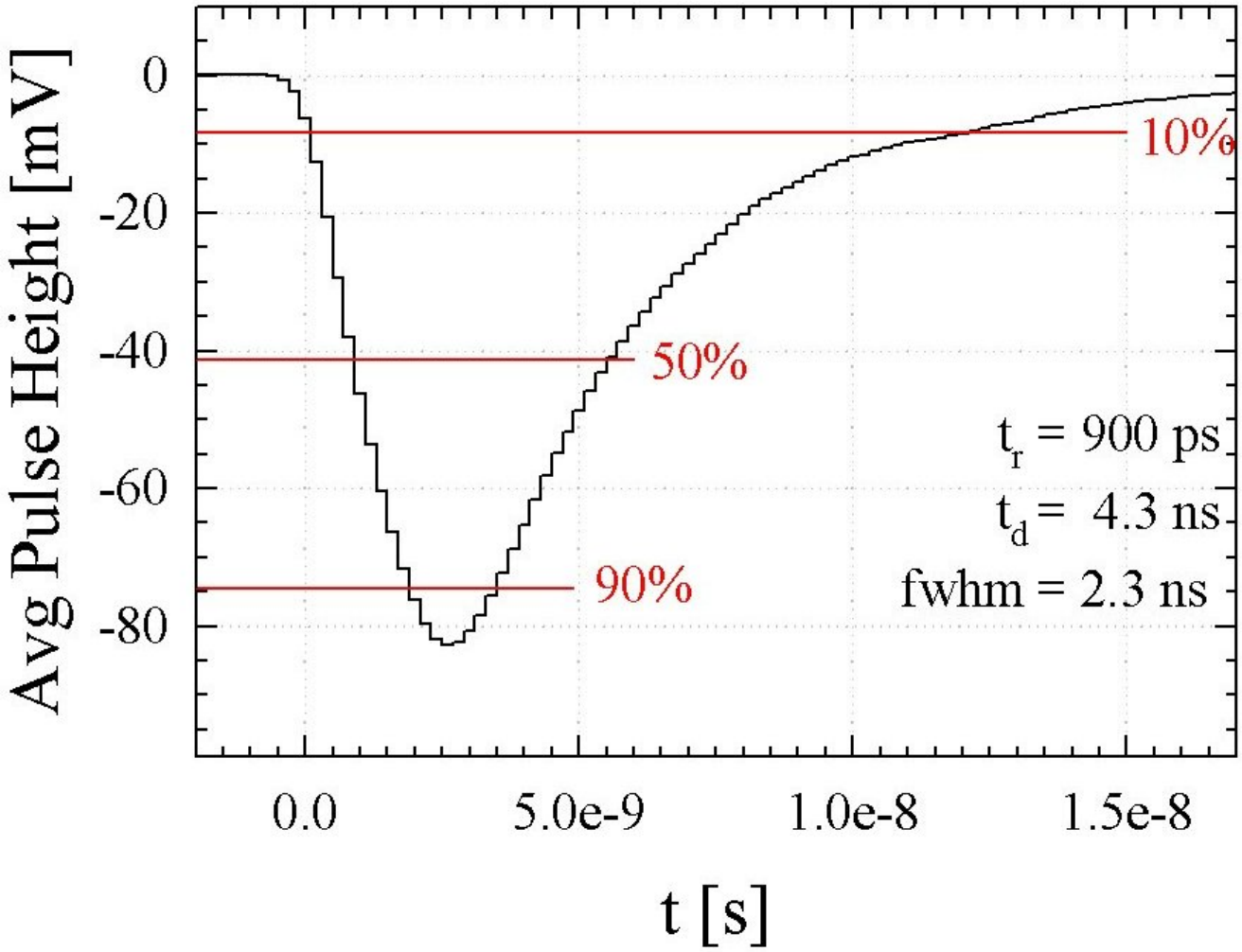
• life time measurements 195 MeV/u ^{197}Au and 290 MeV/u ^{238}U on Ni

• vacancy transfer in the quasimolecular regime 68 MeV/u ^{238}U on Au and 68 MeV/u ^{209}Bi on Au

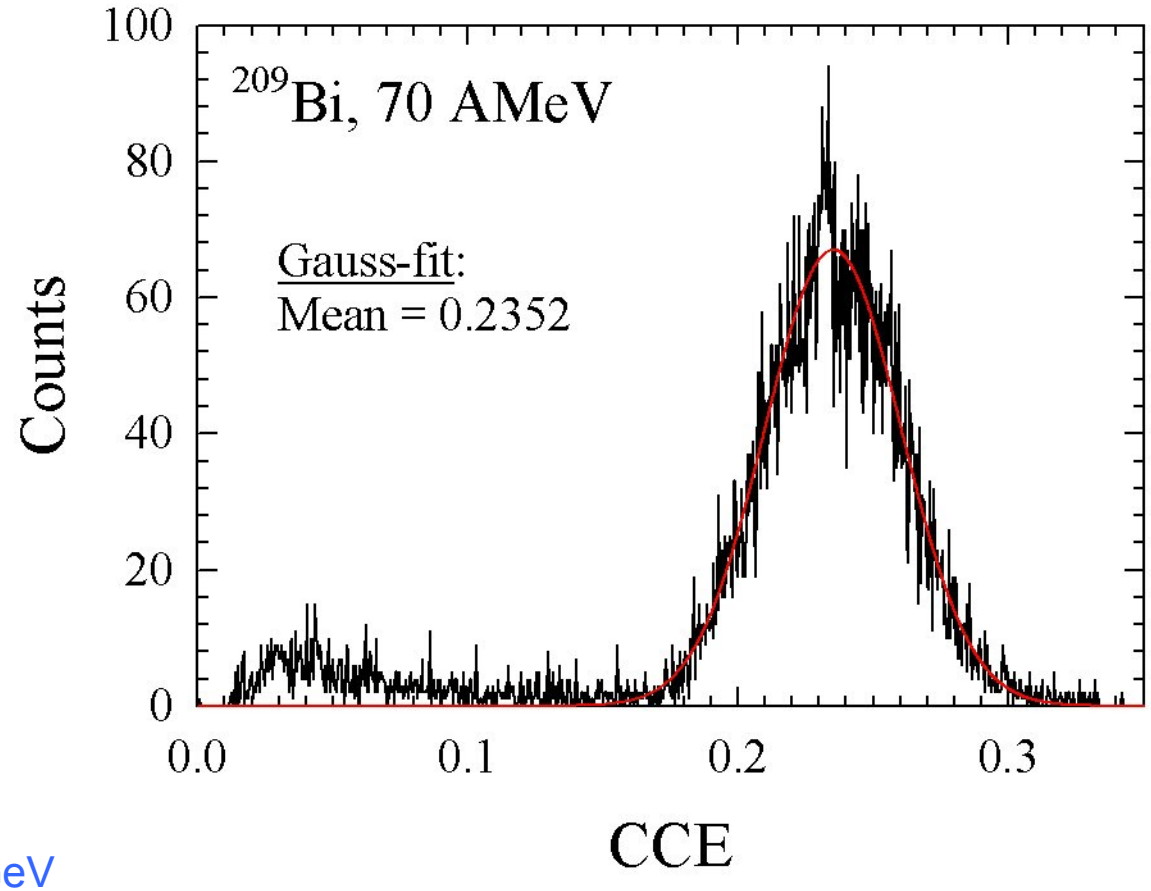
U_{bias} = 0.5 V/μm -1.5 V/μm



68 MeV/u Bi^{82+} $d_D = 200\ \mu m;\ E_D = 1\ V/\mu m$



CVD-detector parameters: Ph distribution

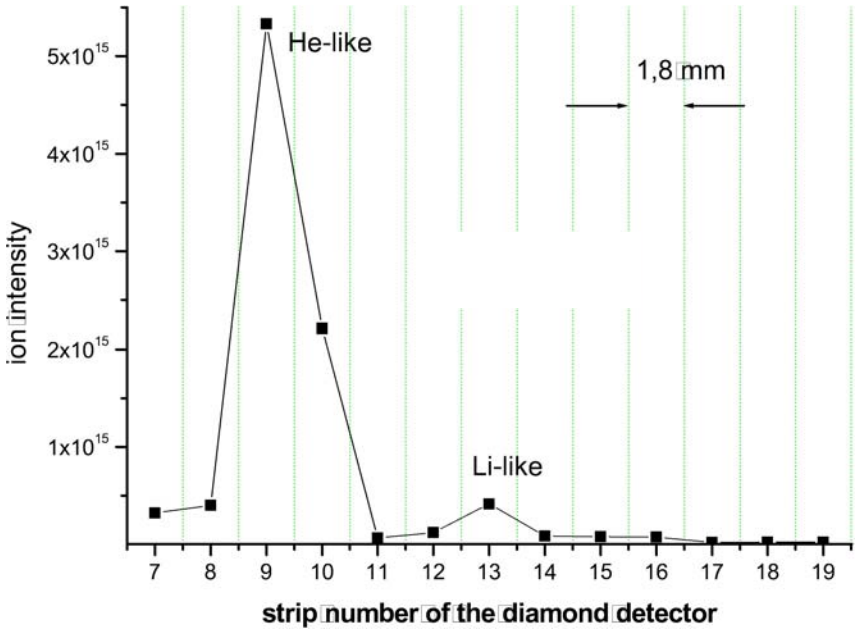


E_{loss}= 3.9 GeV

2.9 x 10^8 electrons ⟶ Q= 46 pC ⟶ U_{sign} = 500mV

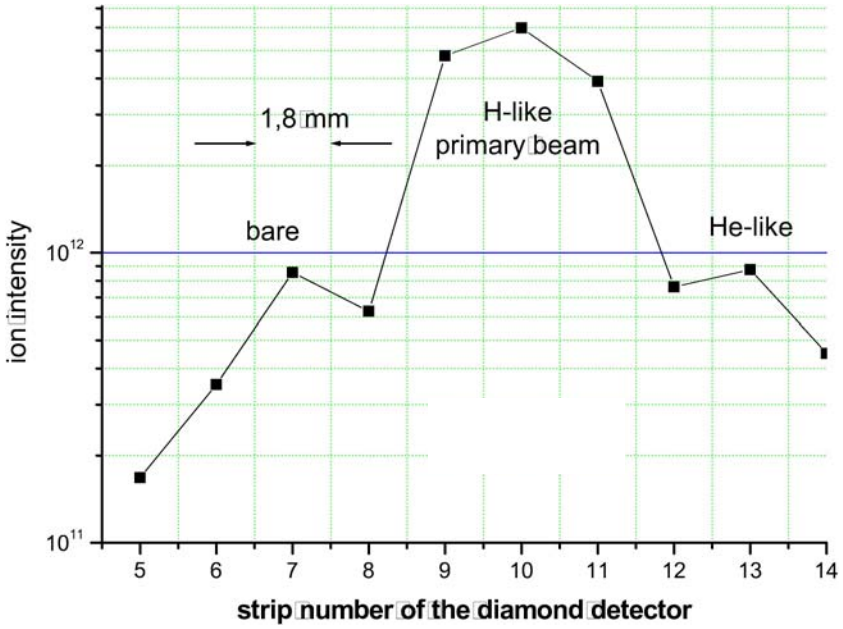
Position read out

195 MeV/u $^{197}Au^{78+}$ + 1.5 mg/cm^2 Ni



E_{loss} = 1.82 GeV in 200 μm

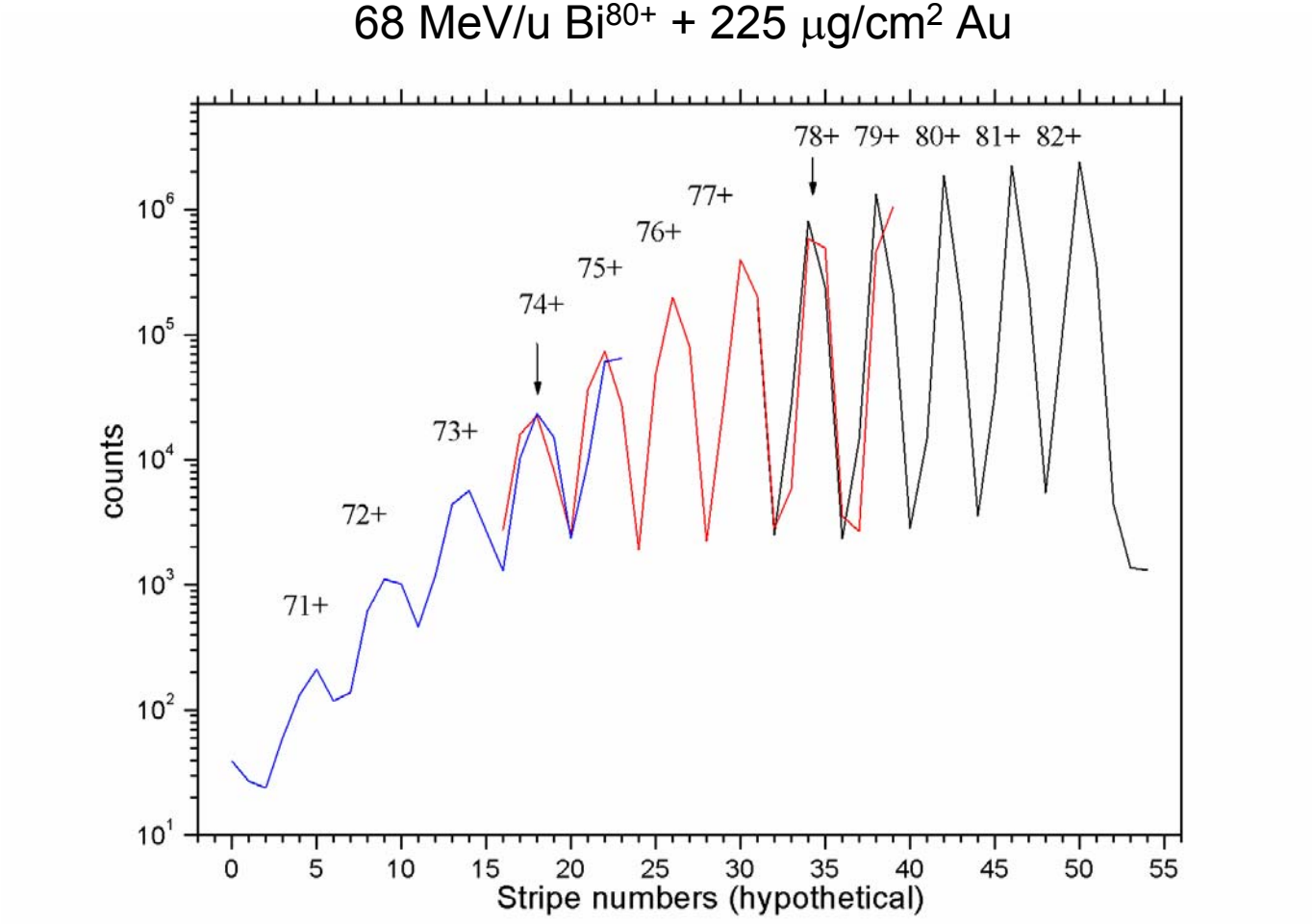
290 MeV/u $^{238}U^{91+}$ + 1.5 mg/cm^2 Ni



E_{loss} = 1.84 GeV in 200 μm

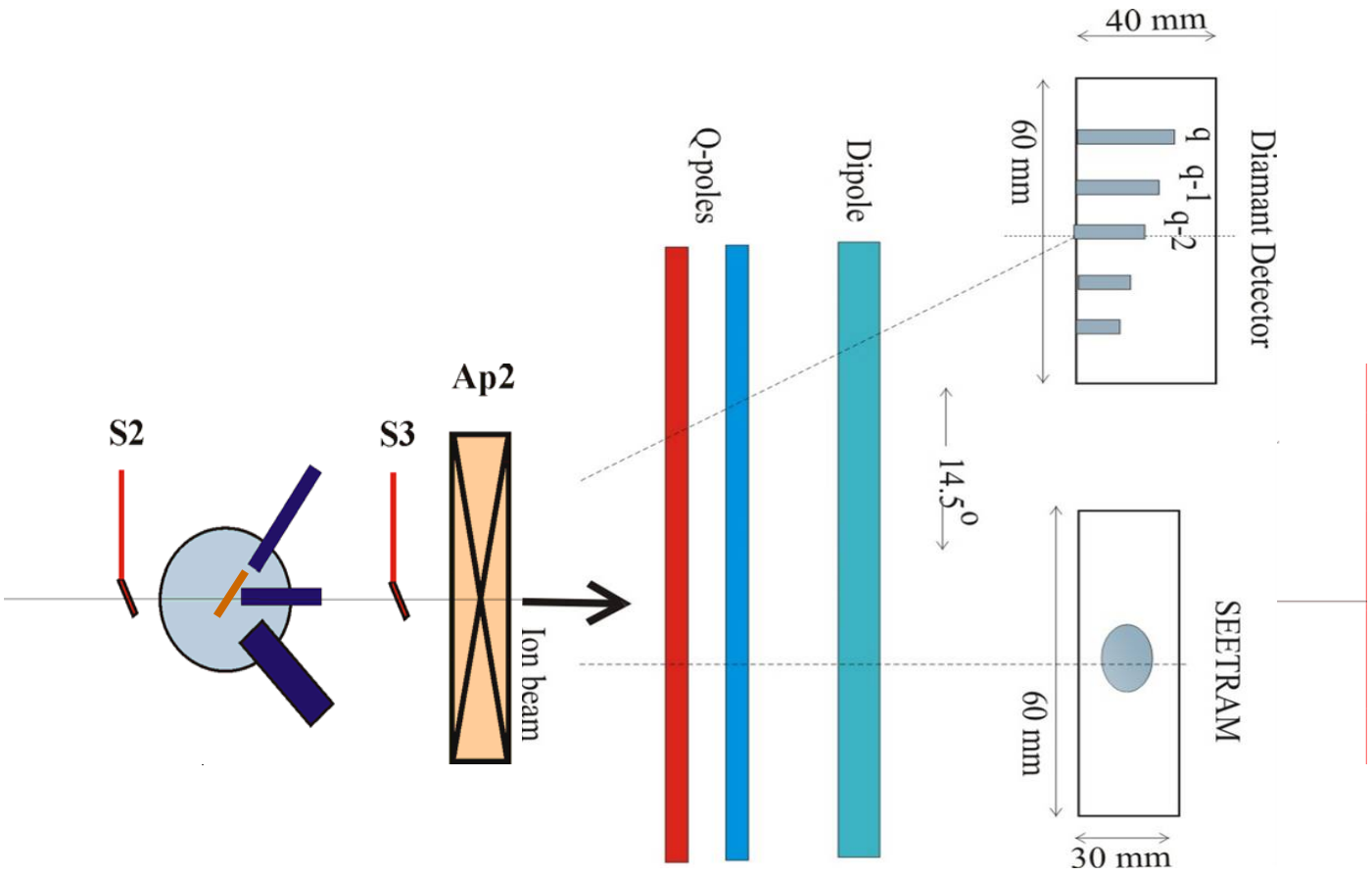
Position read out

68 MeV/u Bi^{80+} + 225 μg/cm^2 Au



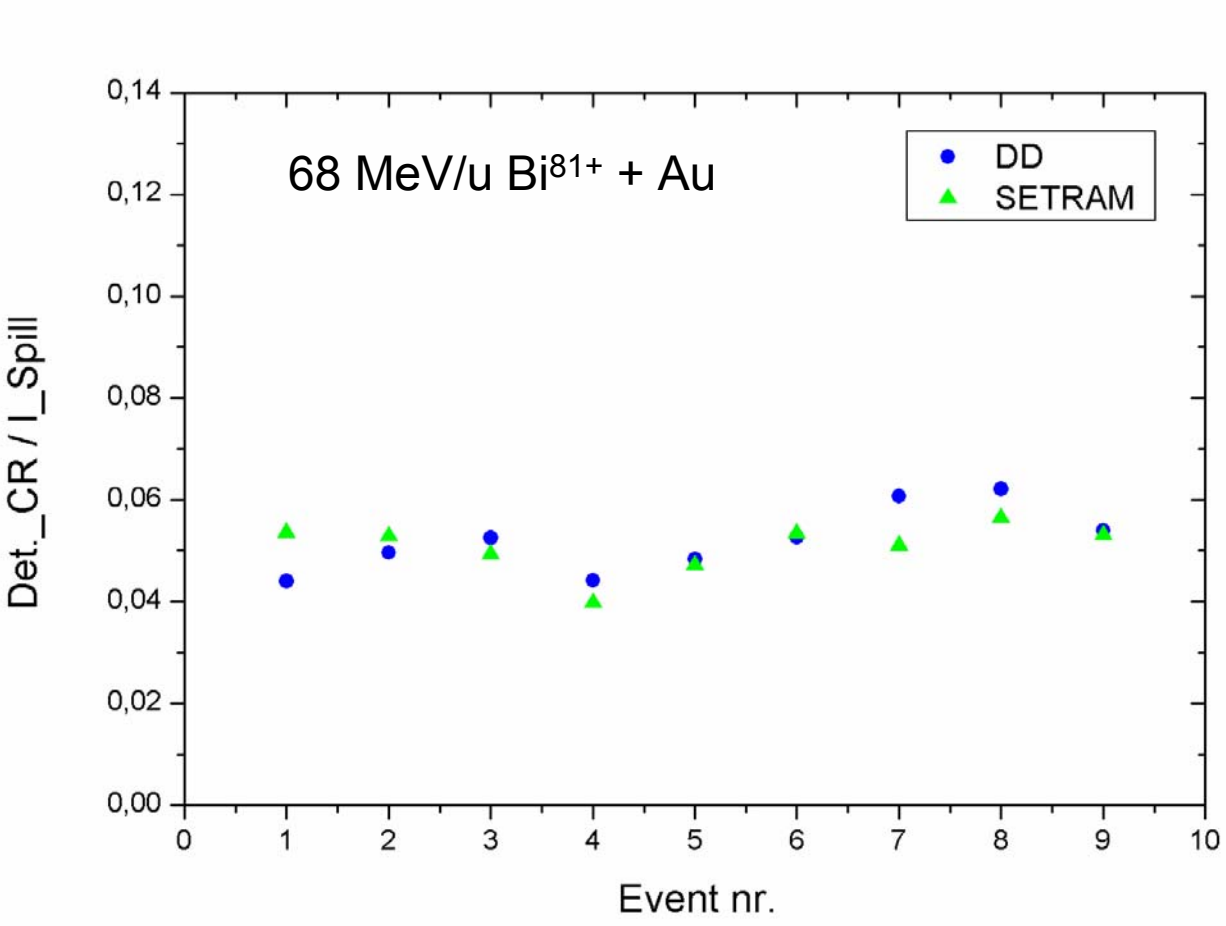
E_{loss} = 3.4 GeV in 200 μm

Detection efficiency estimation



Detection efficiency

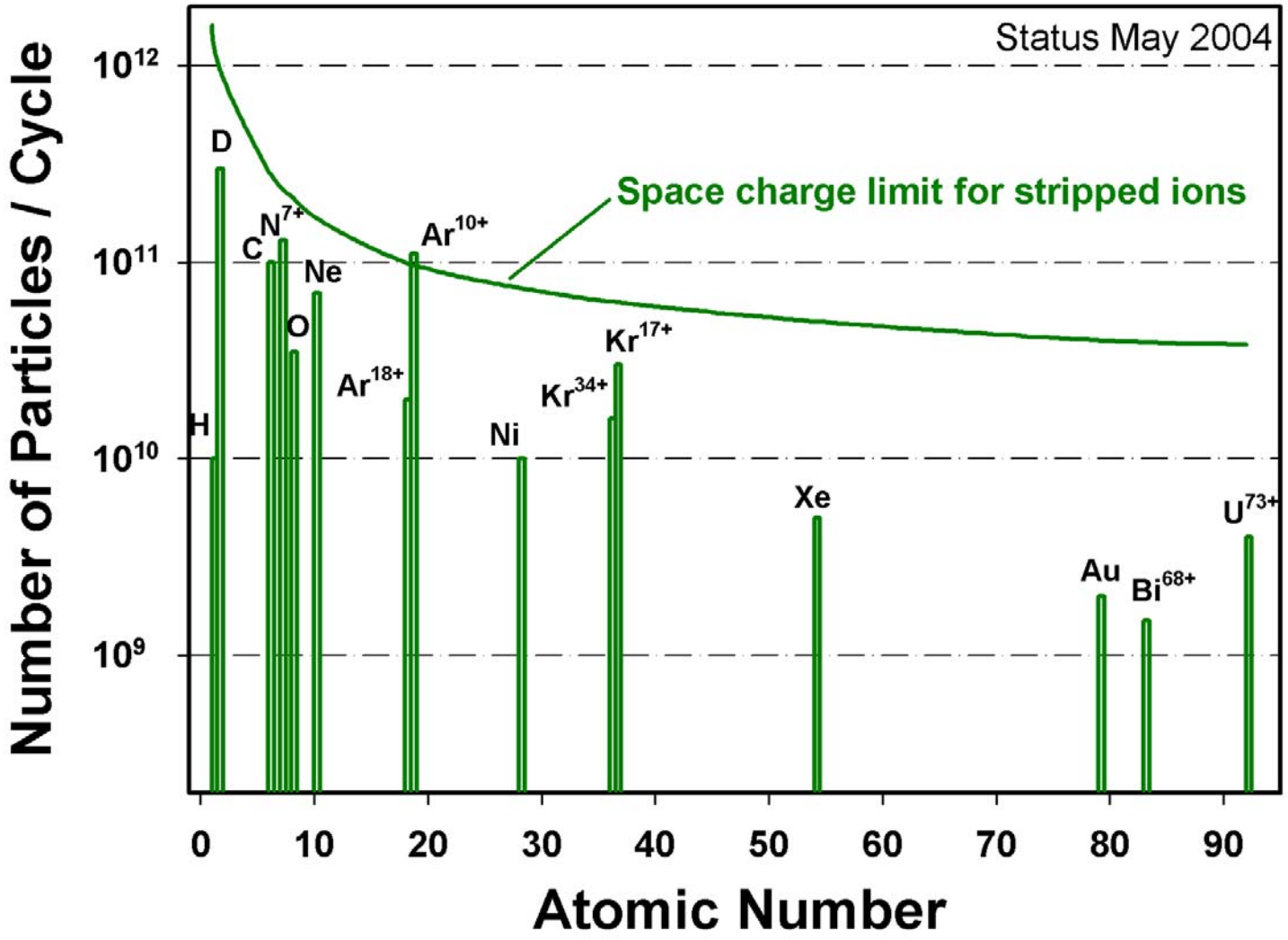
Count rate: Diamond detector / SEETRAM detector



Estimated detection efficiency:

$\varepsilon = 100\ \%$??

Beam intensity at GSI facility



Atomic Physics Program at FAIR

Stored Particle Atomic Research Collaboration

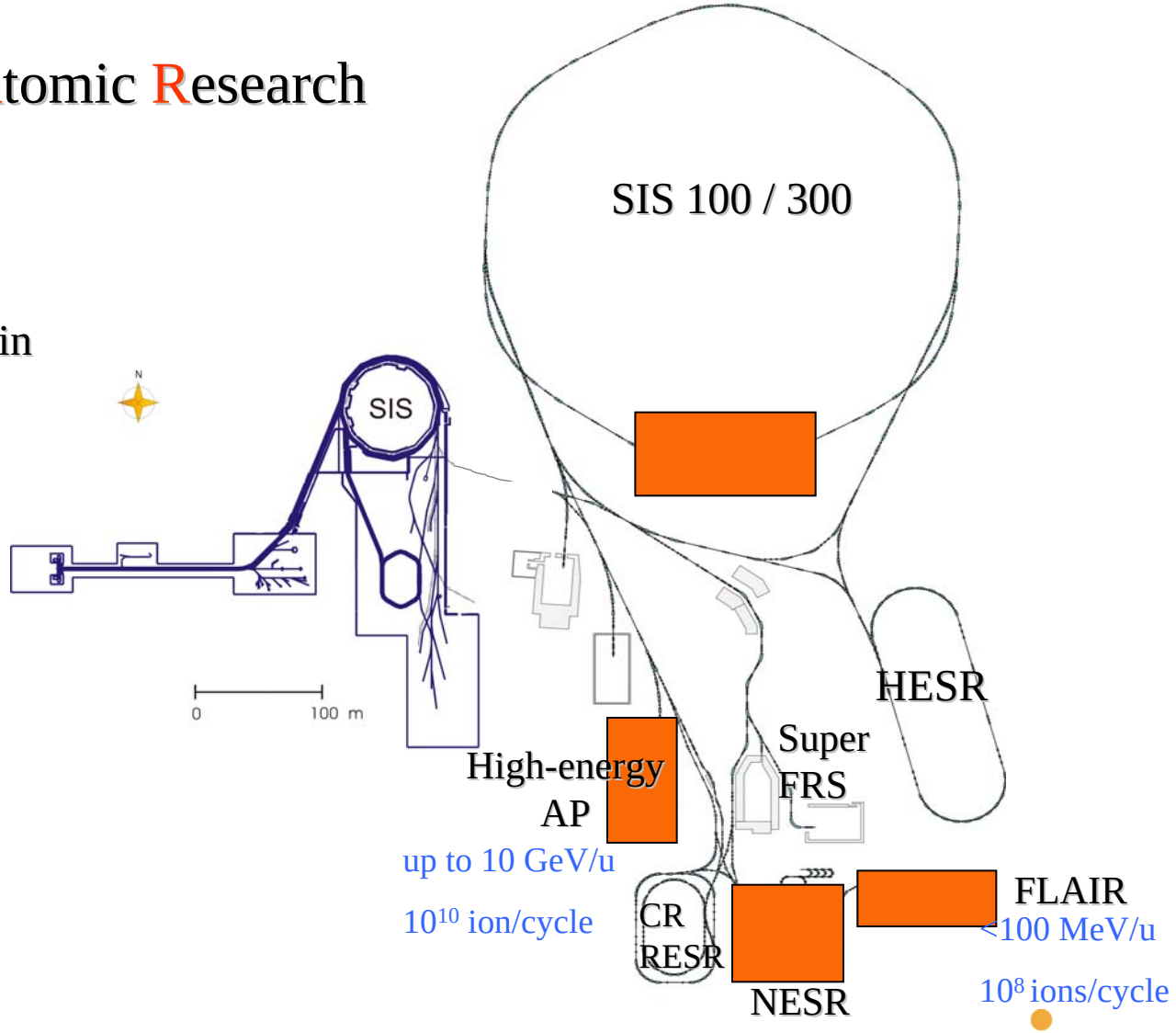
Areas of research:

- Fundamental interaction in extreme fields
- Fundamental tests
- Nuclear Ground-Stae properties

Stored and cooled relativistic HCI

Exotic Nulclei

Antiprotons



Summary and outlook

The CVD-diamond detector is a promising device for atomic physics experiments with highly charged ions:

- good detection efficiency
- excellent timing properties
- radiation hard

For low energy HCI, $E_{ion} < 20$ MeV/u maybe the only solution for beam monitoring!

Goal: a 2-dim diamond detector for highly charged ions at intermediate energies

First step: try to build a two-dimensional position sensitive detector on polycrystalline CVD-diamond with

- an active area of ~ 20 x 20 mm^2
- a higher granularity (strip width below 1 mm)
- high-vacuum compatible

Questions to be investigated:

- radiation damage
- space charge effects: internal polarisation
- detection efficiency

Acknowledgement

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