Electronics and Trigger developments for the Diffractive Physics Proposal at 220 m LHC-ATLAS

Patrick Le Du       Jean-François Genat

CEA Saclay

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Prague, Czech Republic
Outline

- Diffractive Physics at LHC
- Roman Pots at ATLAS
- Silicon Detectors
- Timing using Micro-channel Plates
- Trigger and DAQ
- Conclusion
Diffractive Physics at LHC

Project to install Roman Pots detectors at 220m from the ATLAS IP

Collaboration between:

- Prague, Cracow, Saclay, Stony Brook, Giessen, Paris 6,

- Chair: Christophe Royon (DAPNIA CEA Saclay)
Physics processes

- **Study of inclusive events (the only events which are existing for sure)**
  - Determination of gluon at high $\beta$, search for SUSY events (or any resonance) when dijet background is known

- **Exclusive Higgs:**
  - Signal over background: $\sim 1$ if one gets a very good resolution using Roman Pots (better than 1 GeV), enhanced by a factor up to 50 for SUSY Higgs at high $\tan \beta$

- **QED WW pair production**
  - Cross section known precisely, allows to calibrate precisely the Roman Pot detectors

- **Diffractive top, stop pair production**
  - Possibility to measure top and stop masses by performing a threshold scan with a precision better than 1 GeV if cross section high enough
RP220 vs. other projects

- High Luminosity
- Additional signal and flag at the L1 ATLAS Trigger
- Natural follow-up of the ATLAS luminosity project at 240 m to measure total cross section
- Complementary to the RP420 (Roman Pots at 420m)
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Two horizontal pots at 216 and 224 m on each arm with detectors as close as possible to the beam: $10 \sigma = 1 \mu m$
Roman Pot Layout

Read out and Trigger LOGIC (FPGA)
Power and Clock distribution
Slow control
Cooling

To Alcove

FE ASIC (PA, SH, Pipeline)
Plus FAST OR

MCP-PMT

8 x 8 Pixels
Light Guide

Radiator

Edgeless Silicon Strips

2.54 x 2.54 cm

4.5 cm

Beam

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Silicon detectors

One Roman Pot:

Five Silicon strips detectors:
- 25 μm pitch detector of 2.54cm x 2.54cm,
- 1000 channels, 10-bit address.
- 2X, 1Y, 1U, 1V detectors
- Two of them used for L1 trigger.
Detector geometries

25.4 x 25.4 mm detectors
50 μm pitch

XYZ and UV detectors

Readout chips

Edgeless cut

Four types of detectors

Roman pots specific requirements

- Achieve 10 μm position resolution: 50 μm pitch strips read in digital:

\[ \frac{25}{\sqrt{12}} = 14.4 \, \mu m \text{ resolution} \]

- Edgeless:
  Collect edge currents through the bulk to allow full depletion, or avoid them.

TOTEM:
- Rings biased at the strip potential as close as possible to the edge, collect currents due to cut, allow to be sensitive down to 20 - 50 μm

Proposed by Canberra: edge equipotential, no more edge current flowing.

# Detectors specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>2.54 x 2.54 mm²</td>
</tr>
<tr>
<td>AC coupled</td>
<td>&gt;10pF/cm, insulated to &gt;300V</td>
</tr>
<tr>
<td>Interstrip</td>
<td>&lt; 1.5 pF/cm</td>
</tr>
<tr>
<td>Full depletion</td>
<td>60-100V</td>
</tr>
<tr>
<td>Thickness</td>
<td>300 µm +/- 20 mm</td>
</tr>
<tr>
<td><strong>Leakage current</strong></td>
<td>50nA/cm² at 300V bias</td>
</tr>
<tr>
<td>Resistance poly (one side)</td>
<td>1.5 +/- .5 MΩ</td>
</tr>
<tr>
<td>Interstrip resistance</td>
<td>&gt; 2 GΩ</td>
</tr>
<tr>
<td>Pads AC and DC</td>
<td></td>
</tr>
<tr>
<td>Edgeless on one side</td>
<td>&lt; 30 µm</td>
</tr>
<tr>
<td>Pitch</td>
<td>25 µm</td>
</tr>
<tr>
<td>Pitch adapters to 100 µm on detector (four rows)</td>
<td></td>
</tr>
<tr>
<td>Defective strips</td>
<td>&lt;1%</td>
</tr>
</tbody>
</table>

Quantities: 20 + 12 spares = 32

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Availability from the industry

TOTEM: CERN and IOFFE PTI (Russia) produce edgeless first detectors moved to INTAS-CERN EU project.

Companies contacted:

- Canberra (AREVA Belgium)
- Hamamatsu
- Sintef (Norway)
- VTT (Finland)

- Canberra started small prototypes 6.4 x 6.4 mm, 50 μm pitch, DC coupled, edgeless at 25 and 50 μm, available for tests beg 2007.

- Hamamatsu and Sintef made also offers.

VTT claims to be able to do edgeless to 20 μm. Semi-3D availability

Detectors tested for reverse current at FZU Prague

Presently wire-bonded to ATLAS SCT hybrids at CERN

Mirek Hravana

**CANBERRA 50 μm pitch test detectors**

Tests at FZU Prague (July 2007)

Reverse current measurement depending on the strip position typically 25 nA OK. Further tests need a full detector wire-bonded and biased.

Breakdown voltage 110-130 V OK

Test stand at Saclay

CERN provided a test stand with hybrids equipped with regular ABCDs chips used for the ATLAS SCT
Thanks to Shaun Roe and Francis Anghinolfi

Future ABCD chip will include fast outputs
(W. Dabrowski)

VME readout module driven by a PC installed at Saclay
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Micro-Channel Plates Timing Detectors

- Used to achieve picosecond coincidences and reconstruct Vertex to 1mm precision

Burle-Photonis provides MCP detectors

8 x 8 segmented anodes readout
Major advances for TOF measurements

Micro-photograph of Burle 25 μm pores tube

Greg Sellberg (Fermilab)

Now 10 μm pores

2” x 2” sensitive area

Courtesy: Henry Frisch    Univ Chicago
MCP PMT single photon signals

Actual MCP PMTs signals
K. Inami
Univ. Nagoya
Tr = 500ps
tts= 30ps

MCP PMTs segmented anode signals simulation
20 photoelectrons  tts = 860 fs
H. Frisch,
Univ. Chicago + Argonne

N photo-electrons improves as $\sqrt{N}$

Electronics developed at Univ. Chicago

See Poster by Fukun Tang (this Workshop)

- Two cards 2” x 2” connected to the MCP anode planes

**Picosecond card** with picosecond Time stretcher SiGe chip includes:

- Discriminator
- 2 GHz PLL
- Time stretcher

**FPGA card** includes

- 200ps TDC
- Control, calibration, interface

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Trigger Topologies

RP220 only

P Left track

1 KHz

RP 220

JET 1

JET 2

PL AND PR track with ζ cut
Et JET 1 AND 2 > 40 Gev
JET Rapidity correlation ?
Dijet ENERGY /TOTAL > 0.9

RP 220

P Right track

RP220 + FP420

P Left Track

1,6 KHz

RP 220

JET 1

JET 2

PL track with ζ cut
Et JET 1 AND 2 > 40 Gev
JET 1 Rapidity Cut
Dijet ENERGY /TOTAL > 0.9

FP420

Diffractive Higgs Trigger

Horizontal roman pots
(a la TOTEM)

- 224 m xA - 216 m xB

Front end

PA SH
Chip ABC next
Pipeline buffer
(6.4 μsec)

Left Pretrigger

xA - xB = 0

+850 ns (air cable)

LR Trigger Logic

• LP AND RP
• TR - TL

L1 CTP
Max 75KHz

2 Jets with Pt > 40 Gev/c

Refined Jet Pt cut
Vertice within millimeter
Δ time < 5 to 10 psec

ROD

1,0 μsec

2,0 μsec

2,5 μsec

ATLAS detector

ΔT

+730 ns

ATLAS Standard

Timing and Data flow

Proton @ RP

Flight path 733 ns

Pretrigger Data available @ 220 m (Alcove)

Processing

MCP ---> 4 Events x 6 bit words per Xing
= 104 bit/Bx  Average Rate = 4,16 Gbit/sec (11ns through cable to Alcove)

ALCOVE μCTA crate PRETRIGGER
Matching 2RPs with overlap Si Strips
Add Timing information from relevant MCP PMT pixel (1 mm²)

RP Trigger Data @ ATLAS CTP

LVL1 ACCEPT (75 KHz)

80 bit/BX x 40 MHz = 3.2 Gb/s
80 bit @ 10 GB/s - 880 transfert time

RPs data @ ROD

Data Production per Roman Pot to ROD
4 events x(7 Si detectors x10 bit word stored in the pipeline)
4 events x 1 MCP-PMT detector x (6 bit adress + 8 bit fine timing)
Total per LV1 Accept = 336 bit
Total x 75 KHz =25 Mb/s

Implementation block diagram

- Detector ASIC
- Local Logic
- 20 m Cables
- Shielded Alcove

- Pretrigger logic
- μCTA crate
- Read Out
- Control & Monitoring

- Picosecond CLK
- 160 MHz
- Trigger DATA
- 4,16 Gb/s
- RO DATA
- 670 kb/s

- 20 m Cables

- ATLAS LVL1 CTP
- ATLAS ROD (LVL2 & DAQ)
- Reference clock (Atomic)
- LHC CLK

- 2 x 3,2 Gb/s
- 25 Mb/s
- 75 KHz

- 160 MHz CLK (fiber)

- RP Left Trigger
- 1 Cable
- L1 ACCEPT
- 2 x 3,2 Gb/s

- US 15

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Conclusion

Much work to be completed timely
Not too many people…

- Detectors
  Silicon, MCP

- Electronics
  SiGe-CMOS chips, FPGAs

- System
  Insertion into ATLAS L1 and DAQ
  Micro TCA foreseen

- Install…
backup
3D detectors vs Planar

3D versus planar detectors (not to scale)

Active edge

Collecting electrode

3D

particle

PLANAR

~ 500 μm

Microcracks, chips induce surface leakage current

MEDICI simulation of a 3D structure

<table>
<thead>
<tr>
<th>3D</th>
<th>Planar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depletion Voltages</td>
<td>&lt; 10 V</td>
</tr>
<tr>
<td>Edge Sensitivity</td>
<td>&lt; 10 μm</td>
</tr>
<tr>
<td>Charge 1 MIP (300 μm)</td>
<td>24000e−</td>
</tr>
<tr>
<td>Capacitance (121 μm)</td>
<td>200fF</td>
</tr>
<tr>
<td>Collection Distance</td>
<td>50 μm</td>
</tr>
<tr>
<td>Speed</td>
<td>1-2ns</td>
</tr>
</tbody>
</table>

Drift lines parallel to the surface

Cinzia Da Via (FP440), Brunel, UK 11/2004
Stanford, SINTEF, VTT
“Precise” diamond saw VS dry etching

A fraction of this production will be sent to the CNM of Barcelona for the dicing with dry etching

- If this test is satisfactory (in terms of yield and performance) we could still adopt this technique for the mass production

Gennaro Ruggiero (TOTEM)

Micrometer range cut uniformity allows low edge surface currents.

Jean-François Genat, April 24-25th 2007, Prague