NATIONAL ACCELERATOR CENTER - SEVILLE

“BEAM TRACKING DETECTORS”

Marcos Alvarez
On behalf of:

- Dr. Joaquín Gomez Camacho;
  (DITANET steering committee member from CNA-Seville).

- Beam Tracking Detectors (BTD) collaboration;
  (GANIL - CEA (Saclay) – CNA (Sevilla)); Dr. Julien Pancin (GANIL).

- Slowed Down Beam collaboration;
  (GSI – U. Köln – CNA); Dr. Plamen Boutachkov (GSI) {previous talk}.

- CNA – IMSE (Microelectronic National Institute) - University of Seville.
  (different groups and Spanish government projects).

- Basic Nuclear Physics (FNB) group of CNA:
  B. Fernández, Z. Abou-Haïdar (Ditanet), A. Bocci (Ditanet), A. Garzón,
  J. Praena and J. P. Fernández and M. Alvarez.
In collaboration with and supported by

DITANET - PROJECT (2008)
Excellent environment to test detectors, electronic devices and acquisition systems.

Currents 1pA - 1µA
Energies 500KeV – 25MeV
Ion beams H - Cu

CNA - 3 MV TANDEM - SEVILLE (TOOL)
Tandem at CNA, Seville

Ultra-High Vacuum Line

New Nuclear Physics Line 2007-2009

Ion Implantation Line

Ions $0 < A < 60$
Energy is $(Z+1)*3$ MeV
Availability of Time

NEW ONE
TANDEM AREA DEDICATED TO MOUNT A NEW NUCLEAR PHYSICS LINE (2007):

A STRUCTURE TO PERFORM TRACKING STUDIES
Detectors
Target Holder
1.0x1.0x1.5m chamber
Beam Line
intermediate chamber
Centro Nacional de Aceleradores

Beam Line
Target Holder
intermediate chamber
1.0x1.0x1.5m chamber
Detectors
TARGET

Central of GAS
Tracking concepts

Hyde Telescope: DSSD+DE+E

- SeD
- DSSSD
- Diamond etc

Detectors concepts:
- Time resolution
- Position resolution
- Energy resolution
- Counting rate
- Radiation hardness
- Possible active areas
- Noise level

Radioactive Ion beams

- Large acceptance
- Low beam intensity (below 10^5 pps)

Increasing with the future particles accelerators (>10^6 pps)
High counting rate capability!!
Looking for beam tracking system for future particle accelerators:

- small and large area tracking system for different new experiments;
- good position, energy and time resolutions;
- the corresponding integrated fast electronics (FPA and ADC).
- with the possibility of working with high counting rate;
- the corresponding radiation hardness, and
- low level noise.

The ideal detector for tracking:

- Possibility of a large area version 20x20cm; 50x50cm…
- Counting rate $> 10^6$ particles/sec (mainly for future facilities)
- with corresponding radiation hardness and
- NO noise degradation
- Time resolution (with beam) $\leq$ 100ps
- Energy Resolution $\Delta E/E \sim 1\%$
- Position Resolution $\sim 1$mm
Interested institutions (FAIR): (GSI; LNL; GANIL; CEA Saclay; U-Manchester; U-Huelva; STFC Daresbury; IKP-Köln; U-Surrey; U-Liverpool; U-York; IPN Orsay; IFIN-HH; IFJ-PAN Krakow and Univ. of Seville/CNA).

Candidates:

- Low-pressure gas-amplification detectors with dedicated ASIC electronics;
  - Se-D (Secondary electron Detector). A large area detector.
  - Need of fast pre amplifiers, electric and magnetic field applied.
  - An alternative is the low-pressure “MICROMEGAS” detectors. High counting rate, radiation hardness.
  - Different sizes and coupling to low pressure are under investigation.

- Diamonds detectors are very fast, very high counting rate capability and radiation-hard. Good energy resolution.
  - Large area is not available and it is an expensive technology.

- DSSSD and organic-scintillator detectors. Good performance; but limited counting rate and radiation hardness. Good for test proposal!

- Micro Channel Plates MCP detectors. Excellent time and position resolution. Large area readout to be investigated.
S271 TEST (2005) and Experiment (2006) @ GSI:

• 8B BEAM TRACKING

DSSSD’s 16x16 strips:
tested as “beam profile monitor” (2005) and
used as impact position monitor, on target (2006).

Counting rate: $10^4$ pps
Beam energy: 250 MeV/u
Spot: 3cm x 5cm

➢ Good performance for DSSSD tracking @ FRS conditions;
➢ Good candidate for tests proposals!
Experiment S271 (19Mg decay) at GSI – 11/2006, S2-FRS

Two proton radioactivity of 19Mg by tracking decay products, I. Mukha et al.

Tracking scheme in the GSI experiment S271, “Two-proton decay of $^{19}$Mg”

Reaction Fragments tracking

- Fragmentation $^{20}$Mg->$^{18}$Ne+p+p
- Reaction $^{20}$Mg->$^{19}$Mg->$^{17}$Ne+p+p

TEST S310 (Slowed down simulations) at GSI - 08/2007, S2-FRS

- Development of fast timing for a large area DSSSD was initiated;

- Test experiment at UNILAC: 40µm, 5x5cm DSSSD were tested with pre-amps developed @ GSI;

- Dr. Plamen Boutachkov talk!!!
**TEST - Experiment (Slowed down beams) at GSI - 09/2008, S2-FRS**

A 600MeV/u of 64Ni beam is slowed down to 2MeV/u by Al degraders;

Energy of the slowed and scattered 64Ni ions is measured by a TOF method, before target with a scintillator detector and after target with the MCP detector.

The Si detector stop the particles detecting their energy; ExTOF analysis.

The MCP detector consisted of a thin 6cmx4cm foil; associated to the fast pre-amp.

▶ Dr. Plamen Boutachkov talk!!!
Irradiation of thin CVD diamond detectors with low energy 100MHz of p, α, 7Li beam was performed:

$\Delta E/E < 1\%$ of a SC CVD diamond detector was achieved.

TIME Resolution ~ 100ps

Low dead time (70% of efficiency) and satisfactory radiation hardness. No signs of degradation or noise.

Counting Rate: $10^{7-9}$ particles/s

Limitation: To cover a large surface using very thin single crystal diamond films!

**MOTIVATION** for mounting a dedicated Nuclear Physics Line!!!
Diamond Detectors for the R3B Experiment at FAIR, Darmstadt
S. Schwertel, M. Böhmer, R. Gernhäuser, R. Krücken, L. Maier, and S. Winkler

- Time resolution of 60 ps
- Detector efficiency of 98%
- Radiation hardness up to $2.5 \times 10^{13}$ ions/cm$^2$

Detector Layout:
- Detector substrate material is a 100µm thick layer of polycrystalline PC CVD diamond of size 2.54cm x 2.54cm.
- The one side used for position measurement is segmented in 128 strips with a pitch of 200µm and gaps of 20µm.
- Back side is used for ToF measurement. It is divided into 16 aluminium strips each with a gap of 50 µm.

Investigations of new samples of single-crystal CVD-diamond detectors
E. Berdermann, M. Ciobanu, W. de Boer, R. Lovrincic, J. Morse, M. Pomorski, M. Traeger

- 3.5mm x 3.5mm area
- Thickness ~ 50µm
- Energy resolution $\delta E \sim 15$ KeV ($\delta E/E = 0.27\%$).
- Counting rate around $10^{16}$ particles/cm$^2$

GSI Scientific Report 2008
Low Pressure Gas Detector Collaboration

Electronics : Thomas Chaminade (IRFU/SEDI)
Scientific coordinator : Antoine Drouart (IRFU/SPhN)
Detector tests : Mariam Kebbiri (IRFU/SEDI)
Technical coordinator : Julien Pancin (GANIL)
Informatics : Yves Piret (IRFU/SEDI)
Mechanics : Marc Riallot (IRFU/SEDI)

External collaboration : Begoña Fernandez (University of Seville / CNA)
Marcos Alvarez (University of Seville / CNA)
Farheen Naqvi (GSI)

- SeD - VAMOS SPECTROMETER (GANIL)
  - Good position resolution 1 - 2mm
  - Time resolution ~ 250 ps
  - Counting rate 10^3 pps (limited by electronics)

- mini SeD (70x70mm and the same parameters of SeD)
  - Place for improvement (time, position, counting rate)
  - small and big active area with the same detector
  - Low cost
### Quotation for the MiniSeD construction:

<table>
<thead>
<tr>
<th>Pieces</th>
<th>Dimensions</th>
<th>Thickness</th>
<th>Material</th>
<th>Price+ 19.6%</th>
<th>Price to add*</th>
</tr>
</thead>
<tbody>
<tr>
<td>901V-Piece for the strips</td>
<td>164X120mm</td>
<td>3.2mm</td>
<td>PCB</td>
<td>286eur</td>
<td></td>
</tr>
<tr>
<td>902V-Piece for the anode's wires</td>
<td>100X94mm</td>
<td>1.6mm</td>
<td>PCB</td>
<td>44.55eur</td>
<td>250eur</td>
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<tr>
<td>906V-Piece for the cathode's wires</td>
<td>140X144mm</td>
<td>2.4mm</td>
<td>PCB</td>
<td>176.62eur</td>
<td>460eur</td>
</tr>
<tr>
<td>Mylar's window</td>
<td>120X140mm</td>
<td>3.2mm</td>
<td></td>
<td>28eur</td>
<td>80eur</td>
</tr>
<tr>
<td>Grille's window</td>
<td>80X80mm</td>
<td>3.2mm</td>
<td>Aislant</td>
<td>28eur</td>
<td>160eur</td>
</tr>
<tr>
<td>Aislant pieces for the gasket</td>
<td>140X120mm</td>
<td>1.2mm</td>
<td>Aislant</td>
<td>75eur</td>
<td>80eur</td>
</tr>
<tr>
<td>External metal structure(2 pieces)</td>
<td>140X120mm</td>
<td>10mm</td>
<td>Steel</td>
<td>400eur</td>
<td></td>
</tr>
</tbody>
</table>

**Total price estimated: 1242 eur + 1030 eur * !!!**

*To add the first time you construct the pieces*
• **SIMULATIONS:**
  - ELECTRIC AND MAGNETIC FIELD
  - CHARGE PRODUCTION
  - ELECTRONIC SIGNALS

• **CONSTRUCTION:**
  - WINDOWS OF MYLAR
  - STRIP CATHODES (PCB's)
  - WIRE ELECTRODES
  - MECHANICAL PIECES

• **COMPLEMENTARY DEVELOPMENT:**
  - FAST PRE-AMPLIFIERS

• **TESTS:**
  - AMPLITUDES (operation voltages)
  - TIME RESOLUTION
  - POSITION RESOLUTION

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**Beam Line**
Mini Secondary electron Detector (mini-SeD)  
the mechanical construction:

- Cathode (Wires of goldened tungsten, 50 µm diameter)
- Anode (wires 10 µm diameter)
- Gap 3.2mm
- Active area 70x70 mm²
- Cathode (28 evaporated strips)
- Mylar window

(72 wires of goldened tungsten)
MECHANICAL CONSTRUCTION:

FINAL PRODUCT: Mini-SeD prototype

ELECTRODES

CATHODE

ANODE

MYLAR

MYLAR
We introduce all detector parameters in GEANT4 and simulate the charge production and time fluence, which is the input to the pre-amp simulations.

- Energy of the incident beam = 1-20 MeV/u
- Aluminized mylar thickness = 0.9 µm
- Extraction voltage = 10 KV
- Magnetic Field = 100 G
- C4H10 gas at ~4 Torr
- Cu stripers
- FR4 PCB
- 10 µm goldened tungsten (anode)
- 50 µm goldened tungsten (cathode)
- different gaps
- Electric field=600 V
TRANSIMPEDANCE AMPLIFIER CIRCUIT:
CURRENT TO VOLTAGE SIGNAL,
GAIN AND SHAPER FITS
POSITION SIGNALS AND MEASUREMENTS (CATHODE):

- **Mini-SeD**
- **Emisive foil**
- **magnets**

**Cathode signal**
- Amplitude: \( \approx 50\text{mV} \)
- Rise time: \( \approx 8\text{ns} \)
- Bandwidth: \( \approx 30\text{ns} \)

**Table**

<table>
<thead>
<tr>
<th>hbar</th>
<th>Entries</th>
<th>Mean</th>
<th>RMS</th>
<th>( \chi^2 / \text{ndf} )</th>
<th>p0</th>
<th>p1</th>
<th>p2</th>
<th>p3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>805</td>
<td>20.4</td>
<td>3.693</td>
<td>43.33 / 32</td>
<td>86.02 ± 10.22</td>
<td>20.42 ± 0.09</td>
<td>1.482 ± 0.163</td>
<td>1.583 ± 0.716</td>
</tr>
</tbody>
</table>
### TIME SIGNALS AND MEASUREMENTS (ANODE):

<table>
<thead>
<tr>
<th>Signal</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>amplitude</td>
<td>Signal Amplitude</td>
<td>≈150mV</td>
</tr>
<tr>
<td>rise time</td>
<td>Rise Time</td>
<td>≈6ns</td>
</tr>
<tr>
<td>bandwidth</td>
<td>Bandwidth</td>
<td>≈20ns</td>
</tr>
</tbody>
</table>
TIME AND POSITION RESOLUTION RESULTS:

Spatial Resolution $\approx 1.2\text{mm}$

Temporal Resolution $\approx 200\text{ps}$
**Associated Electronics:**

Under constant development (ASIC – MATACQ/AFTER)

Complementar development!!! Common interest!!

<table>
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<tr>
<th>Cathode signal amplitude</th>
<th>( \approx 50\text{mV} )</th>
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<tr>
<td>Bandwidth</td>
<td>( \approx 30\text{ns} )</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Cathode signal amplitude</th>
<th>(Simulations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rise time</td>
<td>( \approx 300\text{ps} )</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>( \text{BW} \times \text{GAIN} )</td>
</tr>
</tbody>
</table>
- **SIMULATIONS:**
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- **TESTS:**
  - AMPLITUDES (operation voltages)
  - TIME RESOLUTION
  - POSITION RESOLUTION

- Time resolution better than 100ps.
- Position resolution lower than 1mm.
- Counting rate of $10^6$ pps (at least).
RESULTS:

• SeD presents comparable results for small (70x70mm) and big (40x70cm) active area;
• Even using old and slow pre-amplifiers we got position resolutions of order of 1mm and time resolution of 200ps;
• The integration between GEANT4 and Multisim simulations are very promising for drawing new fast amplifiers circuits, which must improve the counting rate capabilities.

Next steps:

• To construct new mini-prototypes and test it with different sources (2009-2010);
• To perform first tests of mini-SeD and other mini-detectors prototypes @ GANIL accelerator (2010);
• Perform different tests of beam tracking detectors prototypes @ CNA;
• New developments of electronics (fast and integrated pre-amplifiers).