Development of Micro Pixel Chamber for ATLAS upgrade

Neutron beam tests using Ar and Ne base gas

Developments of resistive electrode

Atsuhiko Ochi, Yasuhiro Homma, Hidetoshi Komai, Yuki Edo, Takahiro Yamaguchi

Kobe University
Requirements for muon detector

- Lower occupancy
  - <30% for 5kHz/cm$^2$ of cavern BG.
- Strong reduction of LVL1 trigger
  - <100kHz @ endcap muon
  - Required angular resolution = 1 mrad
  - Required to send ($R$, $\phi$, $d\theta$) to sector logic

Background rate [Hz/cm$^2$] @ $L=10^{35}$ cm$^2/s$

T. Kawamoto

Micro Pixel Chamber ($\mu$-PIC)

- Replacement of endcap muon system
  - For HL-LHC
  - Improving rate capability and LVL1 trigger performance
- Based on Micro Pattern Gas Detector (MPGD)
  - Position resolution $\sim 100\mu$m
  - Two dimensional readout
  - High rate capacity $> 10^7$cps/mm$^2$
  - Both precision and trigger detector
- Mass production is available using PC board technology
  - There is no floating structures neither wire, foil nor mesh.
- Thin gap structure and appropriate gas are proposed for ATLAS muon system
  - For fast signal and high gas gain
Performances of existence $\mu$–PIC

- **Max gain**: $\sim 16000$
- **Stable gain**: $\sim 6000$

**Graph:**
- Anode voltage vs. Gas gain
- Data points from different runs

**Legend:**
- No. 12 2004/09/24
- No. 12 2004/10/05
- No. 10 2004/05/13
- No. 9 2004/04/21

**Diagram:**
- Knife edge test
- Counts vs. Length along the edge [mm]
- $\sigma = 120 \mu m$

**Counting rate**
- High counting rate
- Uniformity of Gain $\sim 4\% (\sigma)$

**Graph:**
- Anode current vs. Counting rate $[10^6 \text{cps/mm}^2]$
Timing property and position resolution

- First tests has been done with 2GeV electron beam (2009, KEK Fuji beamline)
  - Timing resolution ~ 13nsec
  - Position resolution ~ 141 μm (without ADC readout)
Fast Neutron tests for Ar and Ne based gas
Why neutron tests and gas studies?

- Detectors will be exposed to high flux neutron
  - A few MeV – few tenth MeV neutron will produce recoiled nucleon inside detectors
    - That produce great amount of energy deposit (a few MeV/mm²) in gaseous volume.
  - The concerned problem for gas detector
    - “Raether limit” … the electron cluster more than $10^{7-8}$ cause the detector to discharge.
  - We have to test the detector with both properties…
    - Sufficient gas gain for detecting MIP (muon)
    - Stable operation when huge energies are deposited
- Neutron tests for various conditions are tested
  - Spark rates dependencies on neutron irradiation for
    - Operation gains
    - Gas mixture
The neutron beam in Kobe Univ. (Faculty of Maritime Science)

- Tandem Electrostatic Accelerator
  - 1.5MeV + 1.5MeV
    = 3MeV d/p beam
  - I \sim 1 \mu A

- Be target on BL
  - \(^{9}\text{Be} + \text{d} \rightarrow ^{10}\text{B} + \text{n}\) (~7MeV)
  - \sim10^7\text{neutron/sec. @source}

![Graph showing energy distribution](image)
Neutron Beam tests

- **7 – 13 June, 2010**
  - Accelerator operation training
  - Neutron beam studies
- **21–28 June, 2010**
  - Neutron irradiation test for $\mu$-PIC
- **17–24 November, 2010**
  - Spark rate measurements using
    - Ar + C2H6 mixture
    - Ne + C2H6 mixture $\to$ good!
- **30 May – 5 June, 2011**
  - Spark rate measurements using
    - Ne + C2H6 + CF4 mixture Very good!
Spark rate measurement

- Big pulses were counted using current monitor on HV source.
  - For changing gain and gas mixture

![HV current monitor graph](image_url)

![Spark current measurement](image_url)
Spark rate for fast neutron @ 2010 beamtest

- Spark rates are measured using Ar and Ne based gas.
  - Ar:ethane = 70:30
  - Ne:ethane = 70:30
  - Ne:ethane = 90:10
- Spark rates are drastically reduced using neon gas
Further studies for operation gases

- For trigger chamber
  - Faster electron drift velocity is needed
  - Higher electron correction efficiency is needed
- → Mixing CF4 gas on neon based gas.
Gas gains measurements on μ-PLIC (iron source)
- In two gases mixture (Ne+C2H6), 93:7 has better (in maximum gain) performance than 90:10
  - But, in case 95:5, performances (gain, peak resolution) are worse.
- In three gases mixture (Ne+C2H6+CF4), 10% of CF4 and other mixture of 93:7 (=84:6.3) has best performances
  - Mixture of 90:3:7 has been tested for comparison, but maximum attained gain is smaller.
Spark rates of Ne and CF4 mixed gas

- Ne:C2H6=90:10 has best reduction of spark rate
- Ne + C2H6 + CF4 mixing gas is also good spark reduction comparing with argon based gas
- In 3 component gas, gas mixture of 84:10:6 has good reduction of spark rate.
  - We should consider a balance of electron drift speed and spark rate
- More studies are needed
  - Using isobutene etc.
μ-PIC with resistive cathode

Development of new structure for reducing spark damages
μ−PIC with resistive cathode

- To overcome Raether limit
  - Neutron recoiled nucleon, stopped hadron...
- Resistive electrodes are good solution!
- New type of μ−PIC with resistive material is now developing.
  - Resistive kapton is on the cathodes of μ−PIC.
  - Large current from spark reduces the e-field, and spark will be quenched.
  - Huge signal beyond the “Raether limit” will also be suppressed
  - Signal from low energy deposit will be observed with higher gas gain
  - This design provides one promised possibility of MIP detector under hadronic background
Improvements for production

First prototype
Cracks are on substrate
Sparks on cracks

4th prototype
No crack, but bad quality

5th prototype
Qualities are getting better

10cm

A. Ochi @TIPP2011 13 June 2011
Remnant problems and next design

- Sparks are still occurred on resistive $\mu$-PIC
  - More precise manufacturing are needed
    - Problems for alignment of anode and cathode position
  - Higher resistivity is needed between anodes and cathodes
    - New structure using capacitive readout from cathode is proposed. (Thanks to R. Olivaira)
    - Now we have just start to make a new prototype.

Current resistive $\mu$-PIC  \hspace{2cm} Resistive $\mu$-PIC new design
Summary of current R&D status and Future prospects

- μ–PIC is proposed and developed for one candidate of ATLAS muon detector for HL–LHC.
  - There is no floating structure!
  - We can produce it in printed board facilities at commercialy–based industrial companies.
- Fast neutron (~7MeV) tests are performed
  - We found good suppression of spark rate using Ne+C2H6 and Ne+C2H6+CF4 gases under gas gain of a few thousand.
    - CF4 mixed gases provide fast electron drift speed (important for trigger chamber) and need less voltage for drift gap.
- Development of resistive cathode μ–PIC
  - Producing process and structures is being improved
    - The problems of crack, wrong patterning have been solved
    - There remain the alignment problem, but it will be solved soon.
  - New structure for avoiding large sparks is now being developed.
- Future prospects
  - Until 2012 … R&D, improvements and performance tests of basic structure
    - Time jitter and detection efficiency should be optimized.
  - 2013–14 … Developments for Readout and large size detector
  - Mass production will be available using existence line in private company.
Thank you
and
hope to see you at Kobe
In this summer