Construction of the silicon tracker for the R3B experiment.

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on behalf of the teams at
Daresbury Laboratory, Edinburgh and Liverpool Universities.

Outline:

- FAIR and R3B.
- Overview of Si tracker.
- Mechanics, sensors, ASIC, DAQ.
- Electrical and in-beam tests.
- Conclusion.
• Facilities for Antiproton and Ion Research (FAIR).
• It is an expansion of GSI.
• **Secondary beams of highly unstable nuclei** (up to 1 GeV/u).
• Produced by primary heavy ions beam hitting production target.
• Separated in-flight within 100's of ns: Super FRS.
• **High-energy branch** for secondary beams up to $B_{\rho_{\text{max}}}$ of 20 Tm.
R3B.

- Reactions with relativistic radioactive beam (R3B).
- Emphasis on nuclear structure and dynamics.
- Located in high-energy branch of Super-FRS.
- Kinematically complete measurements of reactions with high-energy radioactive beams.
- Unprecedented high efficiency, acceptance, and resolution.
Silicon tracker.

- Precise tracking and vertexing, as well as energy and multiplicity measurements.
- Conical shape.
- Detect light charged particles (like protons) from the target region.
- Double-sided micro-strip silicon sensors wire bonded to a custom made ASIC.
- 30 detectors: 6 in inner layer; 12 in each of the 2 identical outer layers.
- Total sensitive area $\sim 5600 \text{ cm}^2$.
- 912 ASICs equivalent to 116,736 front-end channels.
- Each outer layer: 384 ASICs (49152 chs); Inner layer: 144 ASICs (18432chs).
- Operated in vacuum.
Mechanics.

- **Vacuum chamber** made of Al.
- Total volume of $\sim0.148\,\text{m}^3$.
- $\sim2\text{mm}$ wall: low material budget (2.2% of $X_0$).
- Reached target vacuum: $1\times10^{-5}\,\text{mbar}$.

- **Support structure** made of Al.
- **Cooling system** based on Cu (pipes and blocks) and H$_2$O+Glycol (coolant).
- New Cu-blocks: better alignment; good thermal contact.
- ASIC temperature range: $0\text{-}70^\circ\text{C}$.
Sensor.

Sensor specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>double sided</td>
</tr>
<tr>
<td>Bulk doping</td>
<td>n-type</td>
</tr>
<tr>
<td>Bulk thickness</td>
<td>300 $\mu$m [ABC] 100 $\mu$m [BD]</td>
</tr>
<tr>
<td>Strip pitch</td>
<td>50 $\mu$m</td>
</tr>
<tr>
<td>Strip width</td>
<td>38 $\mu$m</td>
</tr>
<tr>
<td>Strip length</td>
<td>variable</td>
</tr>
<tr>
<td>Strip stereo angle</td>
<td>16.2°</td>
</tr>
<tr>
<td>Isolation implant</td>
<td>p-spray</td>
</tr>
<tr>
<td>Guard rings</td>
<td>9 floating</td>
</tr>
<tr>
<td>I-leak per strip</td>
<td>3.25 nA/cm [&lt;100 nA]</td>
</tr>
<tr>
<td>Strip capacitance</td>
<td>2.3 pF/cm [&lt;80 pF]</td>
</tr>
</tbody>
</table>

- BD detector for inner layer.
- ABC detector for outer layers.
- Starting production from ABC detectors.
- Sensor successfully assembled to carbon-fibre frame.
- It has $I\text{-leak}<8\mu\text{A}@60\text{V}$ (op.voltage).
- Designed at STFC Rutherford Appleton Lab.
- The R3B ASIC is intended for reading out signals from the N and P strips.
- The chip provides three informations:
  1. strip number.
  2. energy deposit.
  3. time of the hit.

<table>
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<th>ASIC specifications</th>
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<tbody>
<tr>
<td><strong>Size</strong></td>
</tr>
<tr>
<td><strong>CMOS process</strong></td>
</tr>
<tr>
<td><strong>Power consumption</strong></td>
</tr>
<tr>
<td><strong>Channels per chip</strong></td>
</tr>
<tr>
<td><strong>Data rate</strong></td>
</tr>
<tr>
<td><strong>Energy range</strong></td>
</tr>
<tr>
<td><strong>Time stamp</strong></td>
</tr>
</tbody>
</table>

- Readout based on a daisy chain sequence.
- **Four ASICs are connected in a chain.**
- They are not adjacent to each other.
- Rate in each ASIC proportional to the associated strip length.
ASIC testing.

- Tests performed on bare ASICs.
- Front-end characterization performed with internal pulse.
- Comparing ASIC with its specifications.
- Particular focus on: threshold tuning; front-end linearity; signal sampling; ADC to energy.
- **Control ASICs**: set registers, distribute clock.
- **Synchronize tracker** with other sub-detector systems.
- **Transfer data** to experiment DAQ (NDAQ).
- **MIDAS software**: well established in UK nuclear community.
- Total of 3 uTCA crates: 10 FEE cards in each crate.
- 1 FEE card for each detector.
- Current cable has measurable x-talk, exploring other types.
Detector testing.

- Test-pulse injected in each individual channel.
- Input capacitance $\propto$ strip length.
- $I_{\text{leak}} \propto$ strip length.
- **Higher noise for longer strips.**
- More uniform and lower noise with high shaping time.

N.B. N-side has a broken daisy chain.
In-beam test @ GSI.

- GOAL: study reactions produced by a Ca48 beam hitting a CH2 target.
- MEAN: detect correlations of signals produced by particles in CALIFA and Si-tracker.
- OUTCOME: we acquired two data sets which could enable finding correlations.
- BUT: To achieve this goal we had to adopt several work around to overcome several difficulties.
- The scientific goal allowed us to **test our detector system** in terms of:
  1. building.
  2. mounting.
  3. operating.
  4. taking data.
  5. analysing data.

![Table of schedules](image-url)
In-beam test @ GSI.

- 3 detectors to GSI.
- Det101 and Det104 are in front of CALIFA petals.
- Det103 does not have a CALIFA petal behind it.
- Only operated a fraction of Det101.
- Main problems: data corruption, data repetition, high leakage current.
- Problems caused by: cabling (ongoing), firmware (fixed), detector assembly (ongoing).
- Data analysis started.

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<tr>
<th>Exp.5438, cave C</th>
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<tbody>
<tr>
<td>Run290.3777</td>
<td></td>
</tr>
<tr>
<td>Target</td>
<td>Thickness</td>
</tr>
<tr>
<td>CH2</td>
<td>4.98mm</td>
</tr>
</tbody>
</table>

ADC vs TS: Pside (side1)

![Plot of ADC vs TS: Pside (side1) with spill ~25s]
Conclusion.

- The R3B silicon tracker is under construction.
- Mechanics, sensors, ASICs and DAQ are in an advanced stage.
- Tests allowed for an improvement of the setup.