Micro Pixel Chamber for ATLAS muon upgrade

Proposal and current status of developments

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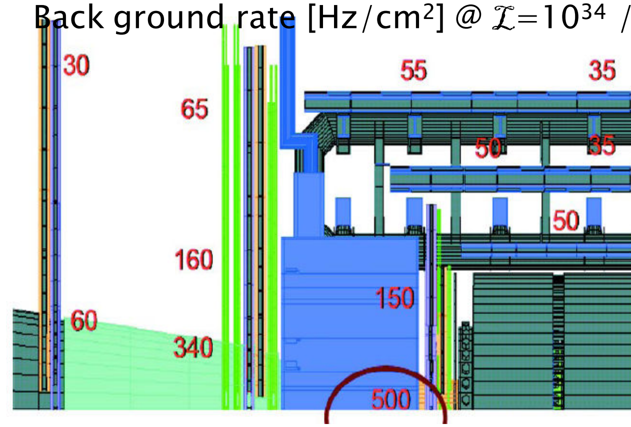
Introduction

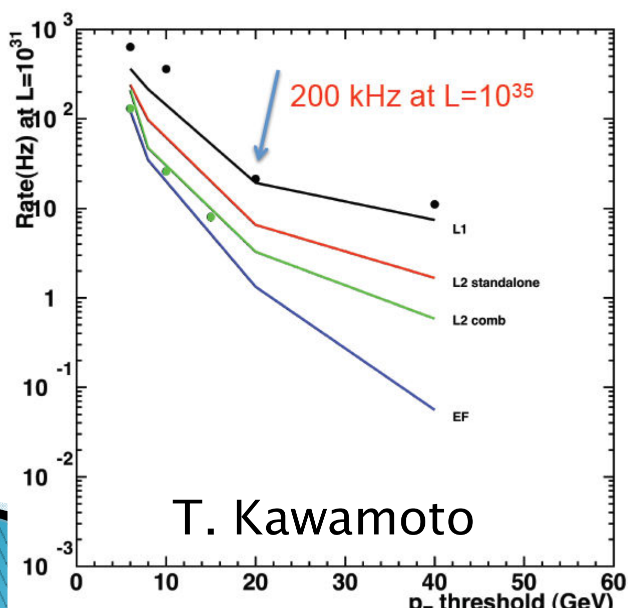
Endcap muon system on SLHC

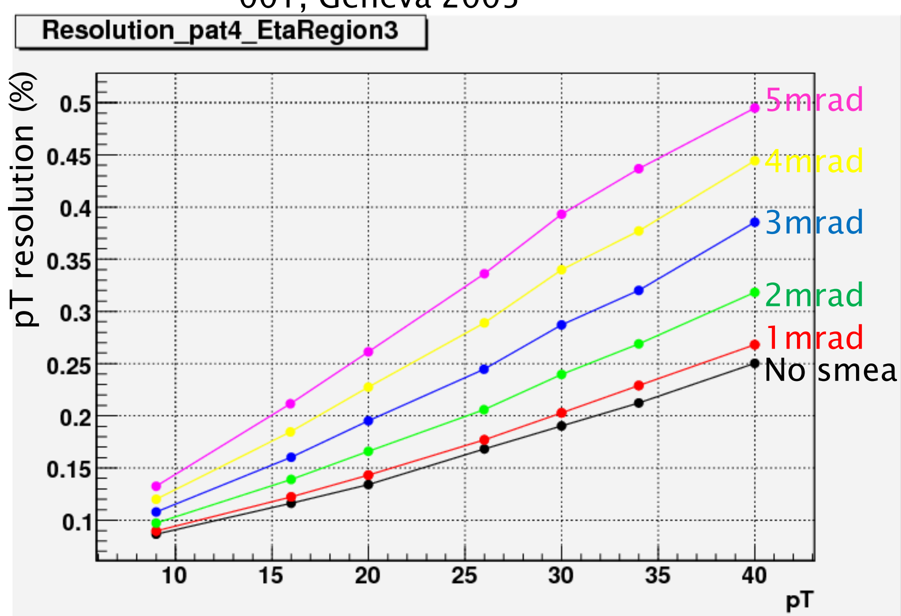
- Requirements for muon detector
  - Lower occupancy
    - <30% for 5kHz/cm² of cavern BG.
  - Strong reduction of LVL1 trigger
    - <100kHz @ endcap muon
    - Angular resolution at SW < ~1mrad

Back ground rate [Hz/cm²] @ $\mathcal{L}=10^{34}$ /cm²s



Baranov et al. : ATL-GEN-2005-001, Geneva 2005





pT resolution for each angular resolution at SW (T. Domae, 2009) $1.55 < \eta < 1.95$

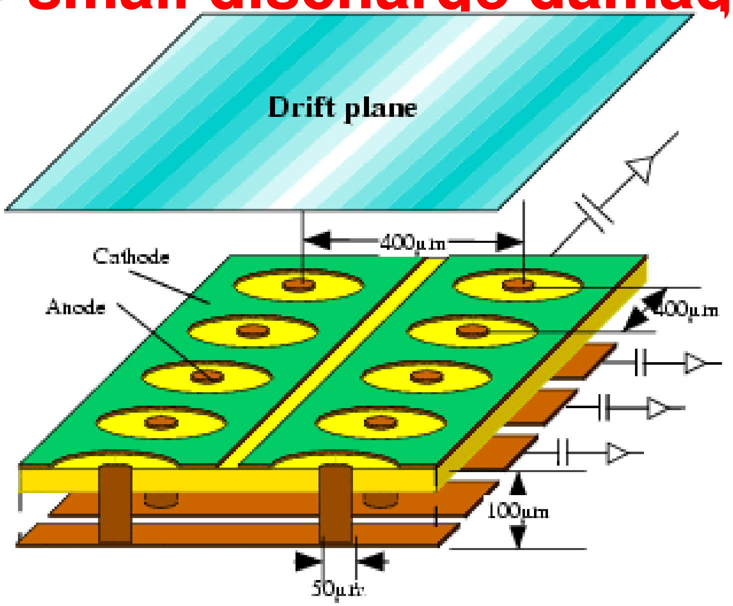
Current detector candidates of ATLAS endcap muon upgrade

- Fine TGC, Fine MDT and Bulk MicroMEGAS have been already proposed as ATLAS endcap muon upgrade. (Phase-I and II)
- Our μ-PIC was newly proposed as phase-II upgrade.

	LVL1 Trig?	Dime nsion	Posi. resol. [μm]	Ang. resol. [mrad]	Max. rate [Hz/cm²]	Timing req. [nsec]	Read elec.	Area / unit [m²]	Cost [CHF/m²]
μ-PIC	◎	2+α	60～115	0.3	$>10^9$	<20	Hit only	<0.1	10^4
Fine TGC	◎	2	50～100		10^5	25	ADC	2	10^4
Fine MDT	×	1	112		10^3	200	Hit Timing		
Micro Megas	◎	2	100		10^{11}	5	?	2	

Basic design of existance μ−PIC

- **Production with PCB tech.**
- **No floating structures**
- **pitch :400μm**
- **high gas gain**
- **small discharge damage**

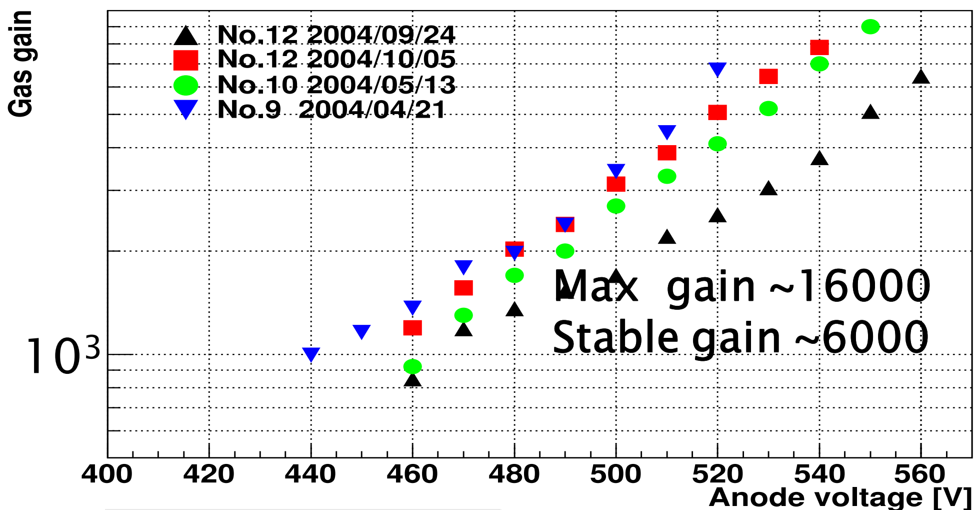


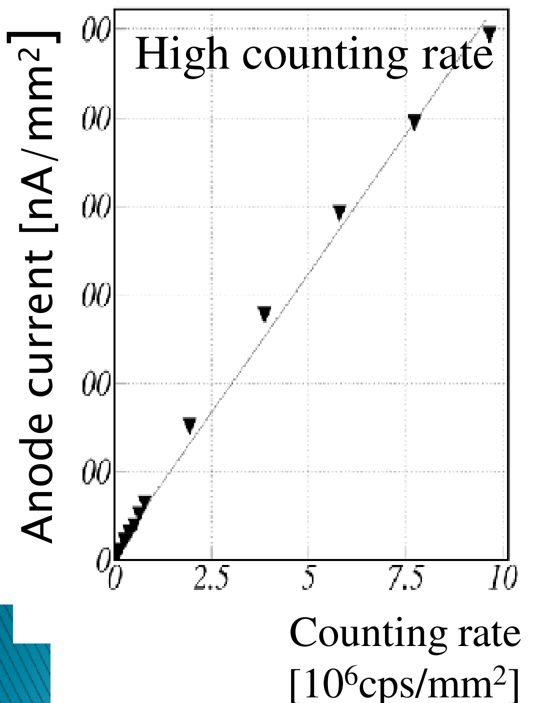
	MSGC	μ−PIC
Maximum gain	1700(with capillary)	50000 (with mesh)
Stable Gain	1000	7000
Long time		>30 days
Area	$10\times10cm^2$	$30\times30cm^2$
Pitch	200μm	400μm (300μm possible)
uniformity (σ)	~35%	4%

- Application: X-ray imaging, γ−camera, Medical RI tracing, etc.

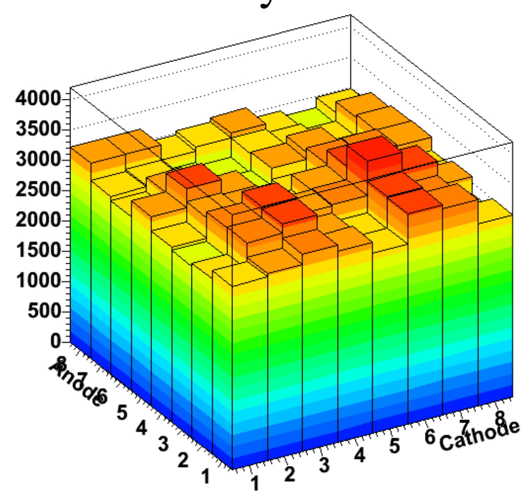
We need more gain and timing resolution for muon trigger

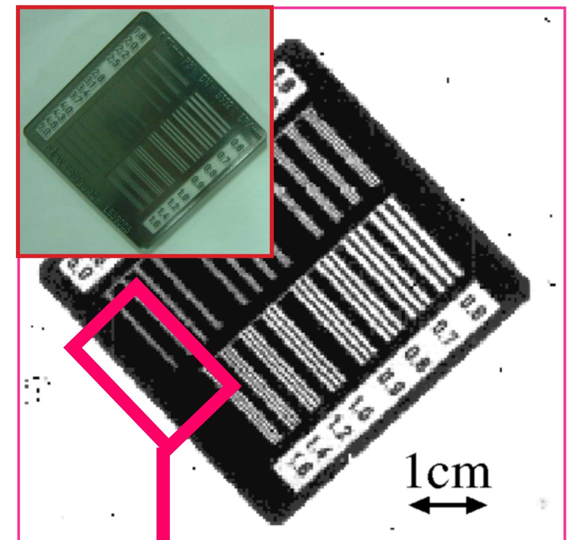
Performances of existance μ–PIC

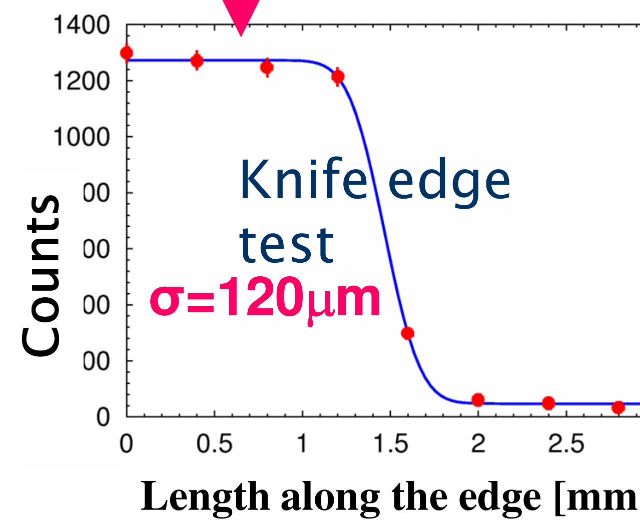




Uniformity of Gain ~4%(σ)



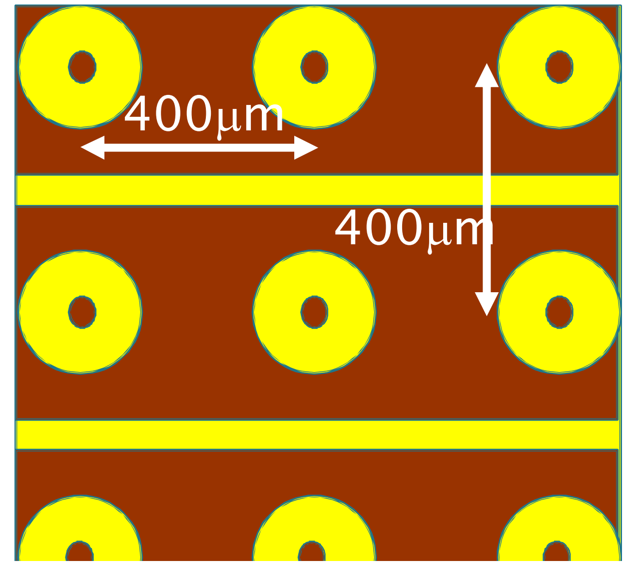


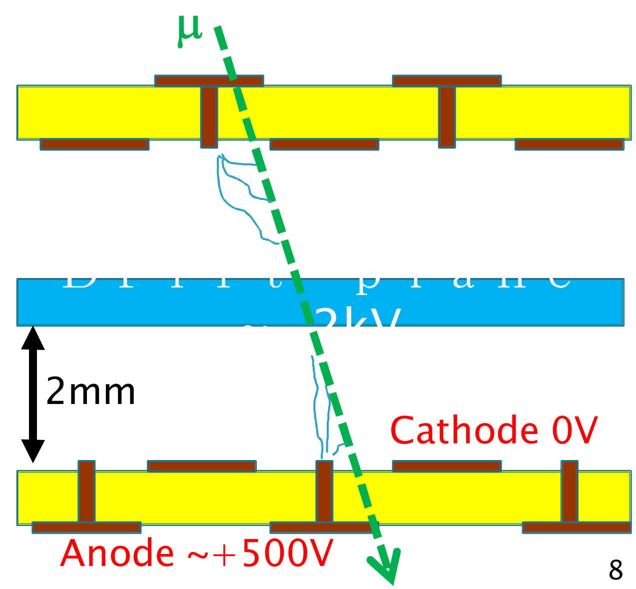


Our plan of ATLAS endcap muon upgrade

New design for ATLAS

- 400μm spacing of readout
  - Proven design
  - Position resolution 400μm/sqrt(12) = 115μm
- Thin Gap structure
  - Gap spacing : 1.5mm – 2mm
  - Fast signal (<25nsec)
  - High gas gain
    - Appling a few kV in drift plane.
- Doublet structure
  - Improving position resolution
    - $\sigma \sim 60\mu m$ with staggering
  - Reduction of non track hit
    - Such as neutron hit
  - Covering the dead space of joint
- μ–PIC will operate as both LVL1 trigger and precision detector

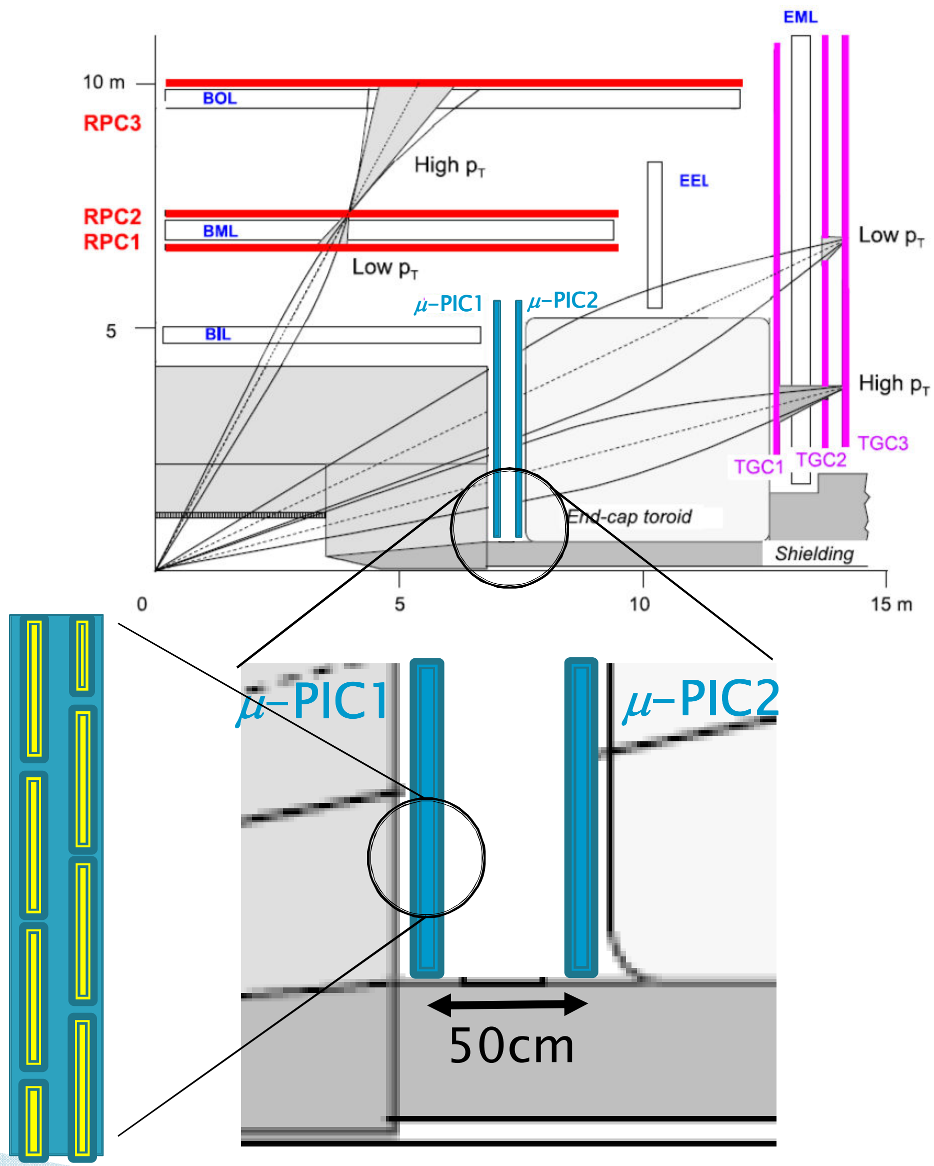




Layout in ATLAS

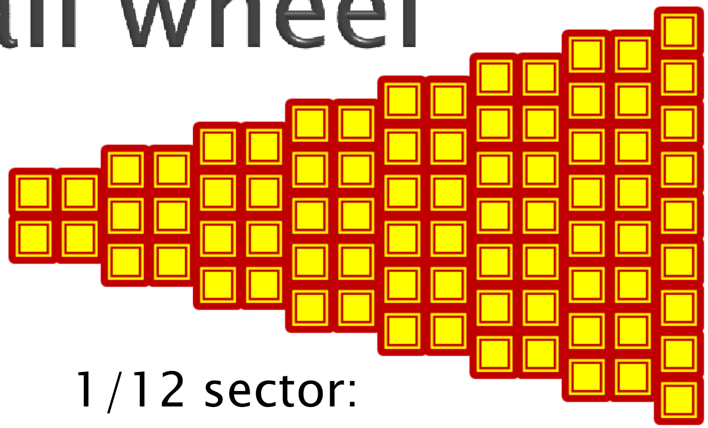
- Detector role
  - Replacement of CSC, FI TGC and EIL MDT
  - Trigger + Precision
- Layout
  - 2 doublets is placed with 50cm spacing

Angler resolution:
0.3mrad
(50cm/115μm)

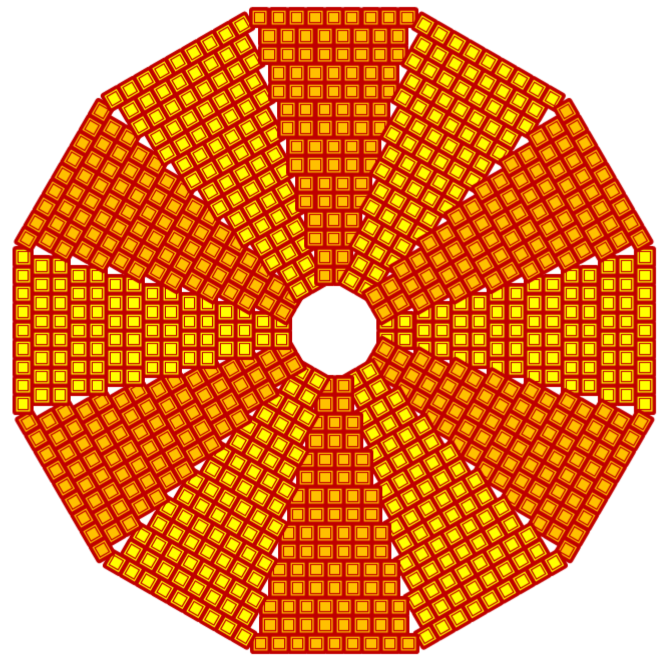


Layout in small wheel

- Detector units layout
  - In the form of tile
  - In case of 30cm X 30cm
    - About 80 units / 1 sector (sector = 1/12 sector)
    - About 1000 units / layer
    - Total 8000 units for 8 layer
  - In case of 10cm X 10cm
    - Total 72,000 units



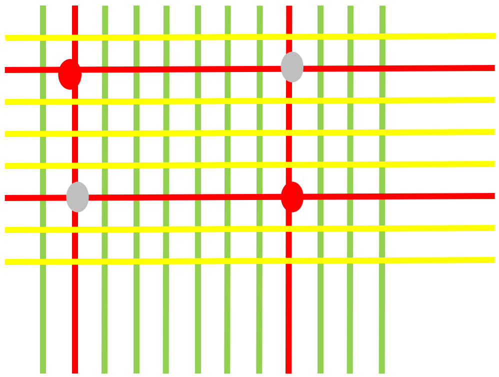
1/12 sector:
using 30cm X 30cm units



Small unit is NOT disadvantage!

- Unit size of μ−PIC is quite small
  - e.g. Size of TGC / MicroMEGAS are 1m X 2m
- But, in SLHC small wheel (5kHz/cm^2 BG), Small size chambers have great advantage.
- Where two dimensional coincidence obtaining from strips, Occupancies and Multiplicities are …

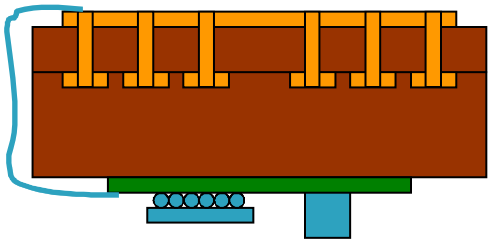
	Area	Hit rate [Hz/unit]	Occu pancy	Multip licity
	10cm x 10cm	5×10^5	1.3%	0.01%
	30cm x 30cm	4.5×10^6	11%	0.6%
	1m x 1m	5×10^7	125%	36%



We don't need to prepare large (a few m^2) detector

Advantages of this plan

- Fine position resolution with 2-dimensional read out
  - 400 μm pitch, σ ~ 120μm
  - σ ~ 60μm with staggering doublet
- Fast signal and small latency
  - Small timing resolution <~10ns with short latency <~20ns
- Both LVL1 trigger and precision measurements
- MUON slope can be measure in LVL1 trigger
  - Angler resolution ~ 0.3mrad with two station with 50cm distance
  - Pt resolution will be improved
  - LVL1 rate is improved several times



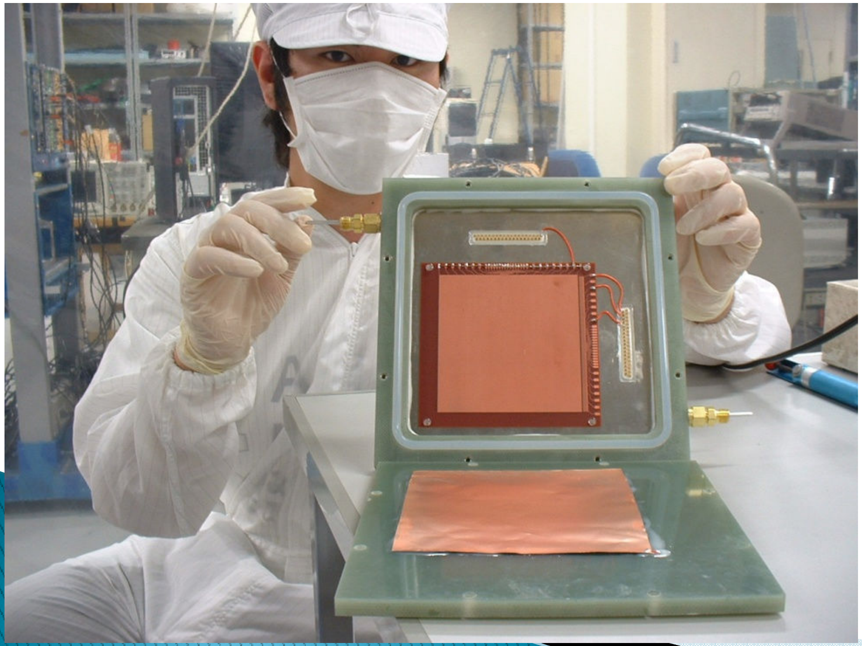
- Lower occupancy using small pad
  - Precision positions are supplied from each unit immediately

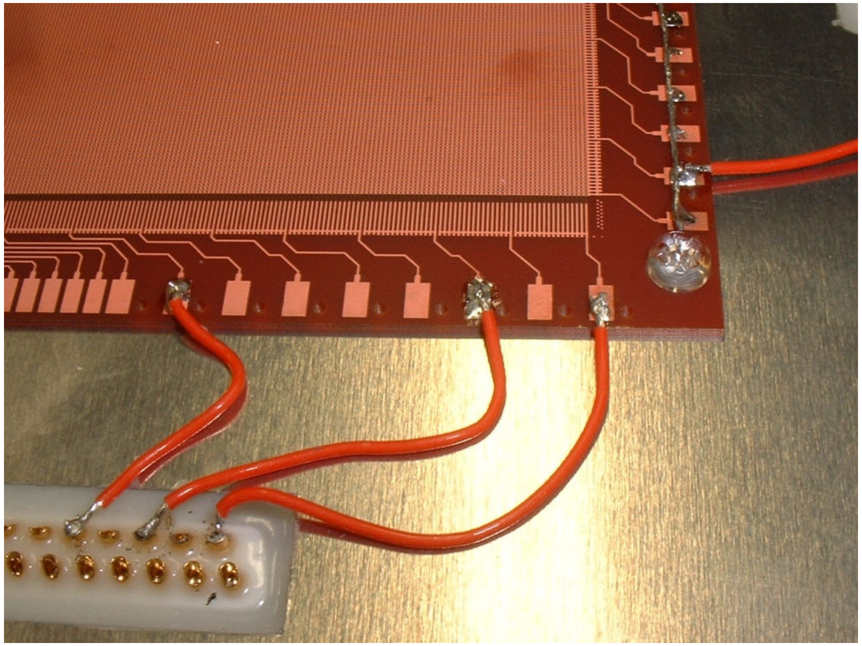
Basic performance tests of prototype thin gap μ-PIC

1. Gain curve
2. Spark probability using α source

Prototype of μ-PIC

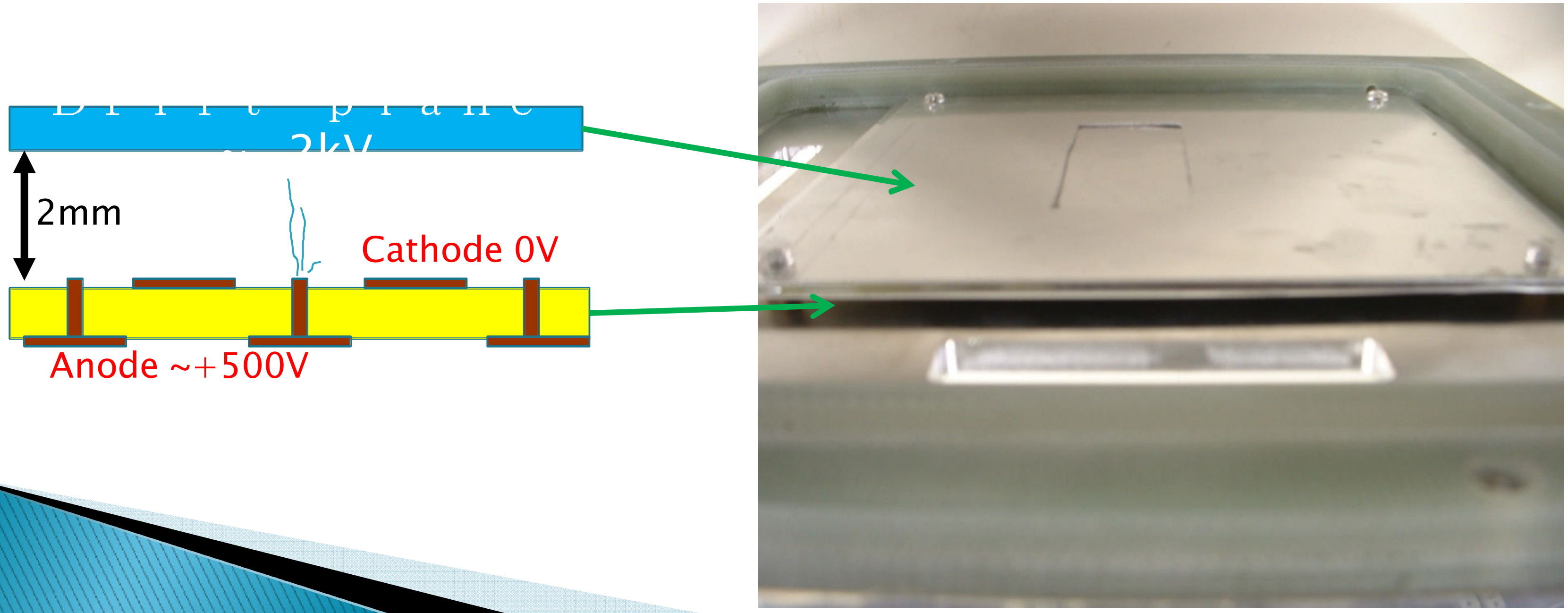
- 10cm x 10cm detection area
- Readout pixel: 400μm x 400μm pitch
- Drift space: 1cm or 2mm
- Gas: Ar 90% + C2H6 10%
- Readout electronics: ATLAS ASD (Analogue out)



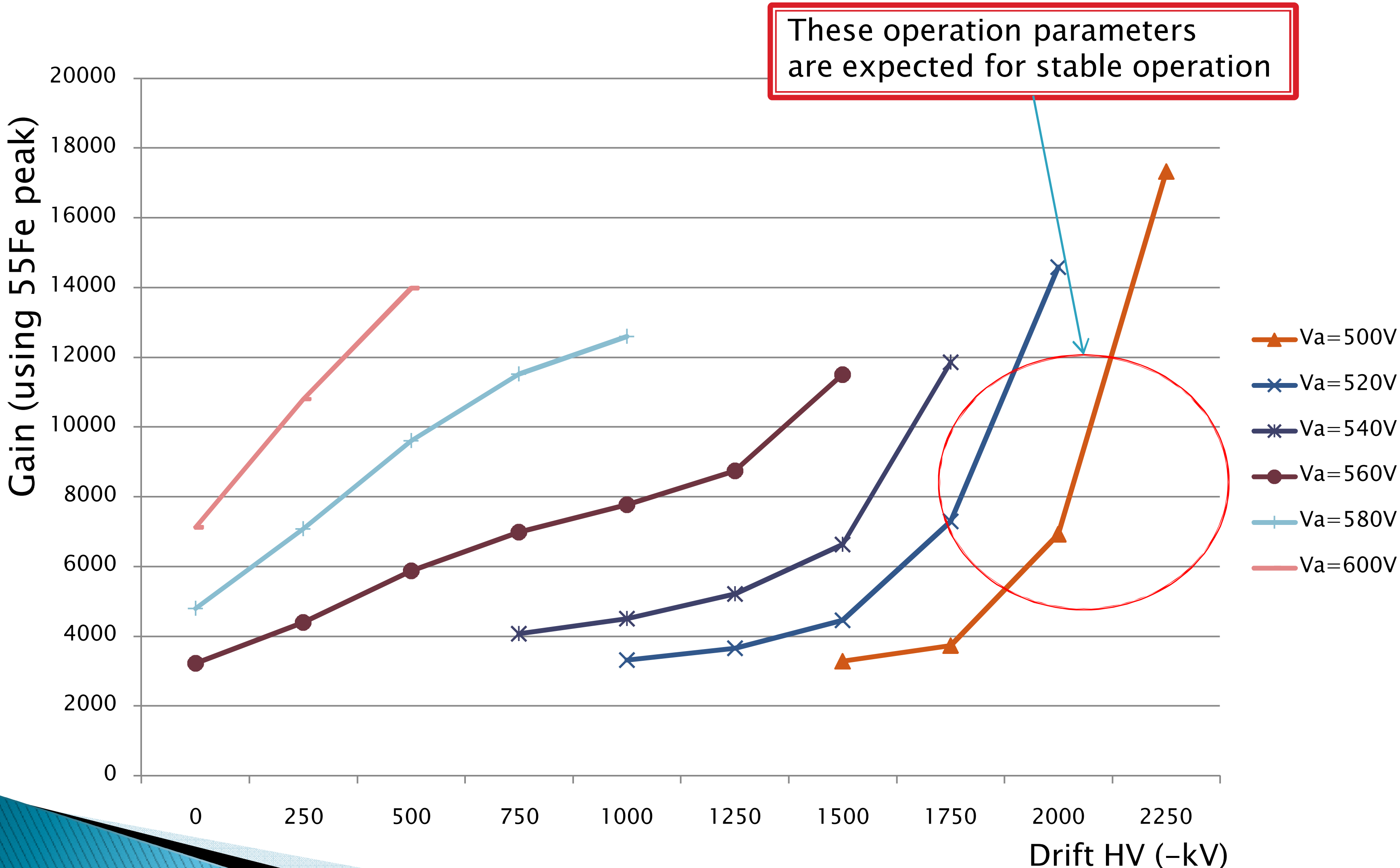


Operation test of thin gap type

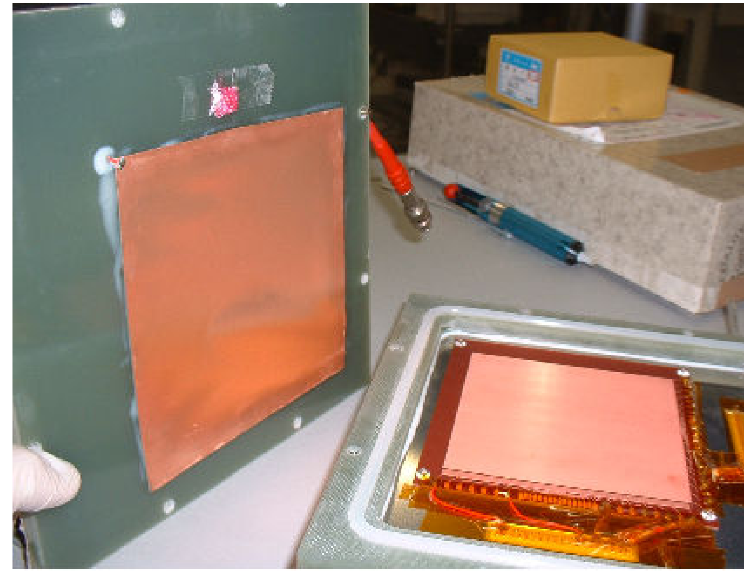
- For ATLAS muon detector
  Detection volume is 1mm ~ 2mm
  - Higher timing resolution (<25nsec)
  - Higher gain with stable operation
    (a few kV of negative HV is applied)



Gain curves for higher drift field



α particle test



- α source inserted inside the chamber
  - Using thorium-contained material
  - A few Bq is estimated
  - Energy of α: 4MeV ~ 9MeV (range: 2.5cm ~ 8.5cm)
  - A source was set beside detection area
- Saturated large pulses were observed (yellow line of the right picture)
- Discharge probabilities (HV over current counting)
  - These discharges are resumed quickly. It doesn't go to continuous discharges.

α test in thin gap μ–PIC

V_anode	V_drift	Est. gain	# of α	# of spark
540	750	4000	200	0
540	1000	4500	200	0
540	1250	5200	70	3
520	1500	4455	200	0
520	1750	7300	200	1 (?)

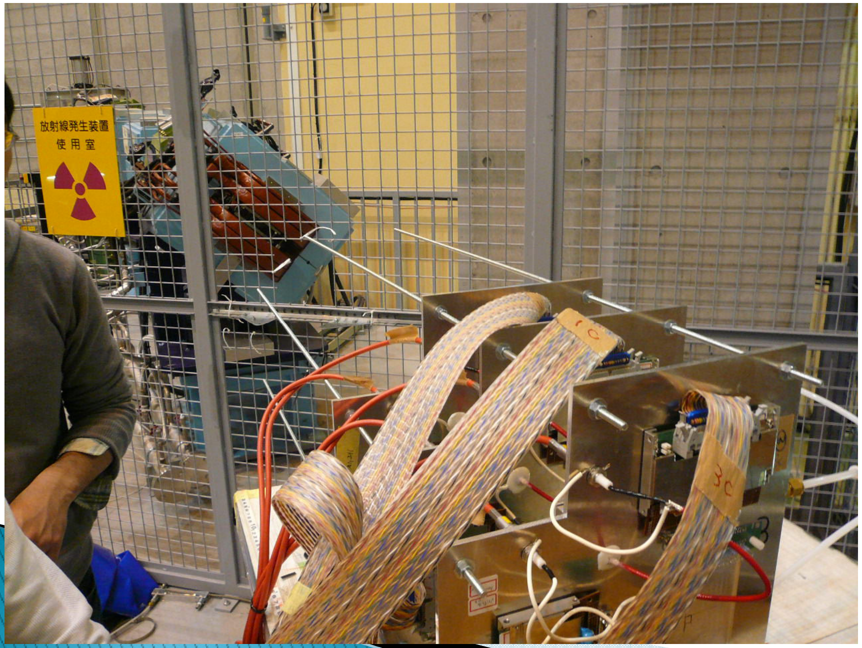
- There are no (or small fraction of) sparks around gain of 5000 using thin gap configuration.
  - Nevertheless using Ar based gas
    (Streamer might be produce in large energy deposit)
- More gas studies will be continued.
  - Aim of stable gain … 10000
- These are very good evidence for stable operation under heavy energy deposit.

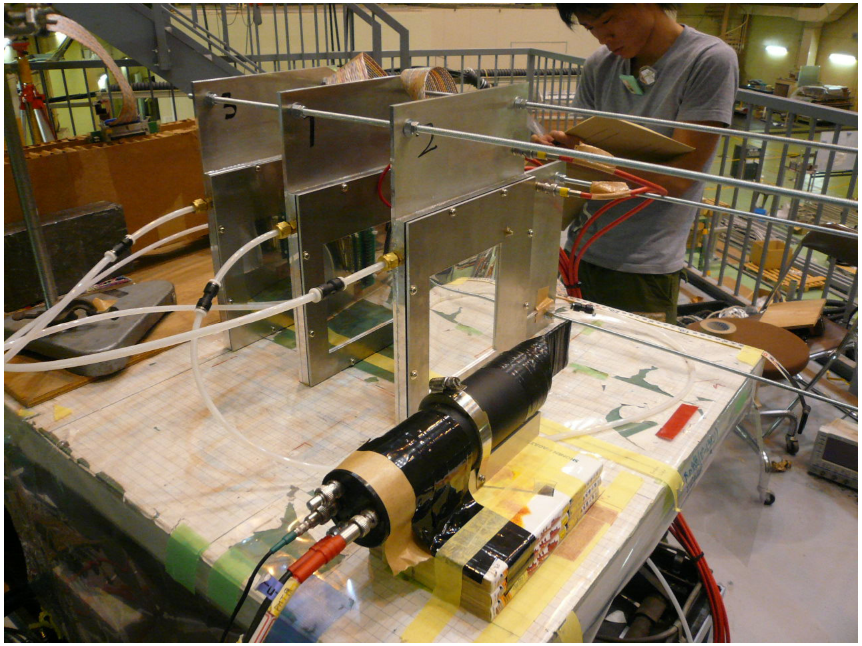
Next step for development

- Beam tests
  - Position/Timing resolution (charged particle)
  - Operation under higher hadronic BG. (neutron)
  - Aging and longtime operation
- Mass production
  - Design suited for mass production
  - Readout electronics
- New design to overcome the discharge
  - Using resistive material

Beam test in KEK Fuji beamline

- From last week, we are preparing the 3 μ-PICs on 2GeV electron beam line.
- Beam intensity is very low, (a few counts/cm2)
  - It will be used only for checking timing and position resolutions.
- These tests will be done in next week!





Mass Production

- μ-PIC sensor part
  - Commercial available using PCB mass production technique
  - One company said, it is possible to make μ-PIC structure less than 12kCHF/m^2.
- Packaging/assembling/readout
  - Under consideration
  - Role of front-end electronics will be light due to higher operation gain (~10000).

Design to overcome discharges

- We want MIP readout (gain needs ~10000), but there are many neutron BG.
- To reduce discharges,
  - Cathodes are surrounded by resistive sheet
- We need Rui's help to make this structure.

Conclusion

- Micro Pixel Chamber (μ-PIC) is proposed as detector for phase-II ATLAS muon upgrade.
  - Trigger + Precision at inner station
  - Production cost is not so much high
    - <12kCHF / m^2 (Detector board + ASIC connection)

- Prototype was made and tested
  - Gain curves → >10000 attained stably
  - Discharge probabilities using α particle are measured
  - Electron beam test (2GeV) is ongoing
- Beam tests are scheduled for more advanced tests
- More advices and helps are need from RD51!

Welcome you to join our developments