HITRAP Low Energy Diagnostics and Emittance Measurement

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Workshop on "Low Current, low Energy Beam Diagnostics"
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Outline

• The HITRAP project at GSI
• Existing beam diagnostics for emittance measurements and particle detection
• Measurements and results
• Outlook
HITRAP @ ESR

**Beam Diagnostics**

**Measurements**

**Outlook**

- **HITRAP LINAC** ~20 m long
- **UNILAC**
- **ESR**
- **SIS 18**
- **ion sources**

- 4-400 MeV/u U^{92+}
- 11.4 MeV/u U^{73+}
- Up to 1 GeV/u U^{92+}

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HITRAP overview

HITRAP  Beam Diagnostics  Measurements  Outlook

DDB section
IH section & MEBT
LEBT & Cooler trap

7m
4meV/u

to experiments

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Experiments @ HITRAP

• Experiments based on Penning traps
  – Laser spectroscopy
  – g-factor measurements of the bound electron
  – Mass measurements of extreme accuracy
  – Polarization of radionuclides
  – Decay spectroscopy of highly-charged radionuclides

• Collision experiments:
  – Collisions at very low velocities
  – Surface studies and hollow-atom spectroscopy
  – X-ray spectroscopy
Low energy/low intensity pepperpot device

- stand-alone device
- multi diagnostic

Pepperpot data:
- hole diameter: 0,1mm (0,1mm W foil)
- hole spacing: 1mm
- drift distance: 31,8mm
- sandwiched between Al frame and 2mm Cu plate
Low energy/low intensity pepperpot device

- stand-alone device
- multi diagnostic

**MCP data:**
- diameter: 40mm
- channel diameter: 12µm
- gain: $10^4$
- scintillator: P-43 ($\lambda_{\text{max}}=545\text{nm}$)
- afterglow (10%): 1ms

**Camera:** resolution: 1392x1040 pixels $\rightarrow$ ~40µm spatial resolution

**Lens:** fixed focus $f=50\text{mm}$, high quality with narrow band pass filter with $\lambda_{\text{max}}@545\text{nm}$
Low energy/low intensity pepper pot device
Diamond detector

HITRAP  Beam Diagnostics  Measurements  Outlook
Pepperpot  Diamond  Energy Analysis

4 different separate diamond layers:
- poly-crystalline CVD 10/15µm
- single-crystal CVD 480/380µm
- poly-crystalline CVD 15µm
- poly-crystalline CVD 600µm
(diameter: 3mm each)
New Energy Analyzer

- 0.3mm slit
- 0.5T permanent magnet
- MCP (chevron type)
- SONY CCD camera
  - 1034x779px
  - 4.65x4.65 µm pixel size

HITRAP Beam Diagnostics Measurements Outlook
Pepperpot Diamond Energy Analysis
New Energy Analyzer

HITRAP  Beam Diagnostics  Measurements  Outlook
Pepperpot  Diamond  Energy Analysis

camera
viewport
MCP
dipole
New Energy Analyzer

Homogeneous field on magnet axis measured with hall probe

Drift distance between magnetic field edge and MCP: 95mm

Redidual field on axis if magnet out: <1 gauss
Bunch shape measurement

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macro bunch: 1-3µs from ESR or
micro-structured: 108MHz (measured) / 370ps (not resolved)
Diamond detector

Diamond detector: beam is bunched!

9.2 ns
Phase probes

Bunched beam detected with phase probe in front of IH-structure

Phase probes

HITRAP Beam Diagnostics  Measurements  Outlook
IH commissioning in 2008/2009

HITRAP Beam Diagnostics Measurements Outlook

$\varepsilon_{90\%} = 9,2 \pi \text{ mm mrad}$

4MeV/u 0.5MeV/u
no signal of 0.5MeV/u beam on either YAG scintillator or P-43 for 3-gradient method or pepperpot measurement

→ 3-gradient method via profile measurements using diamond detector (vertical direction only!)
varying gradient of quadrupole doublet 5 behind IH structure

51.2 T/m

57.6 T/m

64 T/m
0.5MeV/u emittance

independent evaluation in MS EXCEL and MATLAB shows exactly same result

design value at this point: 9,2 \( \pi \) mm mrad

\[
\begin{align*}
\varepsilon_{y,kv} &= 9,3 \pi \text{ mm mrad} \\
\alpha &= 1,15 \\
\beta &= 7,80 \text{ mm/mrad} \\
\gamma &= 0,30 \text{ mrad/mm}
\end{align*}
\]
First test of MCP-Pepperpot-Emittance Meter

**HITRAP Beam Diagnostics Measurements Outlook**

3-gradient method Pepperpot

- Measurement behind RFQ (LEBT)
- Energy mixture: $4\text{MeV/u} > E > 6\text{keV/u}$
Outlook

• MCP-based energy analysis tests ongoing

• tune IH-structure based on energy distribution measurements (1)(spring 2010)

• energy analysis behind RFQ (2) and low energy emittance measurements (3)
Thank you for your attention!

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