Towards spark-proof gaseous pixel detectors

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Outline

- Gaseous pixel detectors
- Detector construction
- Testbeam
- Discharges
- Can we make a spark-proof detector module?
- Recent activities
- Summary & Future plans
Micropattern gaseous pixel detectors

- Low material budget
- Less radiation damage
- Single electron detection
- High position resolution
- 3D track reconstruction

Under microscope
Working principle

- Ionisation in drift gap
- Electrons drift towards amplification gap (50 μm)
- Avalanche multiplication
- Induced signal on pixels
- Pixel position gives \((x,y)\)
- Drift time gives \(z\)
Timepix3 chip

- Designed by Cern, Nikhef, Bonn
- Matrix of $256 \times 256$ pixels
- 55 $\mu$m pixel pitch
- High resolution TDC per pixel
- Rise-time < 25 ns, 1.562 ns resolution
- Simultaneous ToA & ToT measurement
- Low threshold, $5\sigma_{\text{noise}} \approx 500$ e$^-$
- Readout rate up to 80 MHits/s per chip
Detector construction

- Delayed production of InGrids on top of Timepix3 chip
- The only way to go was make use of a Micromegas grid.
- Not integrated - manually placed
Micromegas amplification grid

- 50 $\mu$m high pillars every 1 mm
- Hole diameter $\sim$ 35 $\mu$m
- 60 $\mu$m grid-hole pitch
- 55 $\mu$m pixel pitch
- Mismatch $= \frac{60}{60-55} = 12$ pixels
Testbeam set-up

- End of August 2015
- Two detectors under test
- Muon and hadron beams
- Scintillators for ext. trigger
- Spidr readout
- We record all tracks!

Timepix3 silicon telescope (LHCb VELO group)
Main goal

Correct offline for “timewalk” effect

- All chips suffer from “timewalk”
- Gas gain fluctuations and/or rise-time
- Timepix3 into the game
- Simultaneous measurement of ToT & ToA
- Use ToT to correct the arrival time

Pixel addr 16bit  coarse ToA 14bit  ToT 10bit  Fine ToA 4bit

![Graph showing signal output vs time to threshold and time (a.u.) with threshold level](image-url)
Timewalk correction

Run settings

- CO\textsubscript{2}/DME (50%/50%)
- E\textsubscript{Drift} = 1 kV/cm
- V\textsubscript{grid} = 550 V
- Gas gain \approx 1.1.5k
- 500 e\textsuperscript{−} threshold!
- Muon beam (180 GeV/c) parallel to the chip

Preliminary
Based on residuals wrt external ref.
Chip failure

- Muon beam:
  - Running smoothly for 3 days
  - Not a single spark

- Switch to hadrons:
  - 2 “killer” sparks within 12h
  - One dead chip out of two

Lifetime in a harsh beam is limited to a few hours...
Discharges

- Occur in the amplification gap
- Si-rich SiN not adequate
- Pinhole effect well known in industry
- Multiple layers of different materials might be the solution
Further improving of spark-proofing

- Test setup for sparks
- MEMS labs produce protection layers (SiN, SiO$_2$, SiC)
- Real and/or dummy chips
- Easy to install/uninstall samples
- Test up to 4 samples simultaneously
- Sparks in the house!
Working principle

- Micromegas grid (80 µm pitch)
- Silicon rubbers keep grid in place
- Contact through W-Au wires
- Pollute gas-mixture with radon
- Induced alphas in active area
Setup performance

- CO₂/DME (50%/50%)
- We record all discharges
- Monitor grid current
- Histogram basic quantities
- Characterise protection layer
- Define the optimal working point of the detector
Layer testing

- Tests on dummy chips
- Metal layer on substrate
- One-step deposition of silicon carbide (SiC)
- Thickness of 4 \( \mu \text{m} \)
- Try different metal layer:
  - 1 \( \mu \text{m} \) of Aluminium
  - 0.5 \( \mu \text{m} \) of Titanium
SiC on top of Al (550V, 1 day)

Spark charge

- Entries: 126
- Mean: 464.2
- Std Dev: 378.8
- Underflow: 0
- Overflow: 0

Peak current of sparks

- Entries: 126
- Mean: 1034
- Std Dev: 846.7
- Underflow: 0
- Overflow: 7

Time between sparks

- Entries: 126
- Mean: 575.2
- Std Dev: 711.2
- Underflow: 0
- Overflow: 4

Spark time

- Entries/sec: $10^3$
SiC on top of Al (550V, 1 day)
SiC on top of Al (550V, 1 day)
SiC on top of Ti

- No sparks over the whole voltage range
- Running for week without a single spark
- Investigation for ageing effects
- Irradiation with $^{90}\text{Sr}$ for 1 week
- Total collected dose $\approx 2 \, \mu\text{C}/\text{cm}^2$
SiC on top of Ti

- Black spots on the protection layer observed
- Pattern matches exactly with grid-hole pattern
- The effect is more intense on the edges of the grid
- Polymerisation debris produced during the avalanche
Concluding remarks

- Gaseous pixel detector is a promising technology
  - Correct for timewalk
  - Run in low threshold
  - Record all tracks

- We have developed a powerful tool for spark testing
- Pad enlargement with Ti together with SiC protection layer could solve the problem
- Future work:
  - Test SiC in a beam environment
  - Try different gas mixtures
1. Analysis, probing and cleaning of wafer surface
2. Formation of protection layer
3. Deposition of SU-8
4. Exposure and baking of SU-8
5. Deposition of Al thin film
6. Patterning of Al to form the Grid
7. Dicing to separate chips
8. Development of SU-8
Backup

- **Speedy Pixel Detector Readout (SPIDR)**
- Based on Xilinx VC707 evaluation board
X. Llopart et al., NIM A581 (2007) 485-494
Novellus Concept I
multi station PECVD