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: \(10 \text{ MeV/u} < E_{\text{ion}} < 400 \text{ MeV/u} \) \((15\% \leq \frac{v_{\text{ion}}}{c} \leq 70\%)\)

to determine

- total and differential cross sections for excitation / de-excitation, ionization / capture processes \(\leftrightarrow\) 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
Vacancy transfer in inner shells of super heavy quasimolecules

HCl-beam from SIS / ESR

x-ray detectors

particle detectors

Ap2

Magnetic spectrometer

B_ρ = 10 Tm

Dispersion: 8.35 mm/%

Charge separation

x = D \Delta q/q

for bare U is 9 mm
Two-dimensional Position Sensitive Heavy Ion Detection

$43 \text{ MeV/u} \quad \text{Pb}^{81+} + \text{Au}$

$20 \text{ MeV/u} \quad \text{Xe}^{53+} + \text{C}_{60}$

counts

$m/q$

GSI
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: $0.5\text{ns} \leq \frac{\Delta t}{t} \leq 1\text{ns}$

• count rate: up to $10^6 \text{ s}^{-1}\text{mm}^{-2} / 10^{10} \text{ s}^{-1}$

• active area: at least $80 \text{ mm } x \ 40 \text{ mm}$

• 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: $\frac{\Delta t}{t} \approx 0.5$ 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

$U_{bias} = 0.5 \text{ V}/\mu\text{m} - 1.5 \text{ V}/\mu\text{m}$
68 MeV/u Bi\(^{82+}\)  
\[ d_D = 200 \, \mu m; \, E_D = 1 \, V/\mu m \]  

Avg Pulse Height [mV]  

\( t_r = 900 \, ps \)  
\( t_d = 4.3 \, ns \)  
\( fwhm = 2.3 \, ns \)  

\( t \) [s]
CVD-detector parameters: Ph distribution

\[ \text{Gauss-fit:} \quad \text{Mean} = 0.2352 \]

\[ E_{\text{loss}} = 3.9 \text{ GeV} \]

\[ 2.9 \times 10^8 \text{ electrons} \quad \rightarrow \quad Q = 46 \text{ pC} \quad \rightarrow \quad U_{\text{sign}} = 500 \text{ mV} \]
Position read out

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

$E_{\text{loss}} = 1.82 \text{ GeV in 200 } \mu\text{m}$

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

$E_{\text{loss}} = 1.84 \text{ GeV in 200 } \mu\text{m}$
Position read out

$68 \text{ MeV/u Bi}^{80+} + 225 \, \mu\text{g/cm}^2 \text{ Au}$

$E_{\text{loss}} = 3.4 \, \text{GeV in 200 } \mu\text{m}$
Detection efficiency estimation
Detection efficiency

Count rate: Diamond detector / SEETRAM detector

68 MeV/u Bi^{81+} + Au

Estimated detection efficiency:

\( \epsilon = 100 \% \) ??
Beam intensity at GSI facility

Status May 2004

Number of Particles / Cycle

10^{12}
10^{11}
10^{10}
10^{9}

Atomic Number

0  10  20  30  40  50  60  70  80  90

D  C  N^{7+}  Ne  O  Ar^{18+}  Ar^{10+}  Ni  Kr^{17+}  Kr^{34+}  Xe  Au  Bi^{68+}  U^{73+}

Space charge limit for stripped ions
Stored Particle Atomic Research Collaboration

Areas of research:

• Fundamental interaction in extreme fields
• Fundamental tests
• Nuclear Ground-State properties

Stored and cooled relativistic HCI
Exotic Nuclei
Antiprotons

High-energy AP
up to 10 GeV/u
$10^{10}$ ion/cycle

FLAIR
100 MeV/u
$10^8$ ions/cycle
Summary and outlook

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 \( \sim 20 \times 20 \text{ mm}^2 \)
- a higher granularity (strip width below 1 mm)
- high-vacuum compatible

Questions to be investigated:

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

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 HCl, \( E_{\text{ion}} < 20 \text{ MeV/u} \) maybe the only solution for beam monitoring!
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