CYGNUS GAS WG report

2017 Jun 15th
CYGNUS 2017 @Xichang, Sichuan, China

Kentaro Miuchi

Activity Summary

- 8 TV meetings since September 2016
- core members

  New Mexico, Kobe, Frascati, Wellesley, Sheffield, Hawaii

- main topic: SF6

  gas amplification, pressure
  fiducialization (position resolution)
  tracking, readout
  gamma rejection
  radon removal

for details

https://indico.phys.hawaii.edu/categoryDisplay.py?categId=34

HISTORY

Two years ago（CYGNUS 2015）: “SF6 shock”

THE UNIVERSITY of NEW MEXICO

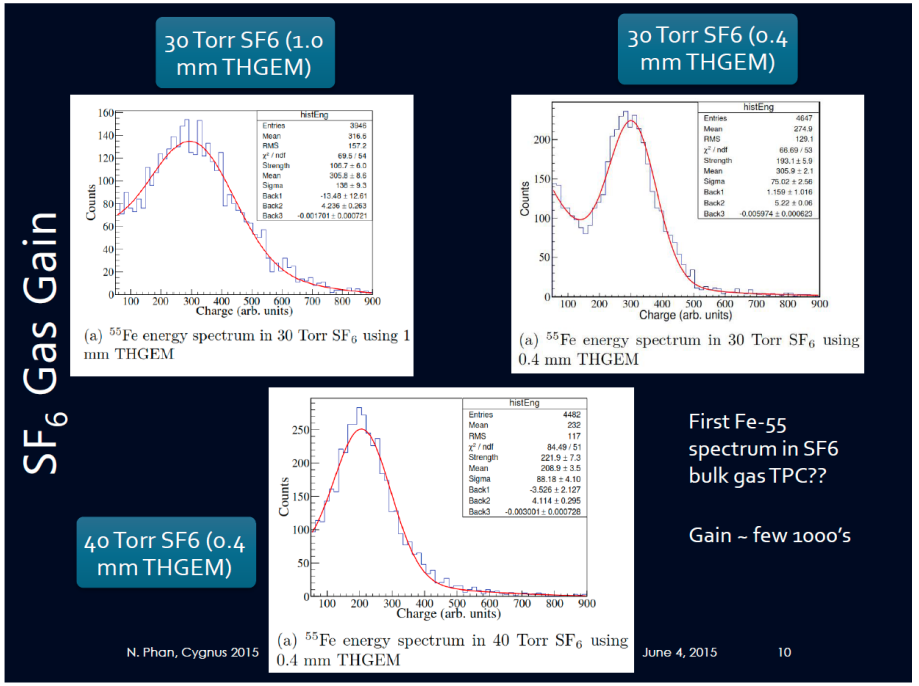
First Studies of SF_6 in a TPC

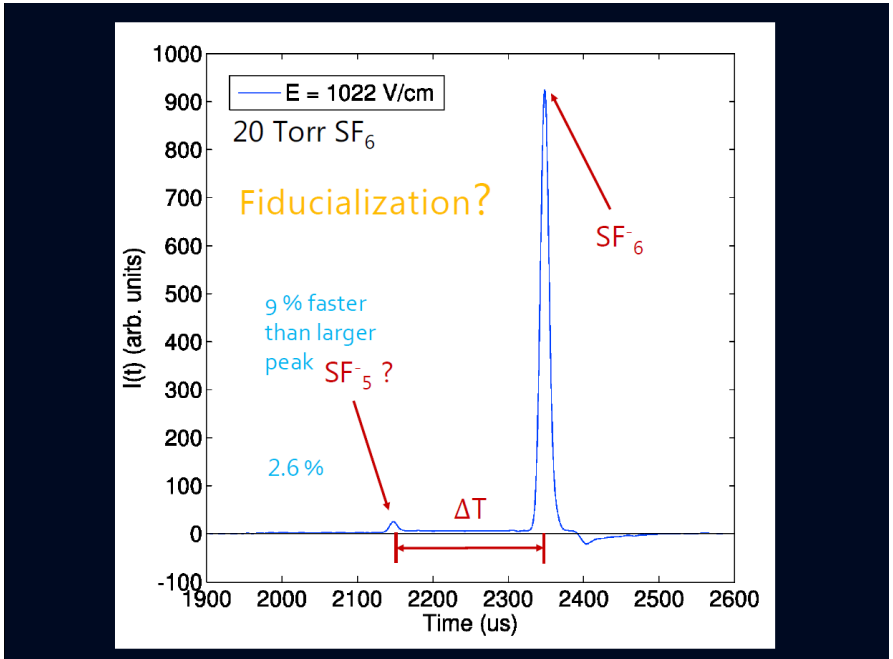
NGUYEN PHAN, ERIC LEE
UNIVERSITY OF NEW MEXICO

2017 JINST 12 P02012

With “Insulating gas” SF6,

- gas amplification with thick GEM
- minority peaks





⇒ SF6 rush

T_0 + 4months (MPGD 2015)

Study of Negative-Ion TPC using μ-PIC
for Directional Dark Matter search

Tomonori Ikeda (Kobe Univ.)

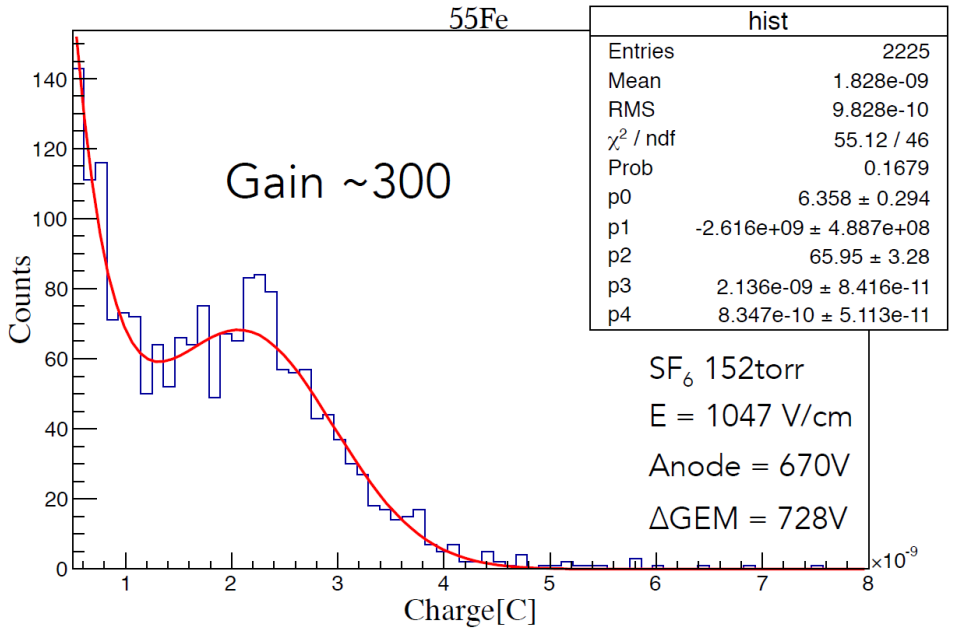
Kentaro, Miuch (Kobe Univ.)
DANIEL, Snowden-ifft (Occidental College)
JEAN-LUC, Gauvreau (Occidental College)
+NEWAGE Group

1. DM Experiments with MPGD
2. NEWAGE
3. Motivation
4. Measurement
5. Summary

to appear in EPJ Web of conference

- gas gain with μ-PIC + GEM system

SF_6 Gas Gain



- Total gas gain is about 300.
- When we improve the amplifier , this gas gain is sufficient. Then minority peak will be appeared.

⇒ tracking study @ Kobe

T_0 + 12 months (IDM 2016)

This project has been funded by the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 657751

Started on 4 May 2015

Identification of Dark Matter 2016
Cutlers' Hall, Sheffield, UK

NITEC
a Negative Ion Time Expansion Chamber for directional Dark Matter searches

Elisabetta Baracchini
Istituto Nazionale di Fisica Nucleare INFN, Laboratori di Frascati

In collaboration with G. Bencivenni, G. Cavoto, G. Mazzitelli, F. Murtas, F. Renga, D. Tagnani

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- First tests of the small prototype with SF_6 mixtures
  - 450 MeV electron beam test with $Ar:CO_2:SF_6$
  - ^{55}Fe data with pure SF_6

May 2016

- triple GEM + TIMEPIX
- gain curves
- tracking indications
- minority carrier indications

NITEC negative ion operation $Ar:CO_2:SF_6$

Negative ion operation with $Ar:CO_2:SF_6$ mixture 52:23:25 @ 370 Torr

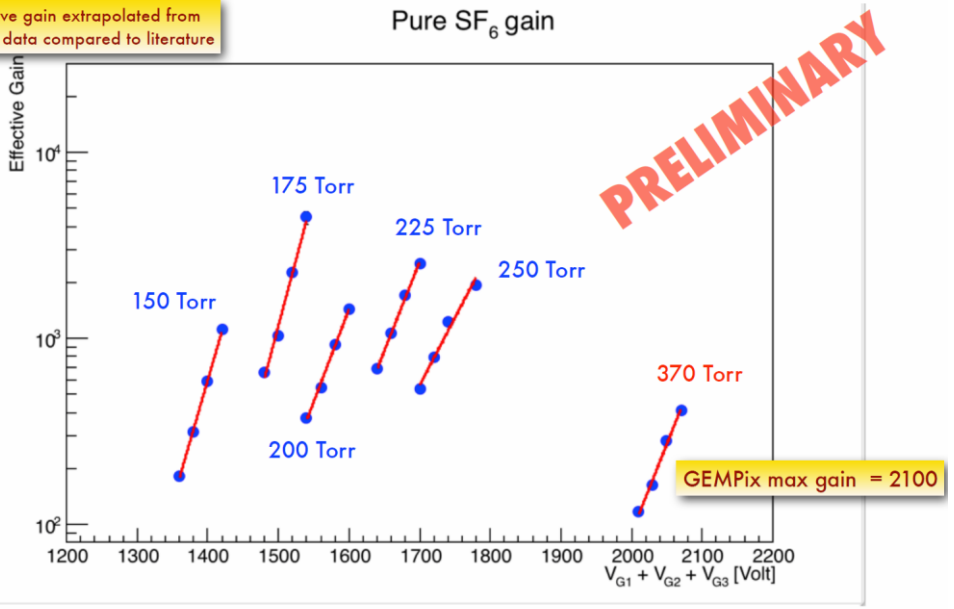
electron drift clusters in **$Ar:CO_2$ @ 740 Torr**

- Encountered several operating issues for the TPC due to the low pressure regime
  - Field cage built by Nikhef before the NITEC start for proton tomography and to be operated at atmospheric pressure
- Pressure and drift field strongly limited by this
  - Data taken at 370 Torr with ~0.3-0.6 kV/cm drift field
- Thanks to this experience, we are carefully designing the large prototype and performing preliminary tests on each component in order to solve all these issues

450 MeV electron beam data @ BTF

NITEC gain measurement in pure SF_6

Effective gain extrapolated from $Ar:CO_2$ data compared to literature



T_0 + 15 months (IDM 2016)

SF6 discussion

Thursday, 8 September 2016 from **19:00** to **21:00** (GMT)
at **phone**

first gas WG meeting

Manage

Thursday, 8 September 2016

19:00 - 19:20 SF6 work at NMU *20'*
Speaker: Dinesh Loomba
Material: **Slides**

19:20 - 19:40 SF6 work at Frascatti *20'*
Speaker: Elisabetta Baracchini
Material: **Slides**

19:40 - 20:00 SF6 work in Hawaii *20'*
Speaker: Sven Thorpe
Material: **Slides**

20:00 - 20:20 SF6 work in Kobe *20'*
Speaker: Kentaro Miuchi
Material: **Slides**

20:20 - 21:00 Discussion *40'*
Material: **Slides**

T_0 + 19 months

Update from Wellesley

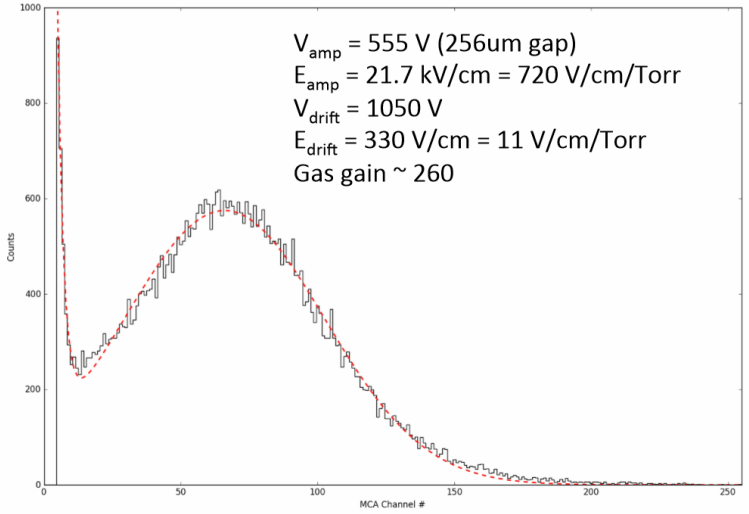
SF_6 + Micromegas & Multi-channel DAQ

James Battat & Catherine Nicoloff

2017 January 18

- gas gain with micromegas

First believable spectrum (30 Torr)



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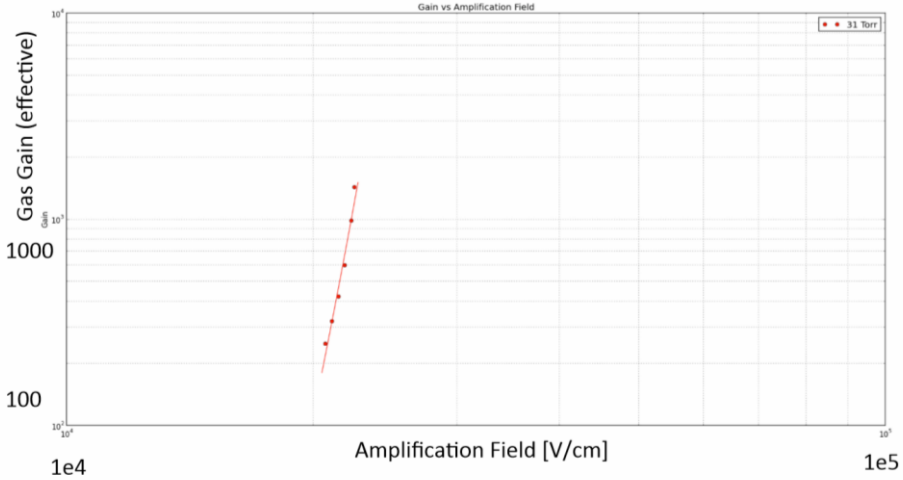
Gas gain vs. amplification, 30 Torr

Fixed V_{drift} (oops) = 1200V. Drift field range: 420 to 450 V/cm



V_{amp} range: 530 to 575V

E_{amp}/P range: 690 to 750 V/cm/Torr

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T_0 + 22 months

The University Of Sheffield.

Sheffield THGEM Update

Andrew Scarff
University of Sheffield

Cygnus Gas Meeting - 20 Apr 17

- gas gain with thick GEM
- radon removal

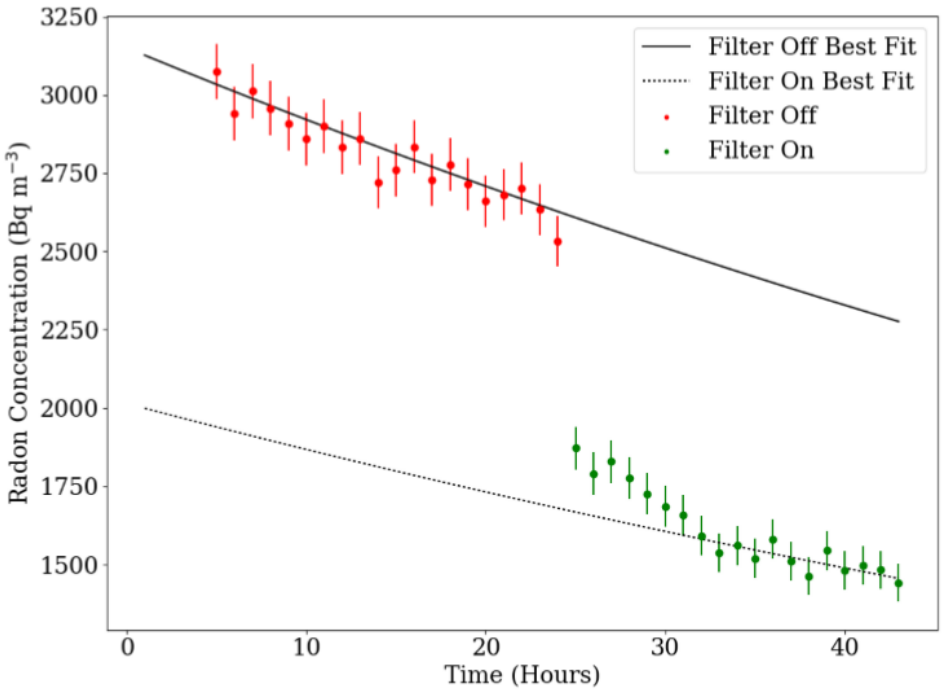
SF_6 Measurements

- Initial measurements using average pulse height feature on scope.
- Compared to values from pulse put through preamp test input
- Preliminary* gain estimate of ~6000 in 30 and 40 Torr
- DAQ issues - hopefully will get more data next week.

By Robert Renz Marcelo Gregorio mr.rgregorio@live.com

Radon Filtration From SF_6 Gas Using Molecular Sieves

Procedure for Testing Radon Filtration



State of the Art

Activity Summary

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- core members

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  gas amplification, pressure
  fiducialization (position resolution)
  tracking, readout
  gamma rejection
  radon ficteration

for details

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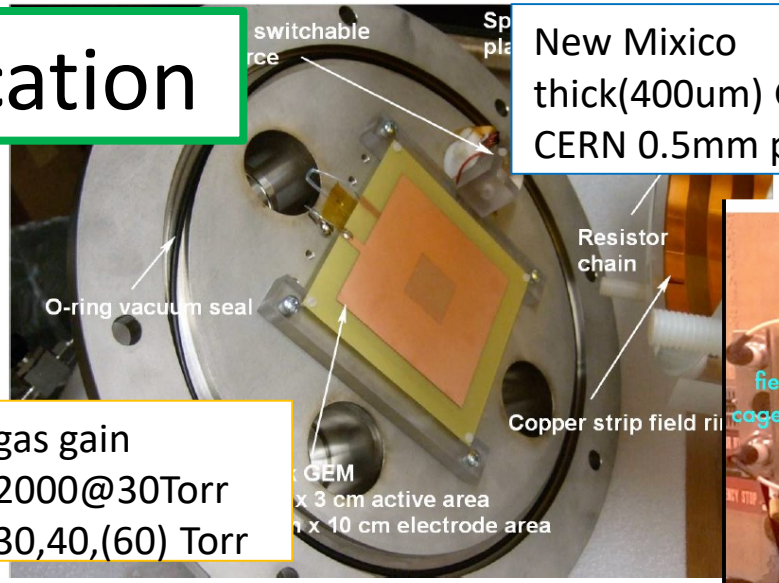
Gas Amplification

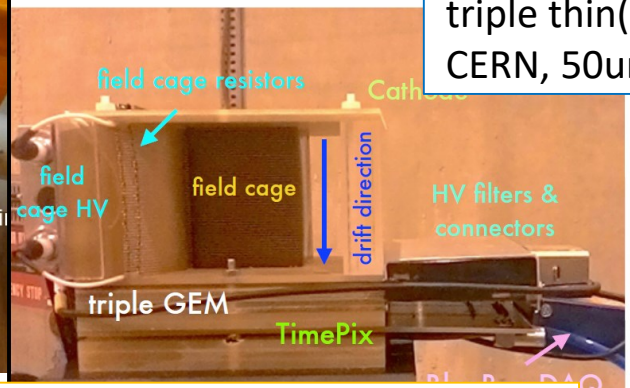
- MPGD varieties

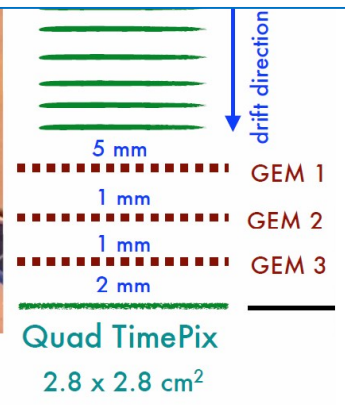
New Mixico
thick(400um) GEM (3 × 3cm^2)
CERN 0.5mm pitch, Φ0.3mm



gas gain
2000@30Torr
30,40,(60) Torr

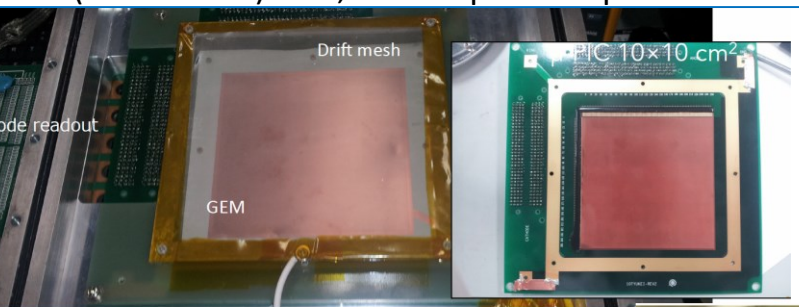
Frascati
triple thin(50um) GEM (3 × 3cm
CERN, 50um pitch, Φ30um

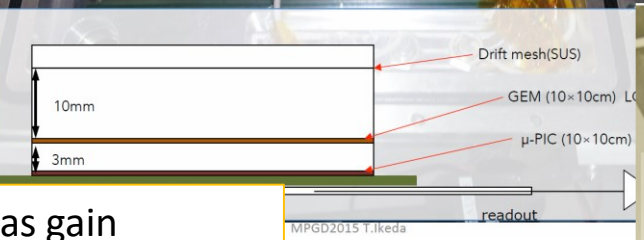




gas gain
5000@ 175Torr, 2000@370Torr

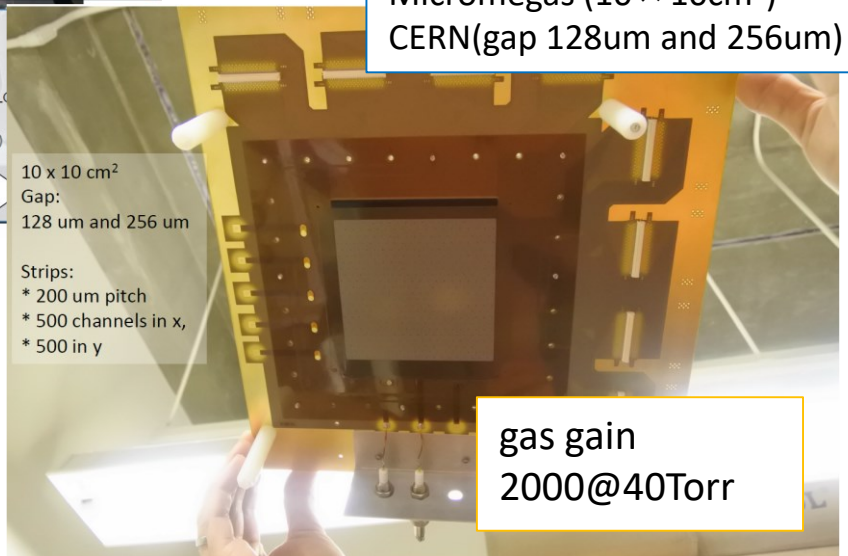
obe
in(100um) GEM (10 × 10cm^2) Scienergy, 140um pitch, Φ70um
u-PIC(10 × 10cm^2) DNP, 400um pitch strip readout





as gain
000@20Torr

Wellesley
Micromegas (10 × 10cm^2)
CERN(gap 128um and 256um)



gas gain
2000@40Torr

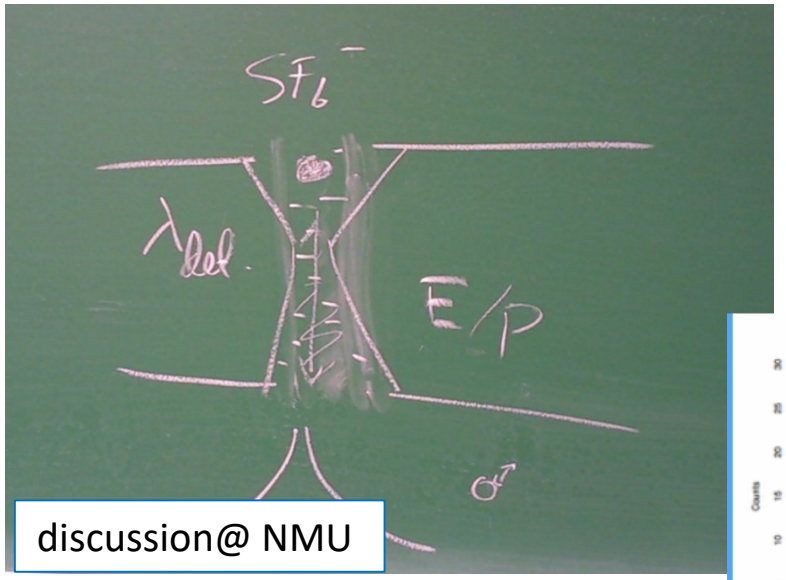
Sheffield
thick(400um) GEM(50 × 50cm^2)
UK , 0.5 um pith Φ0.3um

gas gain
6000@30,40Tor
r

Gas Amplification: what's next?

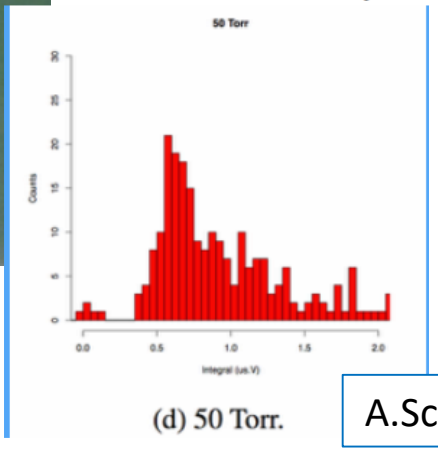
- current tendency: thicker GEM for lower pressure SF6
- Systematic comparison among MPGD varieties.
  (GEM thickness（50, 100, 400um）, uPIC, micromegas(120, 128,256um) ⊕ filed)
  Understanding the amplification process
- Key process: electron capture, detachment, amplification

2017 JINST 12 P02012



discussion@ NMU

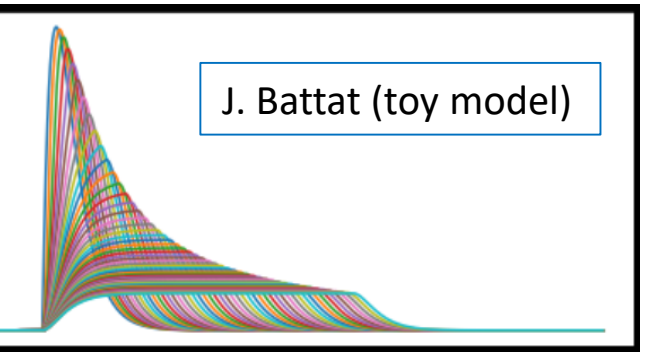
$$SF_6 + e^- \rightarrow SF_6^{-*} \quad \text{(attachment, metastable)} \quad (3.1)$$
$$SF_6^{-*} \rightarrow SF_6 + e^- \quad \text{(auto-detachment)} \quad (3.2)$$
$$SF_6^{-*} + SF_6 \rightarrow SF_6^- + SF_6 \quad \text{(collisional stabilization)} \quad (3.3)$$
$$SF_6^{-*} \rightarrow SF_5^- + F \quad \text{(auto-dissociation)} \quad (3.4)$$



(d) 50 Torr.

A.Scarff (measurement)

⇐ electric field, pressure, temperature…



J. Battat (toy model)

- not implemented in current Garfield++
- implement these process in Garfield++ （Kobe and?）

⇒ help to optimize the geometry, electric field…

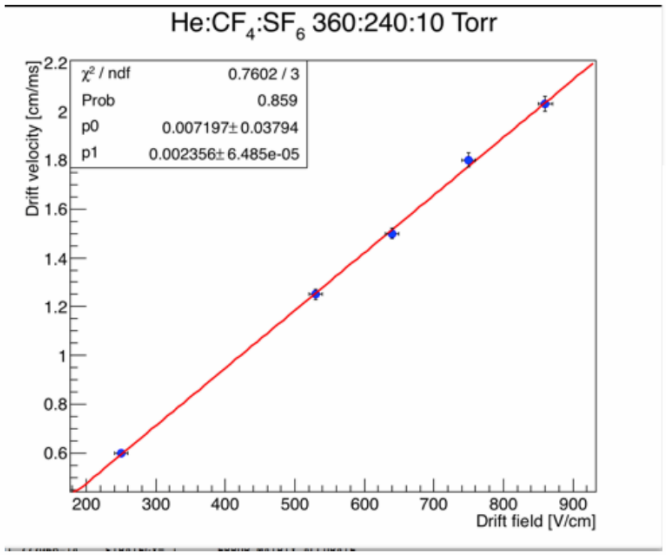
Higher pressure operation

- motivation: normal pressure operation helps the vessel structure (a lot)

Frascati
Ev=300V/cm
220Torr pure SF6

Baracchini CAASTRO 2017

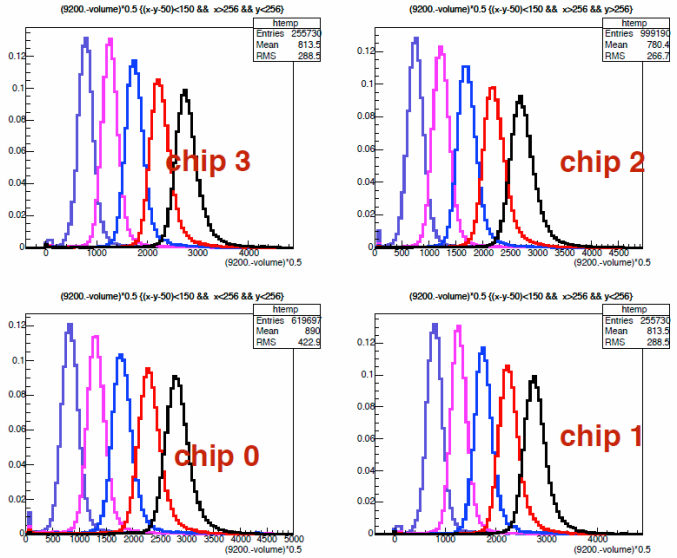
He:CF_4:SF_6 360:240:10 Torr TOA analysis



860 V/cm

```
vdrift chip 0 is 0.0020193 +/- 6.38648e-05
vdrift chip 1 is 0.00203158 +/- 6.42549e-05
vdrift chip 2 is 0.00205442 +/- 6.49827e-05
vdrift chip 3 is 0.00203158 +/- 6.42549e-05
```

Drift times



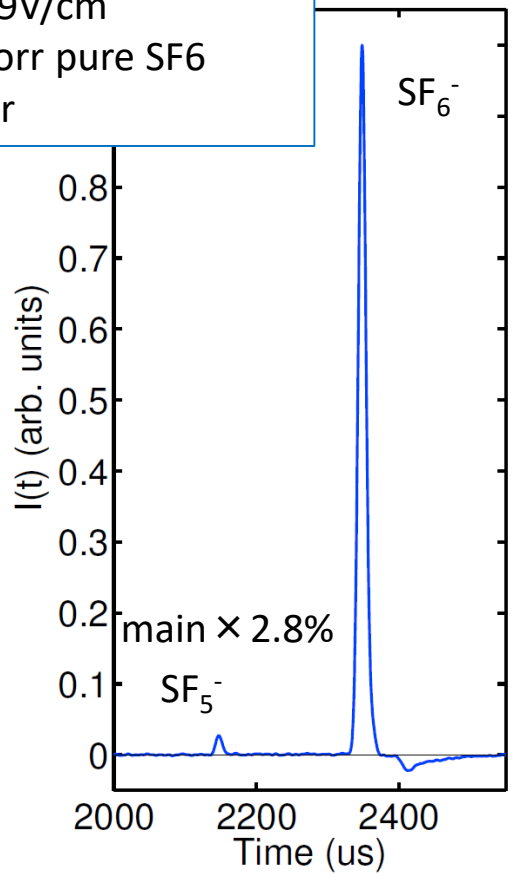
Nearly atmospheric operation!

demonstrated

Fiducialization

- feasible?

New Mixico
1029V/cm
30Torr pure SF6
laser

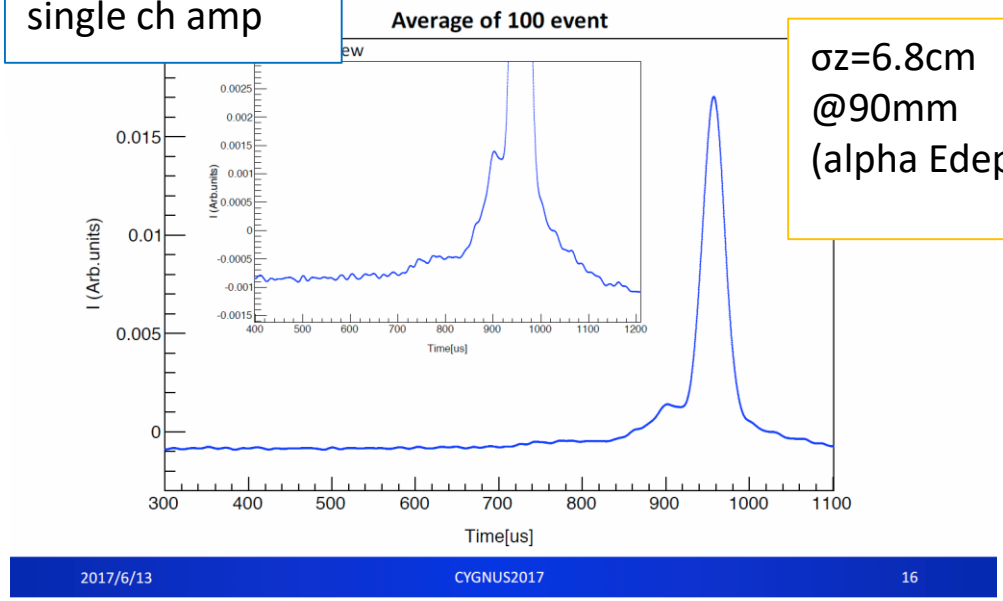


2017 JINST 12 P02012

σz=7mm@z=58cm
(by laser ～*keVee)

Kobe
Ev＝550V/cm
20Torr pure SF6
single ch amp

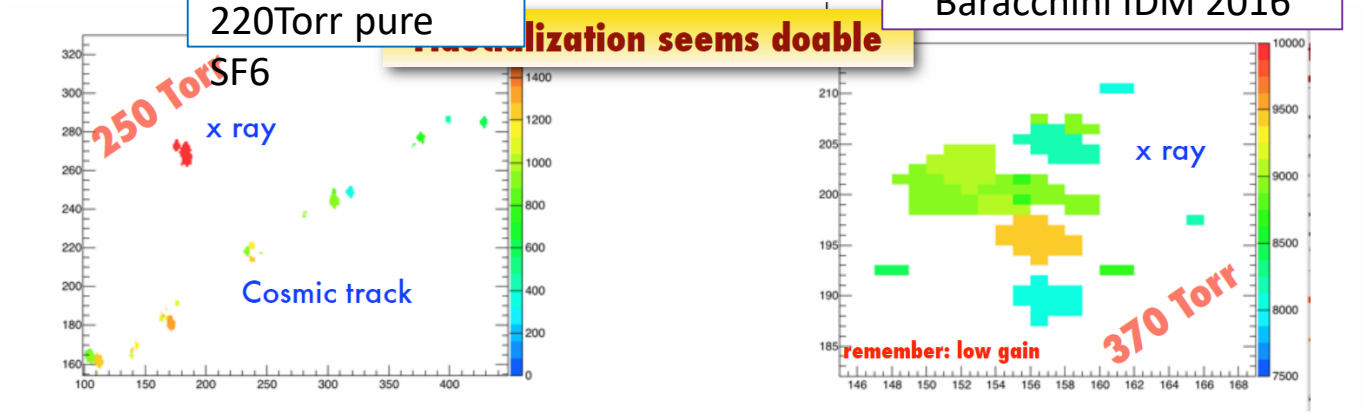
T.Ikeda CYGNUS 2017



σz=6.8cm
@90mm
(alpha Edep=40 keV)

Frascati
Ev＝300V/cm
220Torr pure
SF6

Baracchini IDM 2016



Indication

- Yes, still some more studies are necessary
（especially for low energy）

Tracking (multi-channel readout)

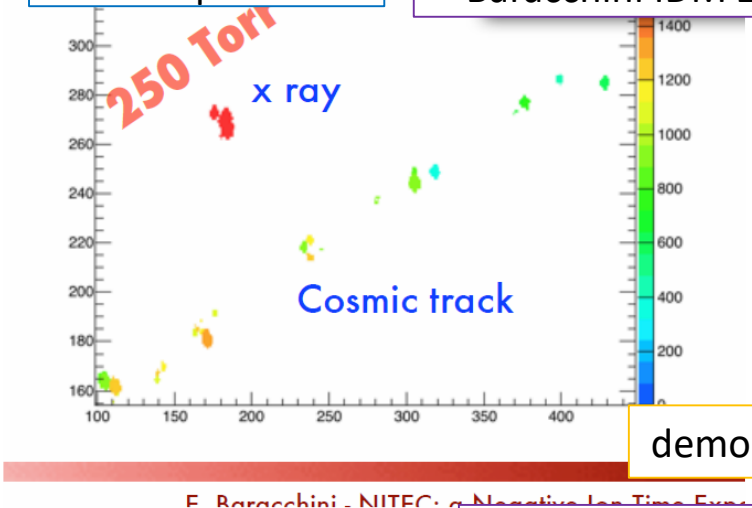
Kobe
20Torr pure SF6

T.Ikeda CYGNUS 2017

Direction Sensitive

Frascati
250Torr pure SF6

Baracchini IDM 2016

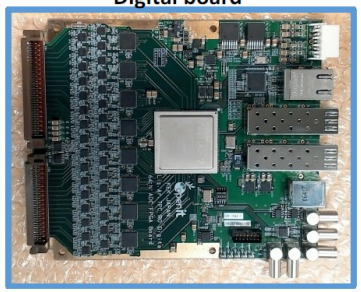


demonstrated

- Drift velocity is very slow, O(μs) as like electron in liquid medium
- ASIC chip developed by KEK and Iwate Univ. for Liquid Ar TPC

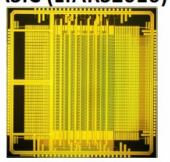
Analog board

Digital board



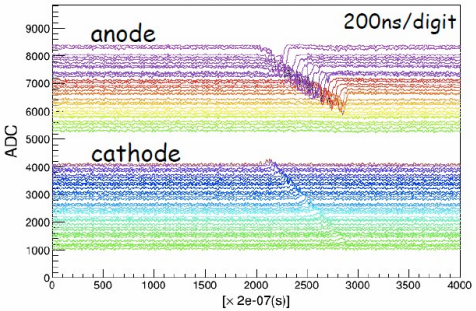
- 12bits FADC
- 4000 sampling (20MHz)
- 64ch on one board

ASIC (LTARS2016)



- 32ch in a chip
- Conversion gain : ~9.0mV/fC
- Shaping time : 1us
- Max input charge : ~70fC
- ENC 2000@300pF

α wave form data

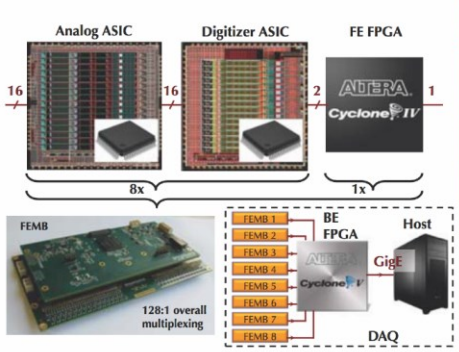


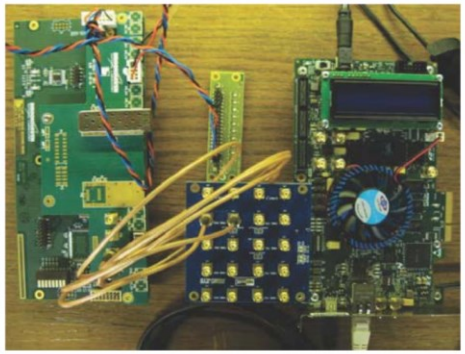
Wellesley

Chen Yang et al., IEEE HPEC 2017 conference

Brookhaven National Lab DAQ

Developed or LAr, but works with NITPC





At BNL, help from:
Drs. Hucheng Chen and Gianluigi de Geronimo and Jack Fried

Custom FPGA development (Back-end) by Wellesley & Boston University (Prof. Martin Herbordt and grad student Ethan Yang).

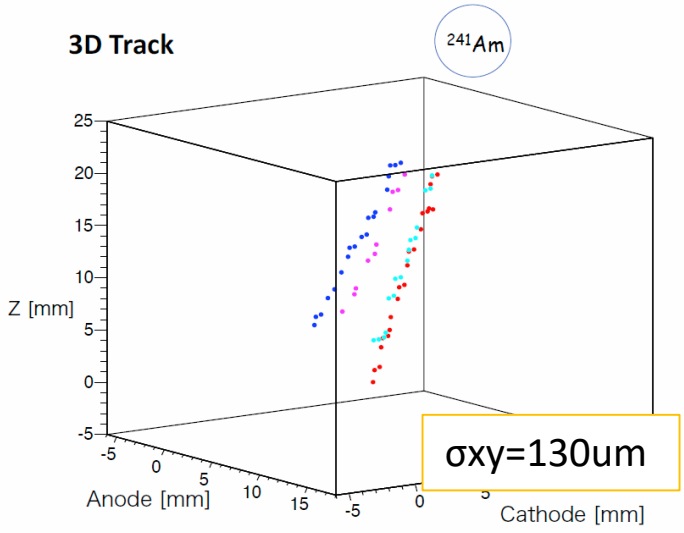
Have demonstrated circular buffer with 31 Gbps throughput.

Challenge: BNL Front-End FPGA code is undocumented...

planned

2017/6/13

3D Track



σxy=130um

- Tracking was suceed
- 2D position resolution : 130μm(RMS)

Radon filteration

Shefield

Radon Filtration from SF_6

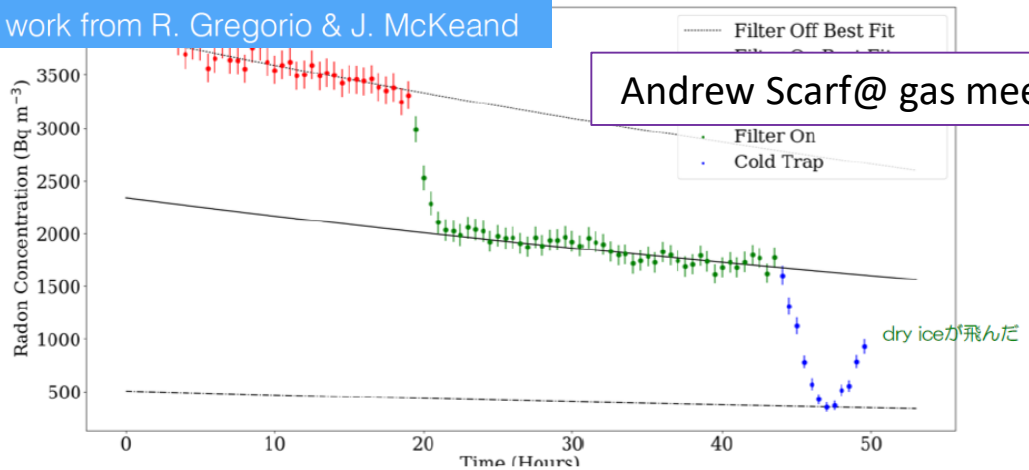
Andrew Scarff

Presented work from R. Gregorio & J. McKeand

Molecular Sieve	Molecular Formula	Pore Size (Angstroms)	Approx. Bead Size (mm)
3A	$0.6K_2O \cdot 0.4Na_2O \cdot Al_2O_3$	3	2
4A	$Na_2O \cdot Al_2O_3 \cdot 2.0SiO_2$	4	2
5A	$0.80CaO \cdot 0.20Na_2O \cdot Al_2O_3 \cdot SiO_2$	5	4
13X	$Na_2O \cdot Al_2O_3 \cdot 2.8SiO_2$	10	4

Table 3.1: Properties and specifications of the molecular sieves that were examined.

Andrew Scarf@ gas meeting



Data	Extrapolated N_0 (Bq m^{-3})	Total Radon Concentration Reduction
Filter Off	3874.8±13.1	-
Filter On	2356.9±10.0	40%
Cold Trap Lowest	504.6	87%

possible to filter out radon from SF6

Conclusion: relatively simple recirculation can remove Rn from SF_6 without absorbing SF_6

Gamma rejection

-

For SF6, yet to be done.

Gamma rejection

- very good (O(1e-8)) rejection is required

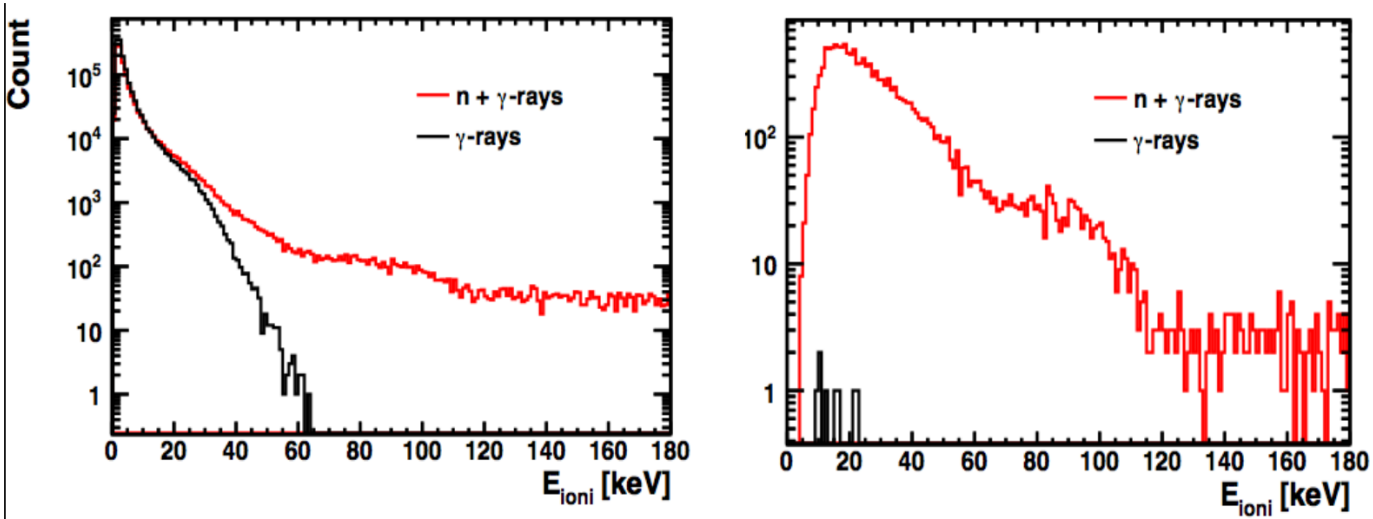
Sheffield

gamma rejection $>1.98\times10^{-7}$ (90% C.L.)

30-10-1 CS_2-CF_4-O_2 <2e-7@30keV

NEWAGE 2e-5@50-100keV

MIMAC



$N_{acpt}/N_{tot} = 1.1 \times 10^{-5}$ electron integrated rejection

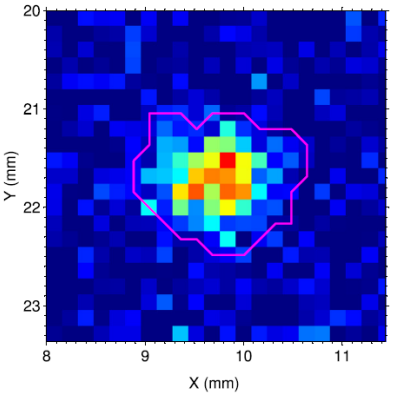
$70\%\,CF_4 + 28\%\,CHF_3 + 2\%\,C_4H_{10}$ @ 50 mbar 1e-5@10-20keV

Gamma rejection

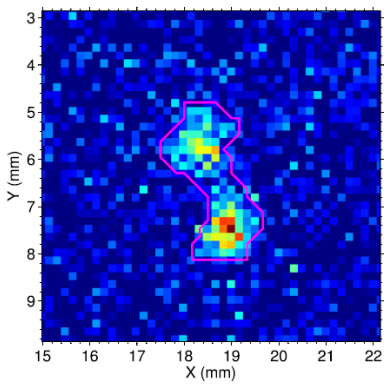
New Mexico

100Torr CF4

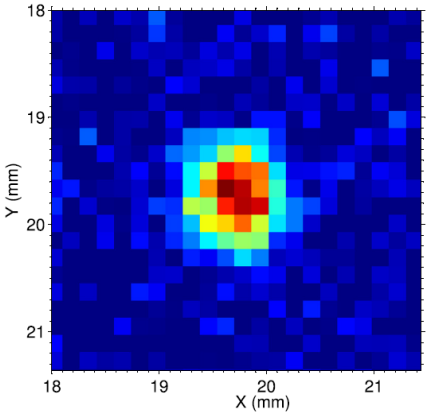
N.S. Phan et al./Astroparticle Physics 84 (2016) 82–96



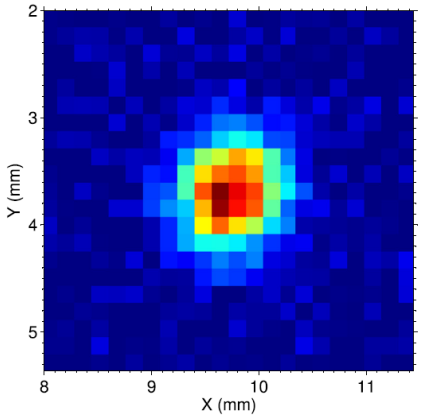
(a) 9 keVee electron recoil



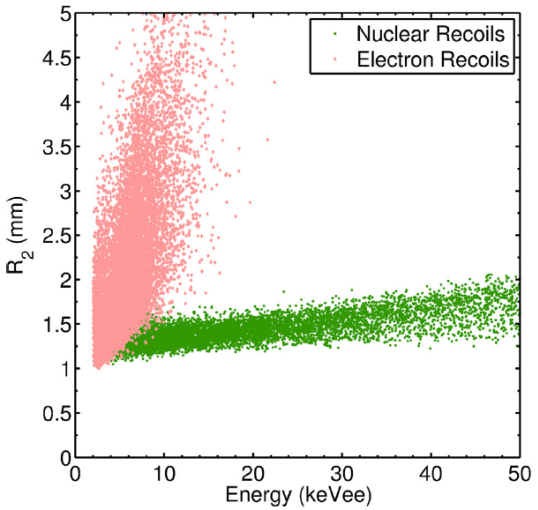
(b) 13 keVee electron recoil



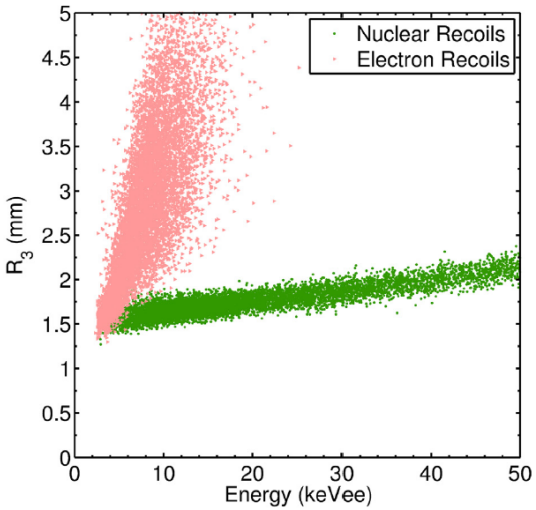
(a) 28 keVr (~ 13 keVee) nuclear recoil



(b) 53 keVr (~ 28 keVee) nuclear recoil



(a) 2D Reconstruction



(b) 3D Reconstruction

Fig. 14. Simulation of range vs. energy for fluorine and electron recoils in 100 Torr CF_4 for 2D (a) and 3D (b) track reconstructions. In the 2D reconstruction (a), events from the electron band leak into the nuclear band up to energies of ~9 keVee. But in the 3D reconstruction (b) events from the two bands are separable down to energies of ~6 keVee.

- down to 10keV promising
- below 10keV, needs more study

Co-working

- On-going activities

US-Japan

U.S.-Japan Common Contents (in English)

U.S.-Japan Science and Technology Cooperation Program in High Energy Physics
Proposal Application form

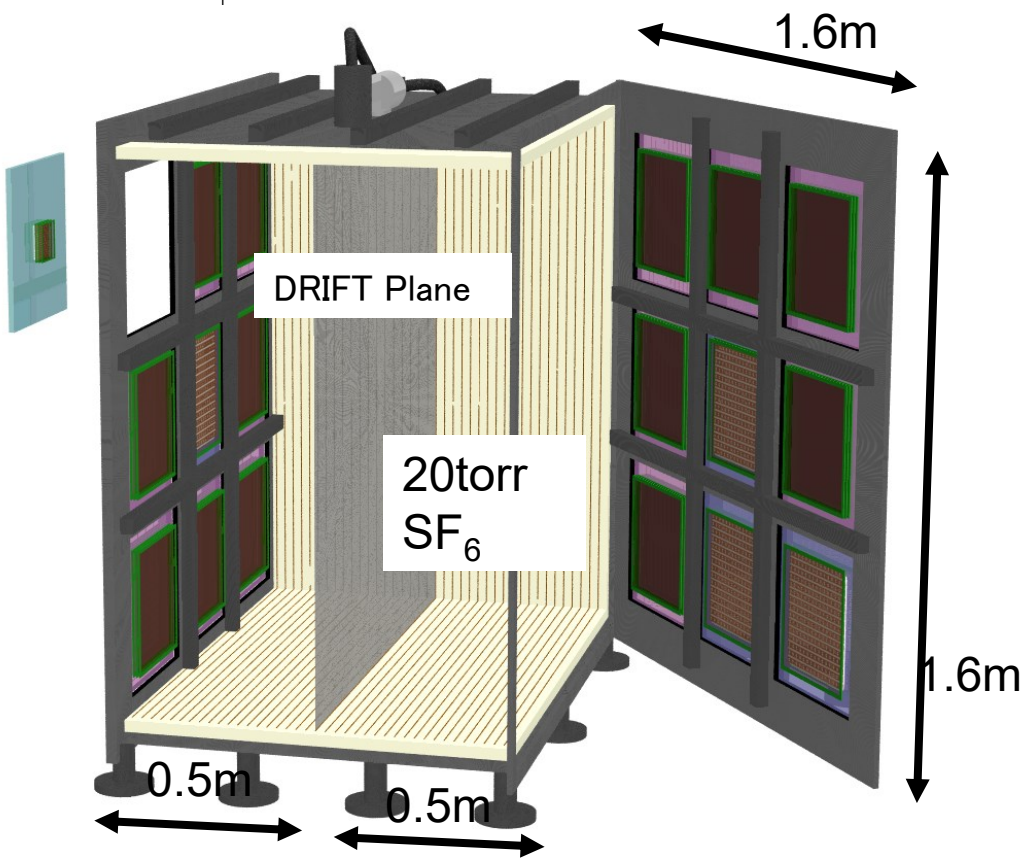
Date 2017/1/16

Title of Proposal	Negative Ion Drift TPC Development for High-Resolution Tracking
Lead Japanese Principal Investigator	*Kentaro Miuchi, Associate Professor, Kobe University*
Lead U.S. Principal Investigator	*Sven Vahsen, Associate Professor and Lead U.S. PI, University of Hawaii*

Micromegas(US)+Electronics(JP)
Oct, 2017

Kobe-Sheffield

- CYGNUS/NEWAGE vessel “observatory”
(complete Aug 2017, go underground in 2018)
- half of the 41cm × 41cm“windows” are open to the community “CYGNUS-KM”
- first proposal by Sheffield (work in Dec., 2017)



interested in?

next meeting: 19th July 21:00 GMT

Send me an e-mail.

- SF6 R&D status (as of 2017-06)

	New Mexico (D. Loomba)	Frascati (E. Baracchini)	Hawai (S. Vahsen)	Japan (K. Miuchi)	Welleseley (J. Battat)	UK (N.Spooner)
Gain device	1mm, 400um GEM(CERN)	3×50um GEM (Kapton,CERN)	3×50um GEM (Kapton,CERN)	100um GEM (LCP Scienrgy) +μ-PIC micromegas(Ray-tech 120um)	128um, 256um micromegas (CERN)	400um GEM (UK)
Readout electronics	Single ORTEC amp	Timepix optical	Single amp	8+8 strips Liq Ar amp	single	single
Drift, max E	60cm 1kV/cm	5cm 0.6kV/cm		10cm 0.4kV/cm		
Pressure(Torr)	20-100	150-370 610 (mixture)		20-152	30-50	30,40,50,(100)
55Fe Eres(σ)	25%	Landau		30%	～40%	
Max gain	3000	5000		2000	2000	
Minority peak	SF5-, SF4-	Hint		SF5-		
fiducialization	σz=7.3mm			σz=7cm		
tracking				3D, σxy=130um		
others	Water contamination effect mobility measurement z-diffusion measurement			ASIC development		radon filteration

backup

- SF6 R&D status (as of 2017-01)

	New Mexico (D. Loomba)	Italy (E. Baracchini)	Hawai (S. Vahsen)	Japan (K. Miuchi)	Weaseley (J. Battat)	UK (N.Spooner)
Gain device	400um GEM(CERN)	3 × 50um GEM (Kapton,CERN)	3 × 50um GEM (Kapton,CERN)	100um GEM (LCP Scienrgy) +μ-PIC micromegas(Ray-tech 120um)	128um, (256um) micromegas (CERN)	400um GEM (UK)
Readout electronics	Single ORTEC amp	Timepix optical	Single amp	8+8 strips Liq Ar amp	single	single
Drift, max E	60cm 1kV/cm			1cm, 10cm 0.4kV/cm		
Pressure(Torr)	20-100	150-370 610 (mixture)		20-152	30-40	30-40
55Fe Eres(σ)	25%	Landau		30%	40%	
Max gain	3000	5000		2000	300	6000
Minority peak	SF5-, SF4-	Hint		SF5-		
fiducialization	PRIORIRTY! updates by upcoming JULY CYGNUS meeting					
others	Water contamination effect mobility measurement z-diffusion measurement			ASIC development		
ref	1609.05249			Proc. of MPGD2015		

- SF6 meeting summary (2016-09-08)

	Dinesh	Elisabetta	Sven	Kentaro	James
device	400um GEM(CERN)	3 × 50um GEM (Kapton,CERN)	3 × 50um GEM (Kapton,CERN)	100um GEM (Liquid Crystal Polymer, Scienrgy)	120um gap micromegas (CERN)
Readout electronics	Single ORTEC amp	timepix	Single EV(?) amp	8+8 strips Liq Ar amp	single
Drift, max E	60cm 1kV/cm			1cm, 10cm 0.4kV/cm	
Pressure(Torr)	20-100	150-370		20-152	
55Fe Eres(σ)	25%	Landau	4%	30%	
Max gain	3000	5000	40000	2000	
Minority peak	SF5-, SF4-	hint		hint	
others	Water contamination effect mobility measurement z-diffusion measurement (comparison with thermal limit)				