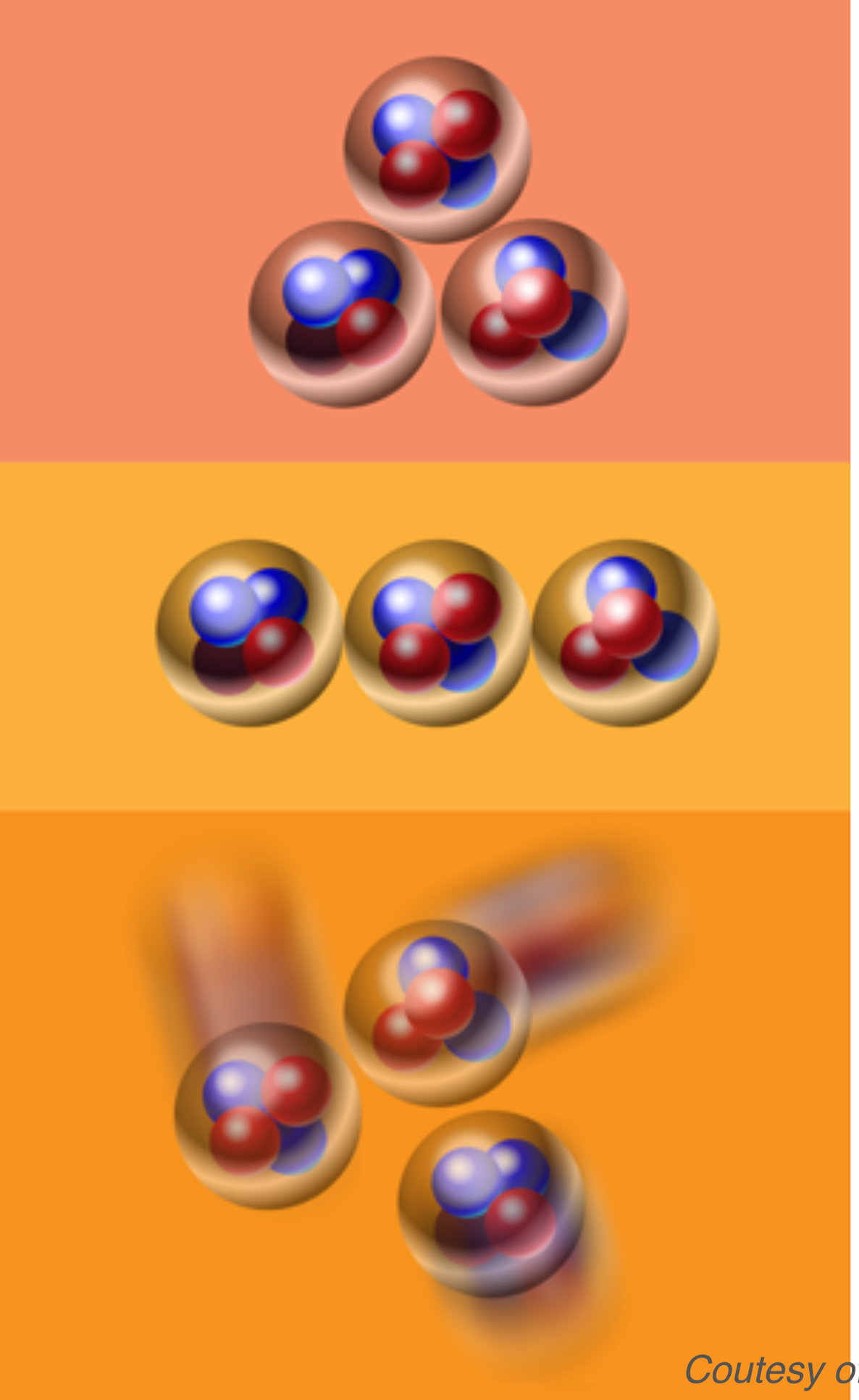

Coutesy of APS

status of **AT-TPC** development

Yongsun Kim

LAMPS meeting, 2020.4.17

- April 2019

	19/04	19/05	19/06	19/07	19/08
Field Cage	계획	디자인 E-Field	구매	시작품의 시작품 제작	테스트
Gas System	계획	디자인	구매 견적	제작	테스트
Readout Chamber	계획	디자인	구매 견적	제작	테스트
Geant4	계획	Event Gene	→	Geom	→
GET system	계획	테스트	→	→	→

- April 2019

	19/04	19/05	19/06	19/07	19/08
Field Cage	계획	디자인 E-Field	구매	시작품의 시작품 제작	테스트
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Geant4	계획	Event Gene	→	Geom	→
GET system	계획	테스트	→	→	→

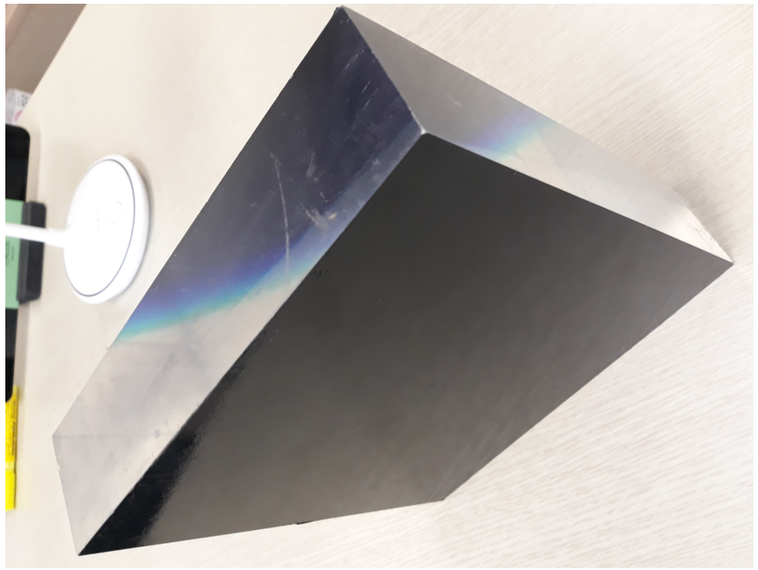
- April 2020

	19/04	19/0
Field Cage	계획	디자 E-Fie
Gas System	계획	디자
Readout Chamber	계획	디자
Geant4	계획	Ever Gen
GET system	계획	테스

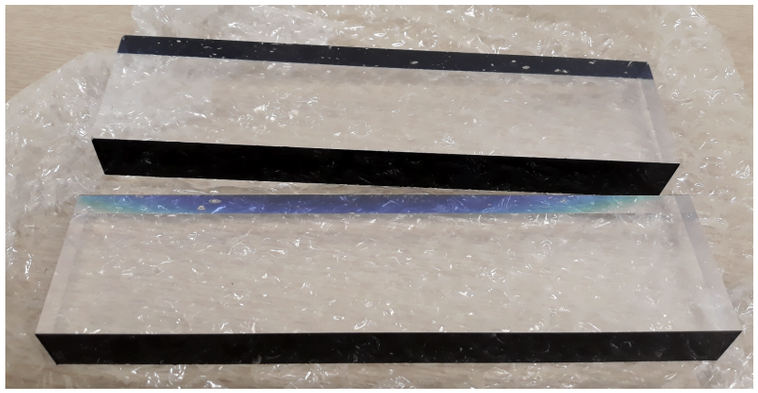
Outline

- Status of plastic scintillator
  - Trigger system for cosmic muons
- Readiness of prototype ATTPC
- Design for the mains experiment, low-E LAMPS

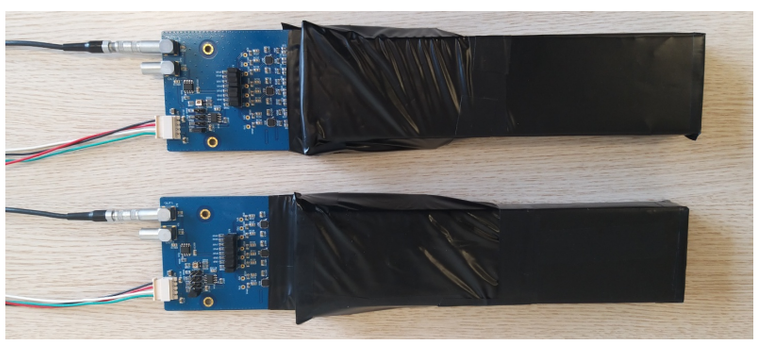
Plastic Scintillator making decent signals



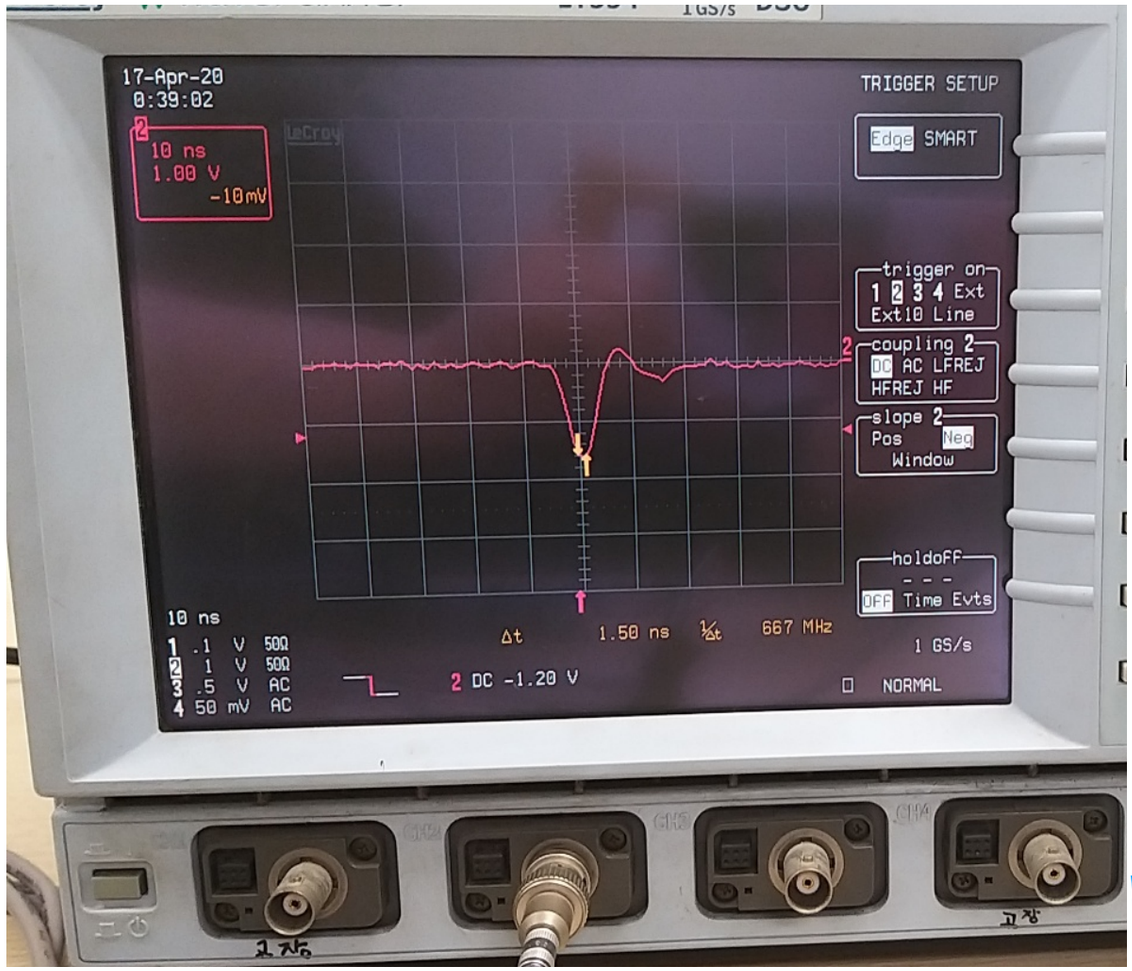
Chunk of plastic scintillator



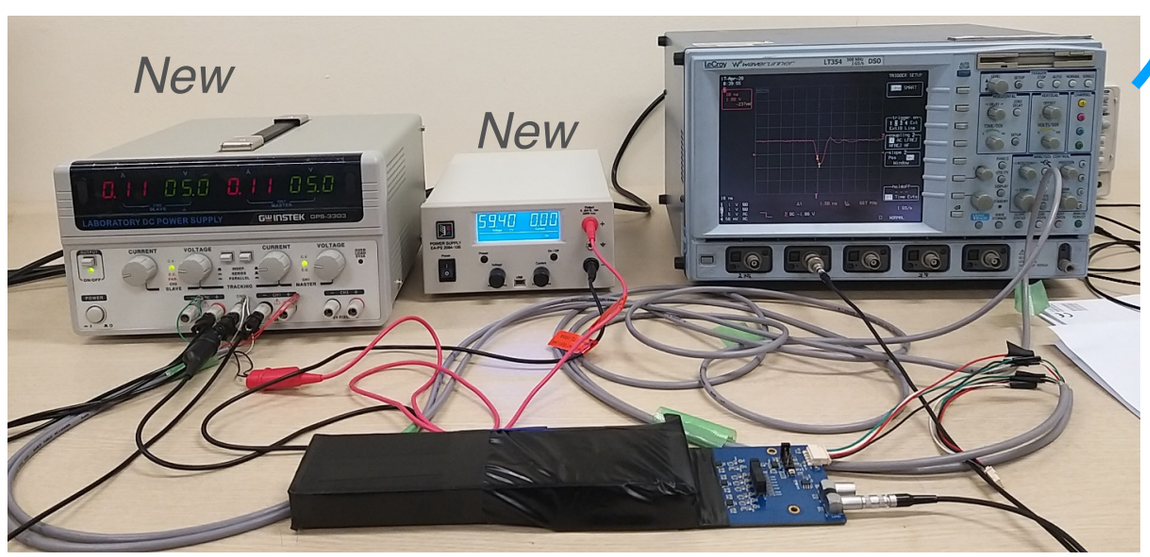
chopped and polished



MPPC attached and tape wrapped

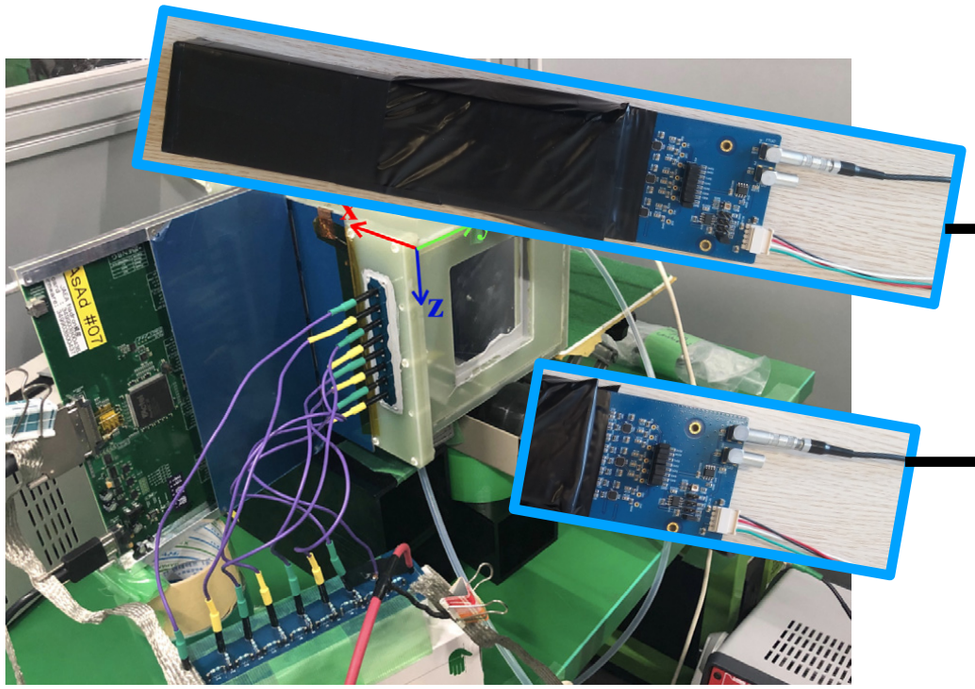


19 year-old oscilloscope works great :-)

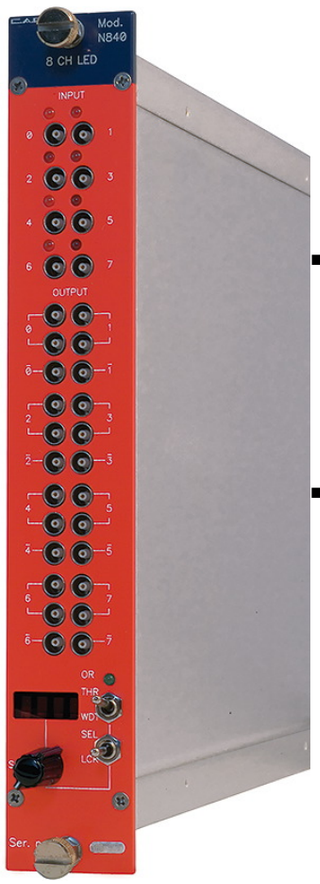


setup with power suppliers

Scintillator trigger



NIM A 962 (2020) 163687, Kim, Ahn

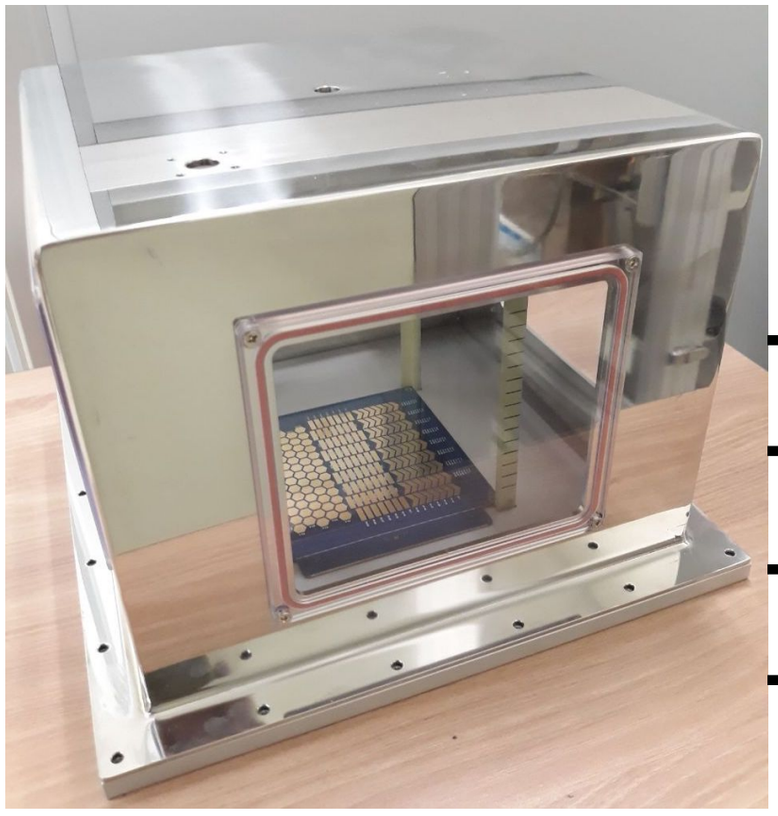


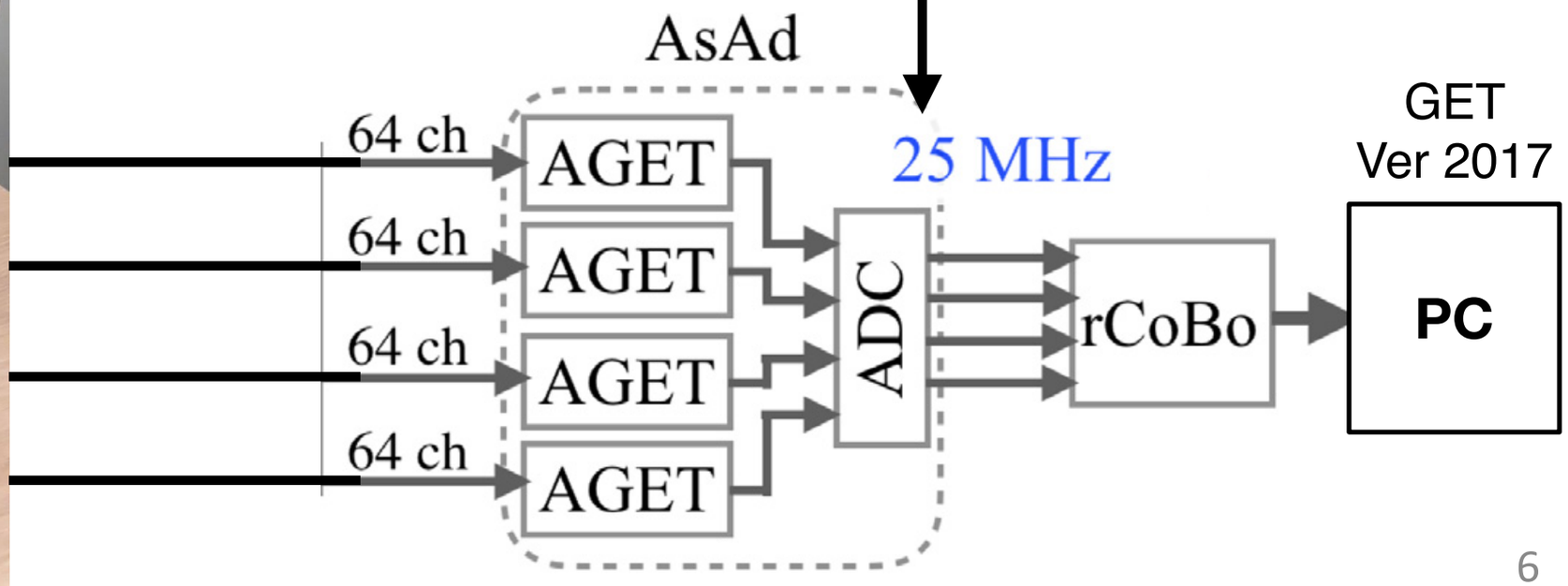
Discriminator (N840)

***AND**/OR logic (N405)*

To be delivered by April 24th

Trigger





Task flow

- gas system is ready for the cosmic ray experiment
- Need MFC and Helium for the low-pressure test later
- Voltage divider to be assembled

Task ID	Description	Preceding condition	notes
CB-1	클린 부스	N/A	DONE
STR	스트론튬	N/A	취소
GAS-1	P10 가스, 가스 실린더, 조절기 선정 (일성가스)	N/A	DONE
GAS-2	Fitting 및 튜브 선택 및 주문(나사 규격 참고 + 튜브 1/4")	GAS1	DONE
GAS-3	압력계 (Pressure gauge)	N/A	DONE
GAS-4	유량계 (Flowmeter) https://www.dwyer-inst.com/Product/Flow/Flowmeters	GAS-1	DONE
GAS-5	질량 흐름 제어기(Mass Flow Controller, MFC) https://kr.omega.com/pptst/FMA-LP1600A.html	GAS-1	Pending
FC-1	HV connector (panel mount type) (>15kV) 선정 http://www.hvp.kr/sub/sub02_01.php?mode=list2&cat_no=128	N/A	DONE
FC-2	Board to wire connector (>2kV) 선정 회사 링크: link	N/A	DONE
FC-3	Voltage divider materials for GEM	FC-2	DONE
FC-4	Copper wire	N/A	11번가
FC-5	Resistor 주문 HVP, digikey, 엘레파츠 link	N/A	DONE

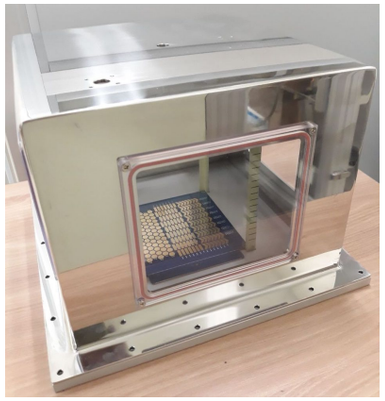
Task flow

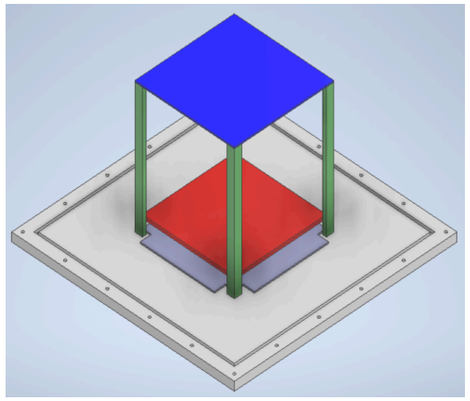
- Gas system is ready for the cosmic ray studies
- MFC and Helium gas for later low-pressure test
- Voltage divider to be assembled
- Two undergraduate students joined the group
  - GARFIELD simulation for the main experiment
  - Measurement of cosmic ray
  - Development of tracking using ML

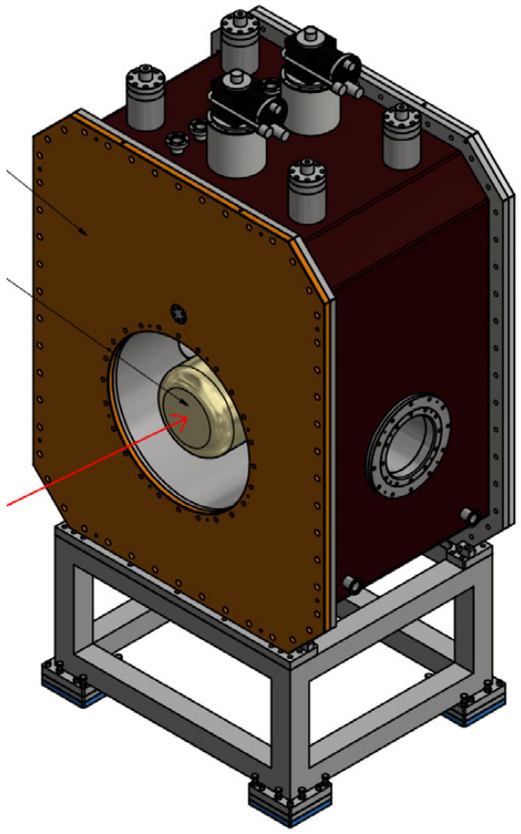
ELEC	Voltage divider 조립 및 전압 측정	FC-2, FC-3, FC-4	
CHM	Aluminum chamber 3D 디자인	Every GAS FC-1 DESIGN-2, 3	DONE
CHM-1	Aluminum chamber 주문	DSGN-1	3D 에코텍
DSGN-2	Readout PCB 디자인 (이룸테크)	CHM	DONE
DSGN-3	ZAP board 회로 디자인 (이룸테크)	N/A	
ASSEM	Assembling of gas chamber	ELEC FC-5	
POWER-1	HV power supply 선정 및 주문 https://www.caen.it/products/dt1570/	DSGN-3	DONE
GEM-1	GEM 주문	N/A	메카로
GEM-2	High Voltage 에 따른 GEM 검수	GEM-1	
GARFIELD-1	가필드 디버깅 및 본 제품 전기장 시뮬레이션		학부생1
SCIN-1	NIM 모듈 주문	N/A	CAEN
SCIN-2	신틸레이터 및 NIM 모듈 작동 확인	SCIN-1	학부생2
SCIN-3	Analysis of cosmic muon kinematics	SCIN-2	학부생2

Gas chamber design for the main experiment

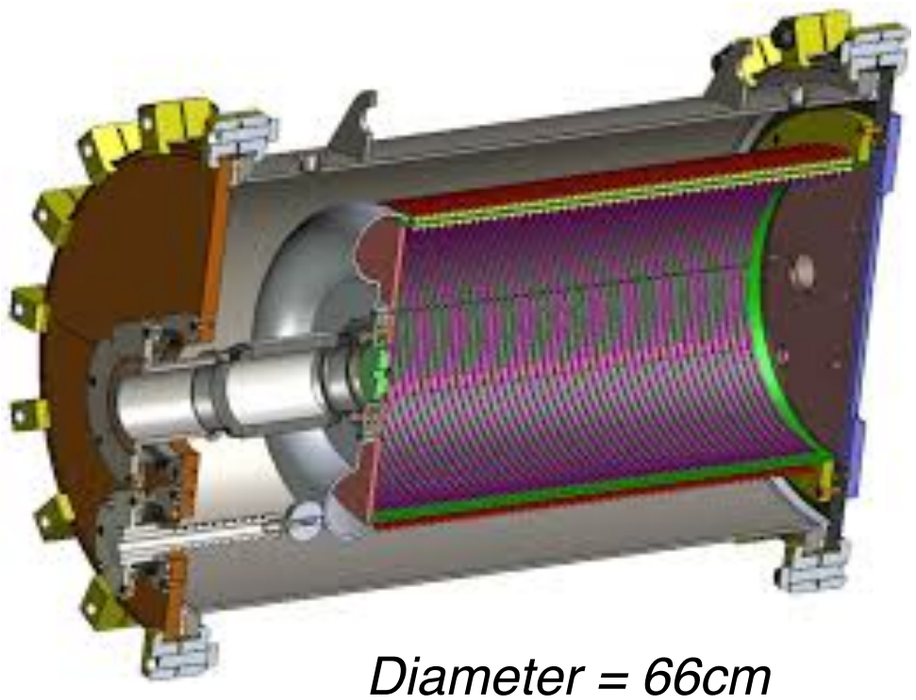
- Prototype chamber





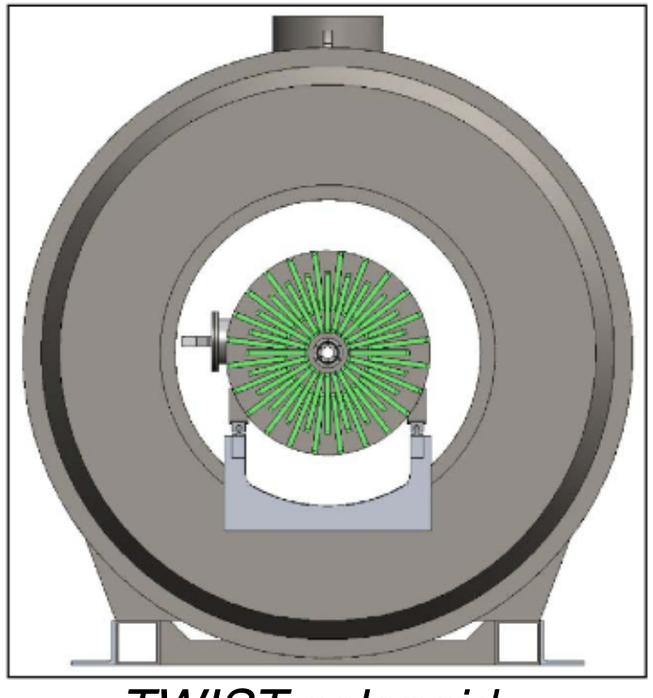


- Original plan



Diameter = 66cm

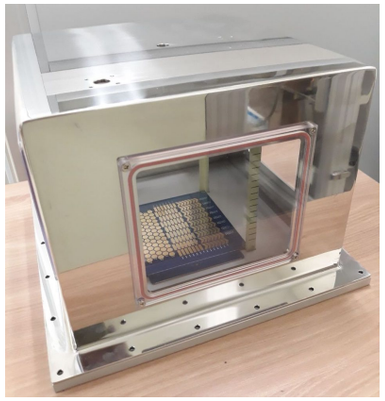
Length = 120cm

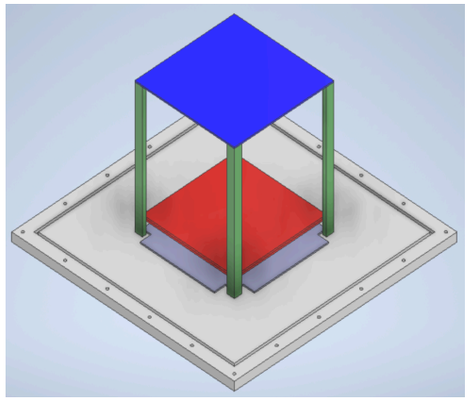


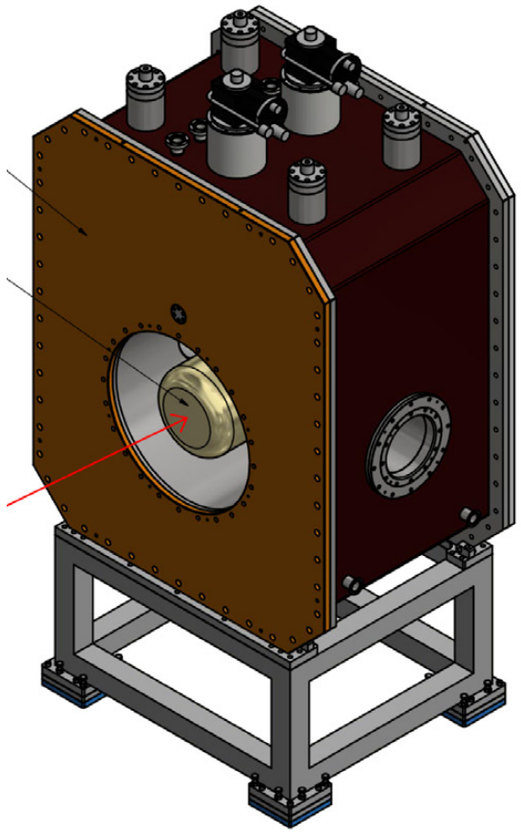
TWIST solenoid

Gas chamber design for the main experiment

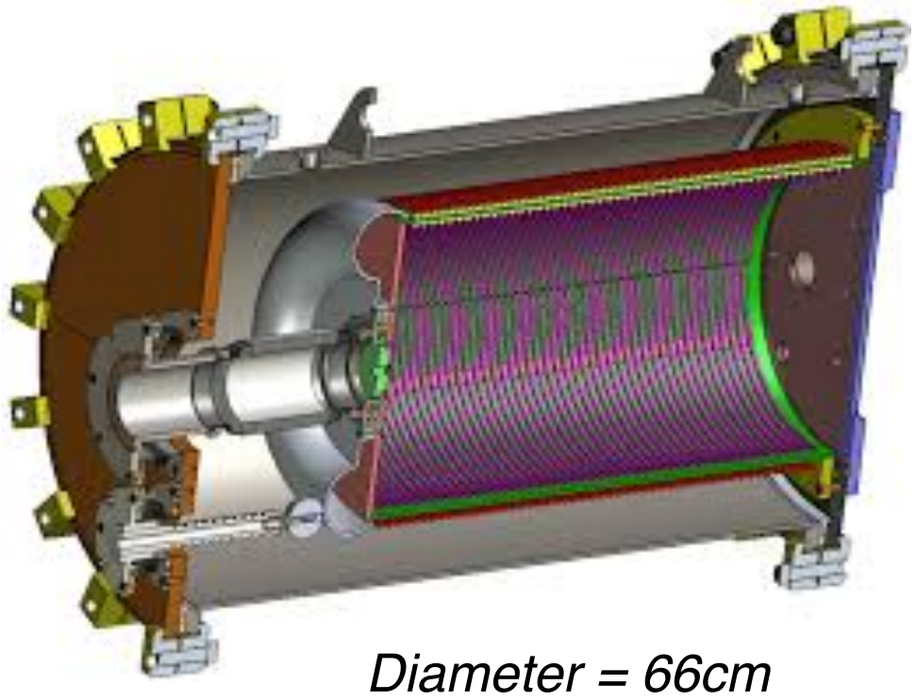
- Prototype chamber







- Original plan



Diameter = 66cm

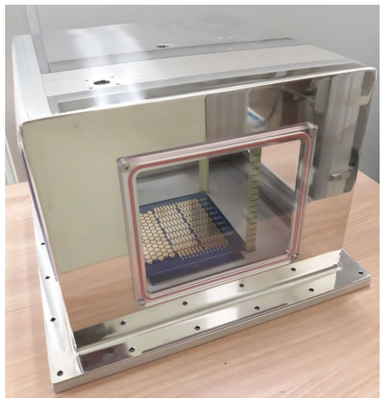
Length = 120cm

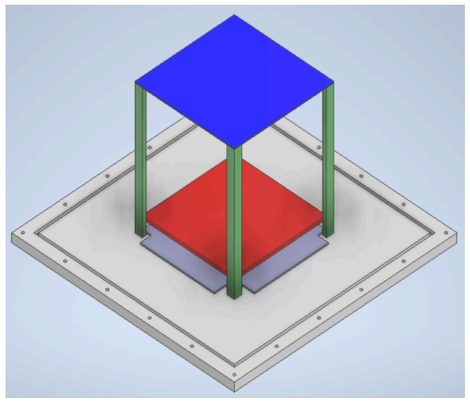
Overview of the AT-TPC scientific program.

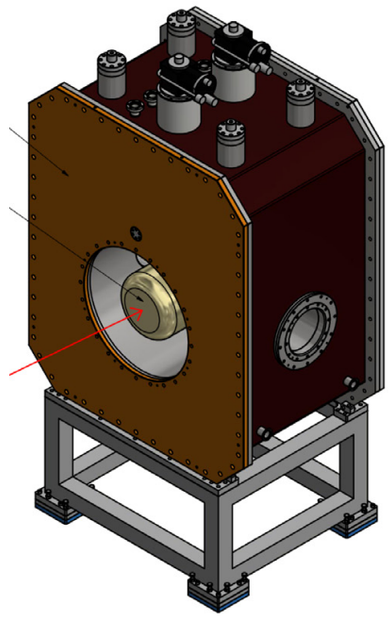
Measurement	Physics	Beam Examples	Beam Energy (A MeV)	Min Beam (pps)	Scientific Leader
Transfer & Resonant Reactions	Nuclear Structure	^{32}Mg(d,p)^{33}Mg ^{26}Ne(p,p)^{26}Ne	3	100	Kanungo
Astrophysical Reactions	Nucleosynthesis	^{25}Al(^{3}He,d)^{26}Si	3	100	Famiano, Montes
Fusion and Breakup	Nuclear Structure	^{8}B+^{40}Ar	3	1000	Kolata
Transfer	Pairing	^{56}Ni+^{3}He	5-19	1000	Macchiavelli
Resonances	Quasimelecular structures	^{8}He+^{4}He	0-3	1000	Suzuki
Fission Barriers	Nuclear Structure	^{199}Tl, ^{192}Pt	20 - 60	10,000	Phair
Giant Resonances	Nuclear EOS, Nuclear Astro.	^{54}Ni-^{70}Ni, ^{106}Sn-^{127}Sn	50 - 200	50,000	Garg
Heavy Ion Reactions	Nuclear EOS	^{106}Sn - ^{126}Sn, ^{37}Ca - ^{49}Ca	50 - 200	50,000	Lynch

Gas chamber design for the main experiment

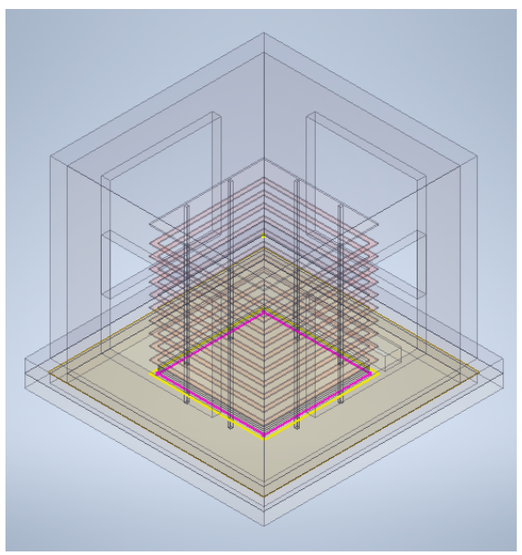
- Prototype chamber

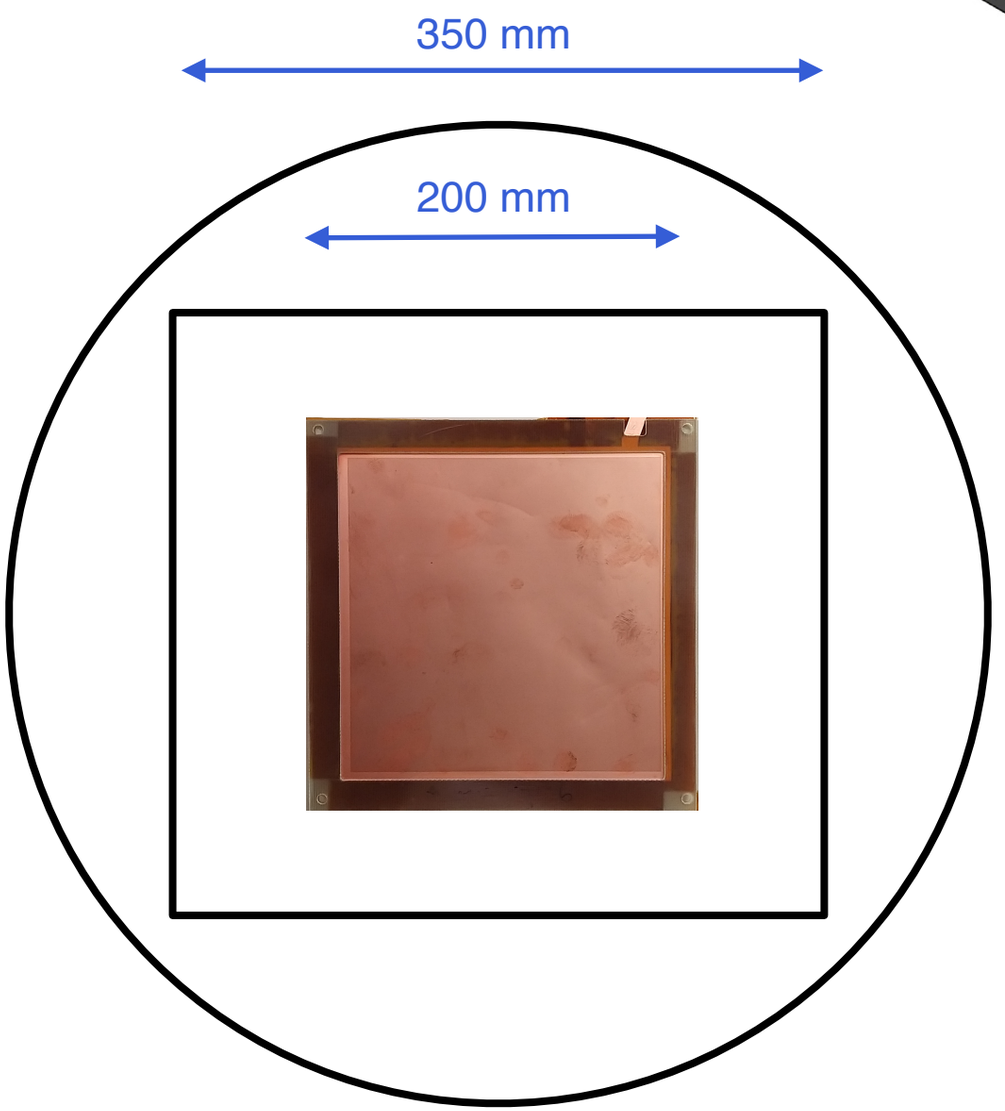






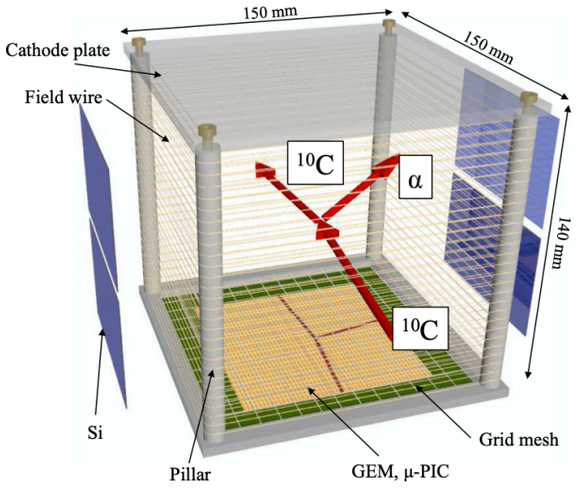
- New plan
  - Focus on 10-20 MeV reactions
  - Square chamber as alternative options an option
  - Best geometry for flat E field

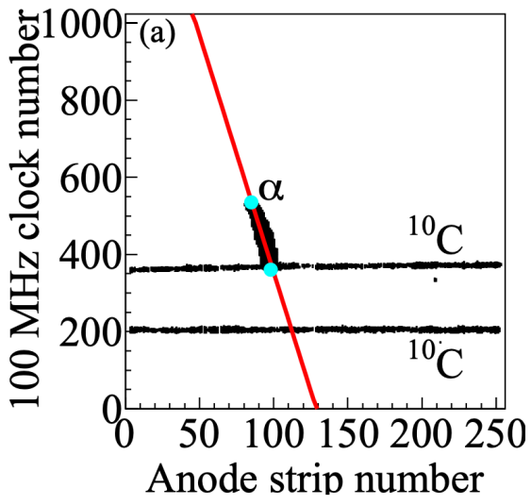




PCB design

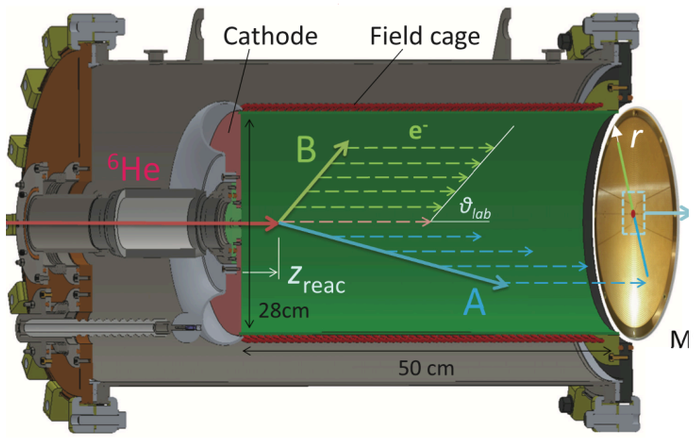
- MAIKO (Kyoto & RCNP)

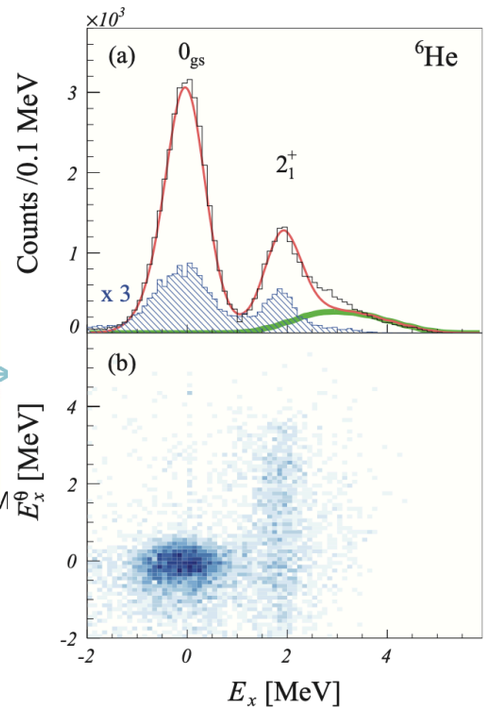




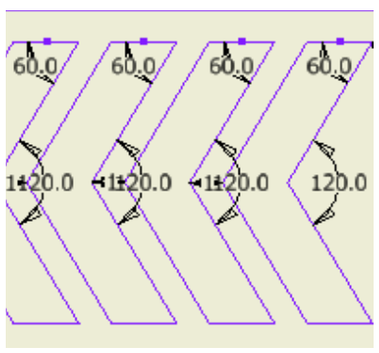
- LAMPS
  - We have magnet, thus don't need track to stop in the active area
    - R for p_T of 10 MeV = 10 MeV / (2C*1T) = 1.6 cm
- Better to have small active area and dense readout pads
  - 150x150mm^2 /4000 = 2.4x2.4 mm^{2}per channel

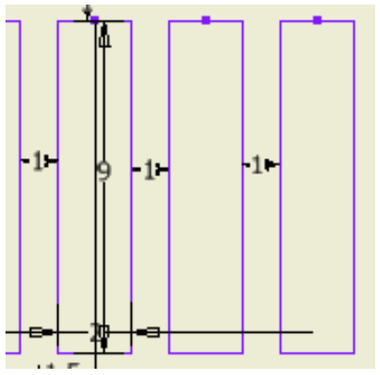
- FRIB prototype

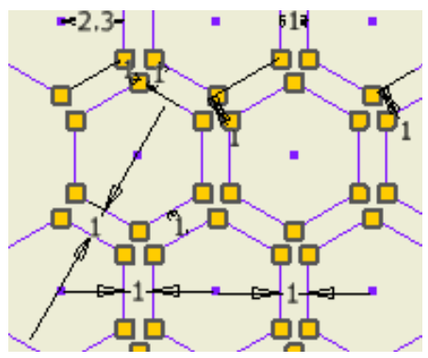




- Resume the pad design study
  - Soyoon Choi

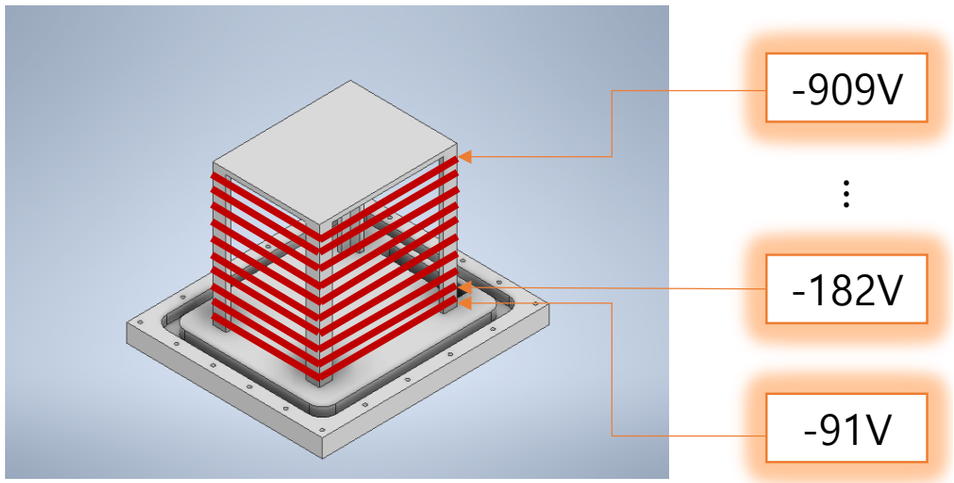






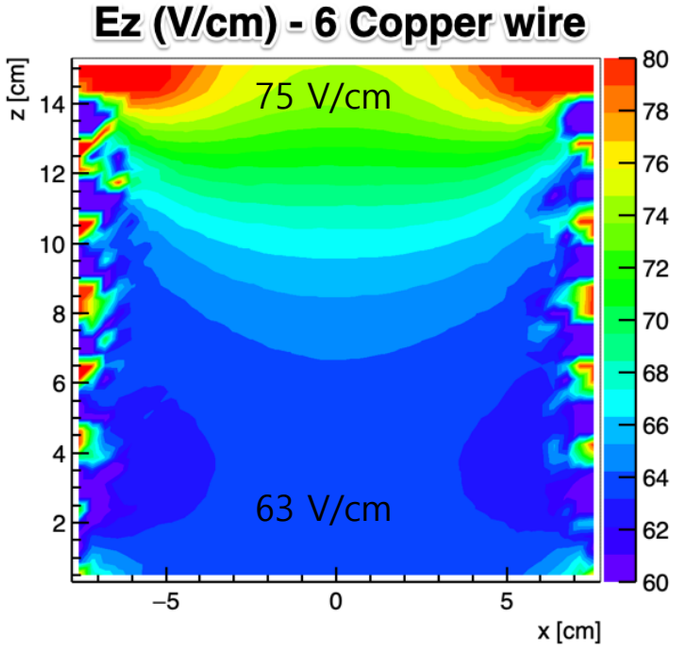
GARFIELD++ simulation with new setup

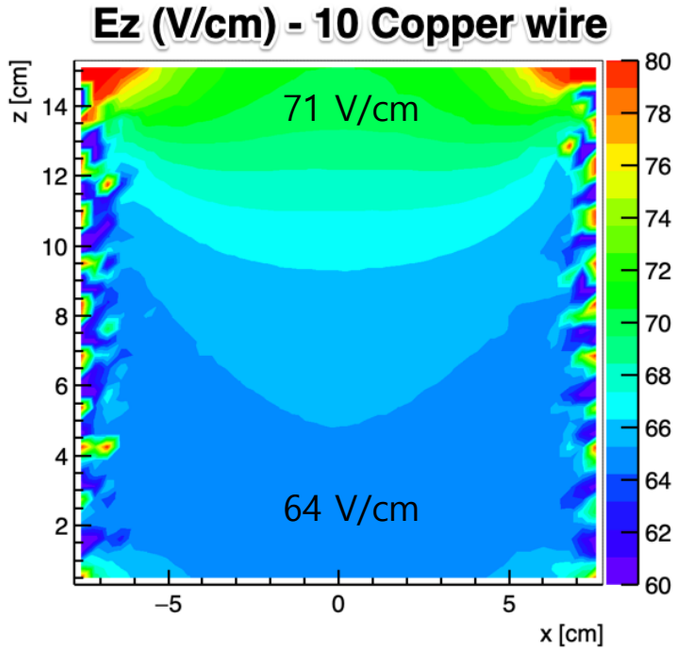
+Boundary Conditions



Voltage divider
(10 Copper wires)

- Rooms for improvement of the voltage divider
  - Project for 학부생1
- To be deployed for prototype



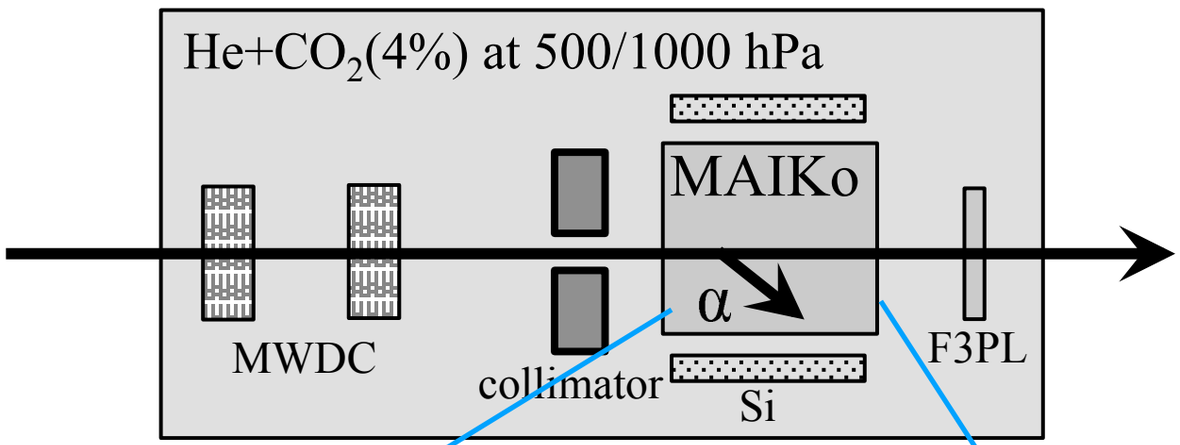


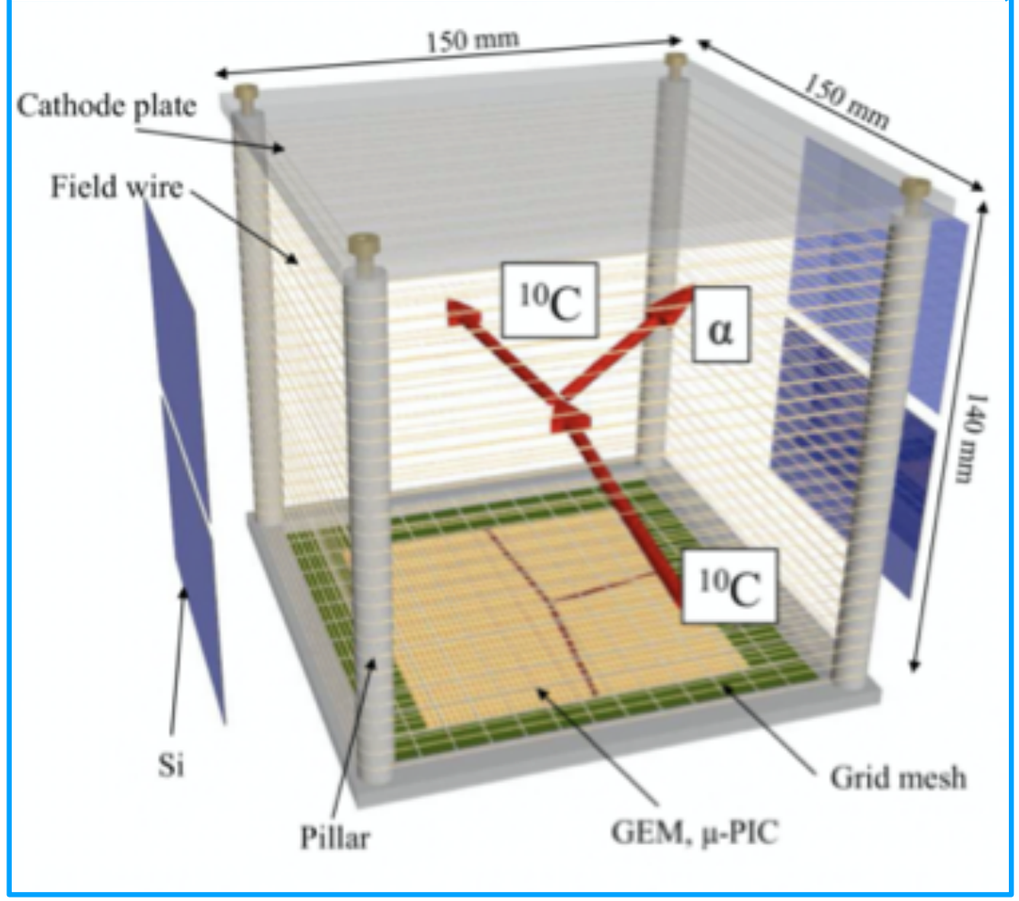
BACKUP

References

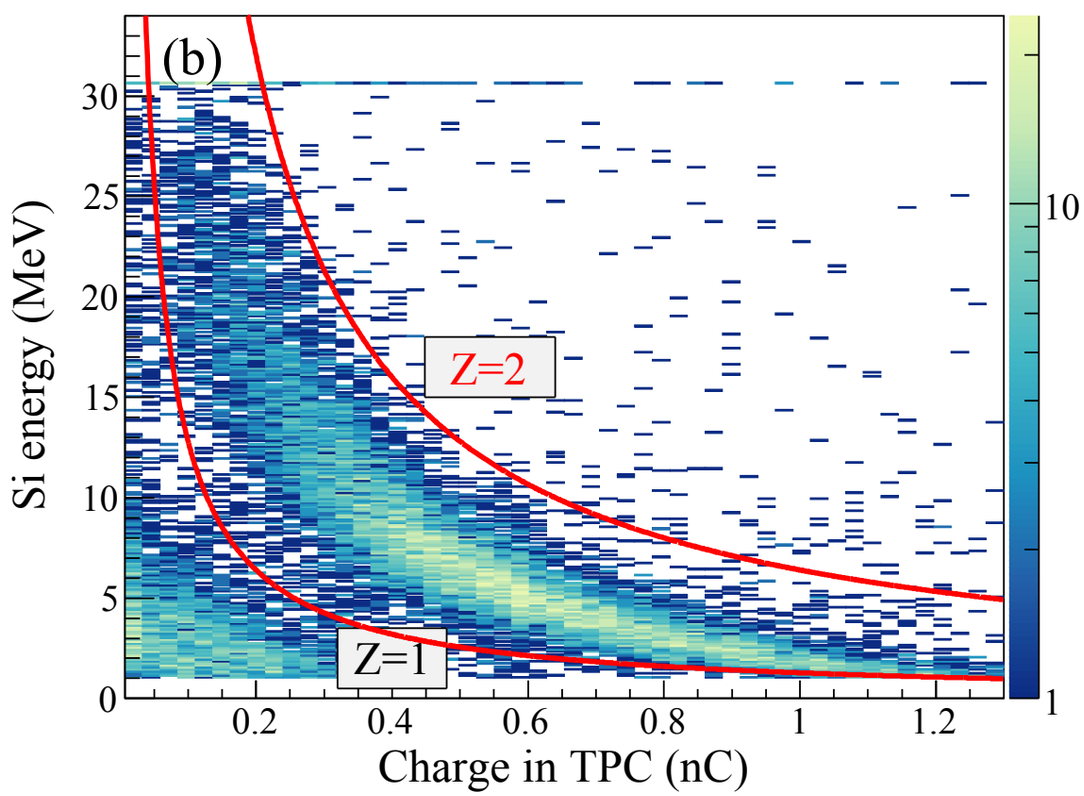
- 1203.3336
  - First excited Hoyle state of ^{12}C)
- 1805.06074
  - Intruder configuration in 12Be)
  - $^{11}Be + d \rightarrow ^{12}Be + p$,
- PRC 87, 054301 (2013)
  - Resonant alpha scattering
  - $\alpha + ^{6}He \rightarrow ^{10}Be$
- 1908.01910
  - Neutron quadruple transition strength in ^{10}C with MAIKO exp.
  - $\alpha + ^{10}C$ @ 68 MeV
- 1811.11580
  - Open problems of alpha clusters (very nice review)
  - Search for Hoyle state in ^{16}O
- 1704.08154
  - ^{20}Ne resonance from $^{16}O + \alpha$ elastic scattering
  - Use of TTIK detector
  - Discussion about Bose-Eienstien condensation

1. MAIKo AT-TPC

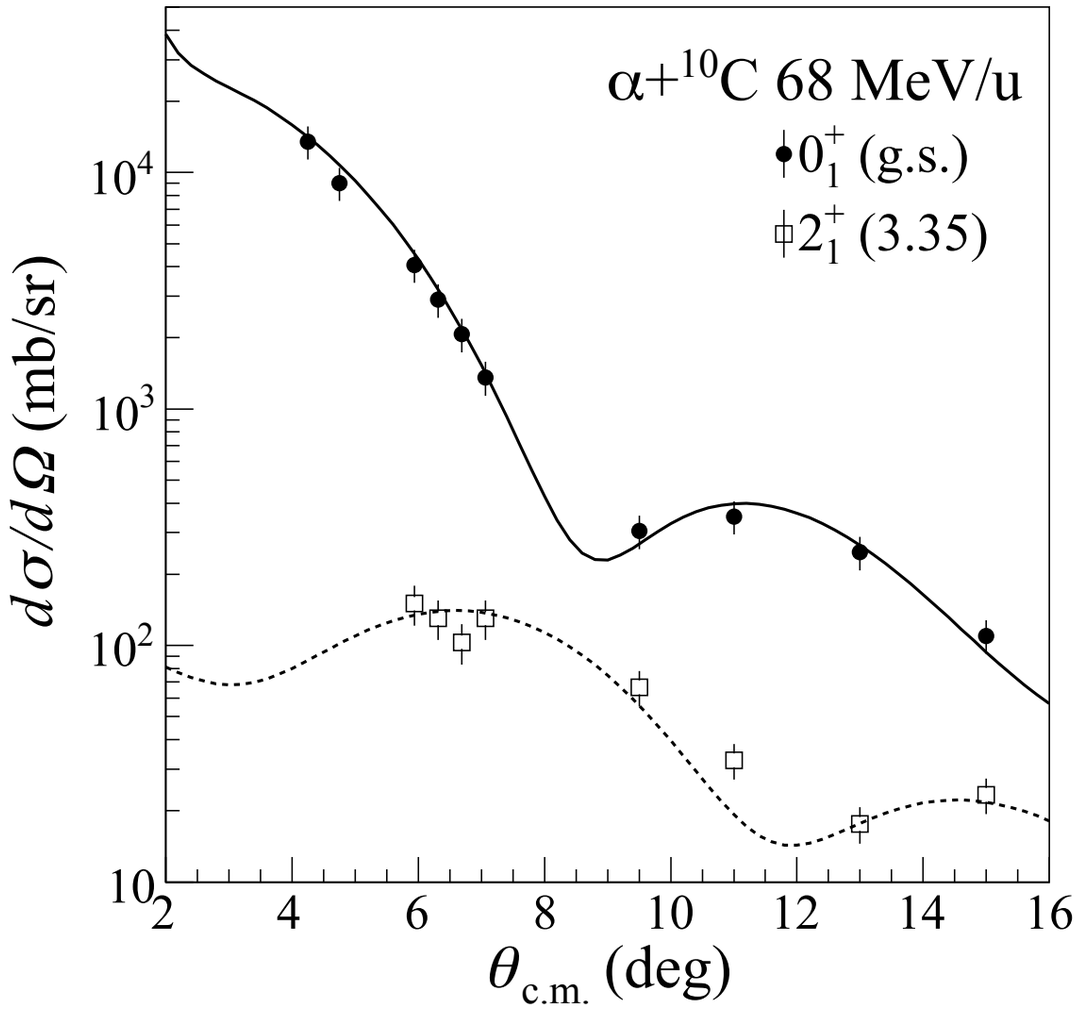




- Good reference for LAMPS AT-TPC
- Study quadruple transition matrix component btw the ground state and 2_1+ states to investigate rearrangement of particle-hole configuration in the nuclear shell model
- Measured M_n/M_p for proton-rich C
- GEM-muPIC in slightly larger dimension than our prototype
- Calibrated by ^{241}Am -> α + X
- Beam intensity = 70k cps



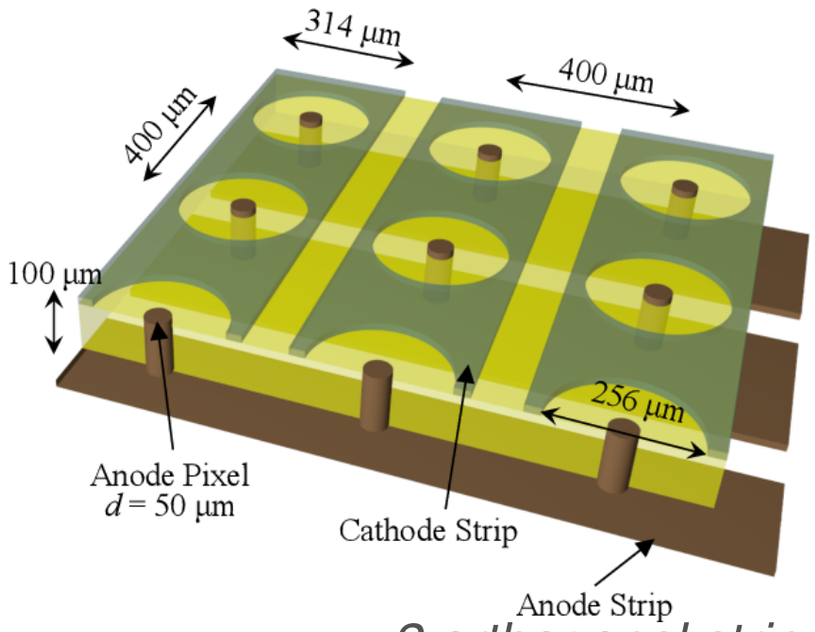
Conclusion of the paper



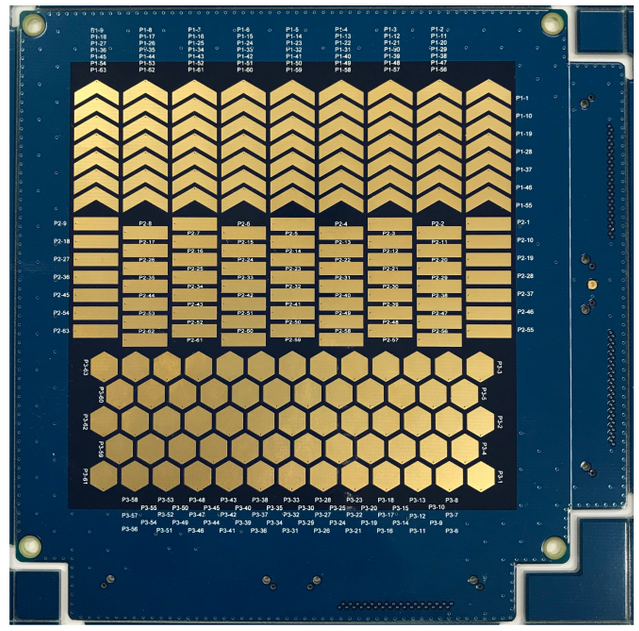
The cross section of the α+^{10}C elastic scattering enabled the determination of the phenomenological α-N effective interaction and the point-nucleon distribution of the ground state in ^{10}C. The rms radius of 2.6 ± 0.3 fm in ^{10}C is consistent with the theoretical prediction by the AMD calculation [47] and the experimental result of the previous proton elastic scattering [13], but slightly larger than that deduced from the interaction cross section [48].

From the cross section of the α+^{10}C inelastic scattering to the 2^+_1 state, the neutron transition matrix element of $M_n = 6.9 \pm 0.7\,(\mathrm{fit}) \pm 1.2\,(\mathrm{sys})$ was obtained. The M_n/M_p ratio in ^{10}C was determined as $M_n/M_p = 1.05 \pm 0.11\,(\mathrm{fit}) \pm 0.17\,(\mathrm{sys})$, and thus, the effect of the $Z = 6$ subshell closure reported in neutron-rich carbon isotopes [31] is not evident in the proton-rich side. This result is supported from the theoretical calculations.

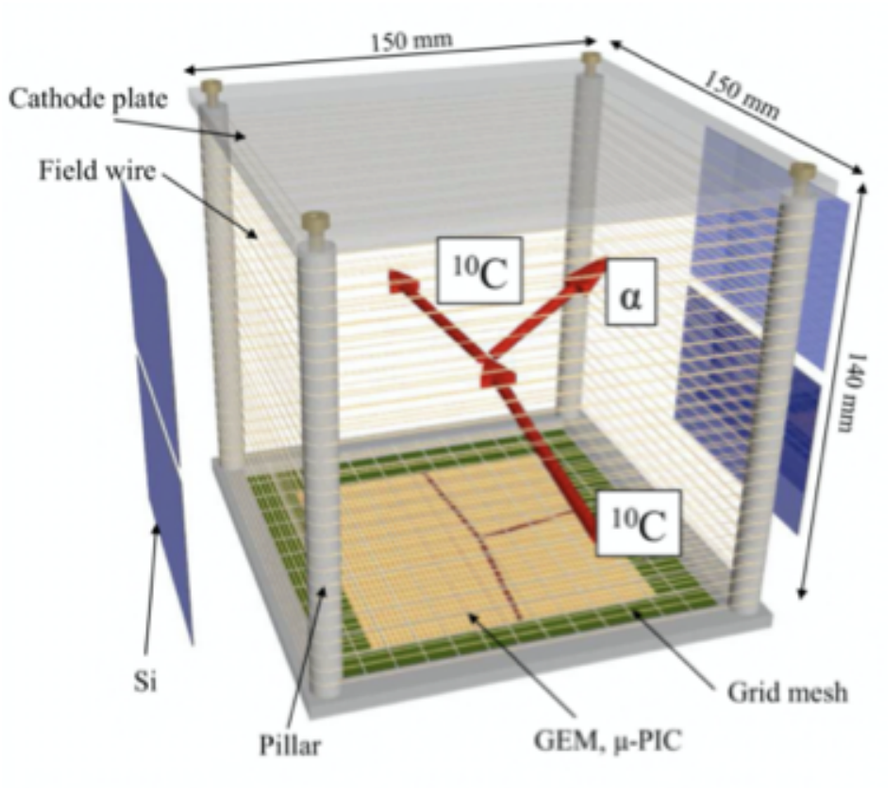
MAIKo AT-TPC vs LAMPS AT-TPC

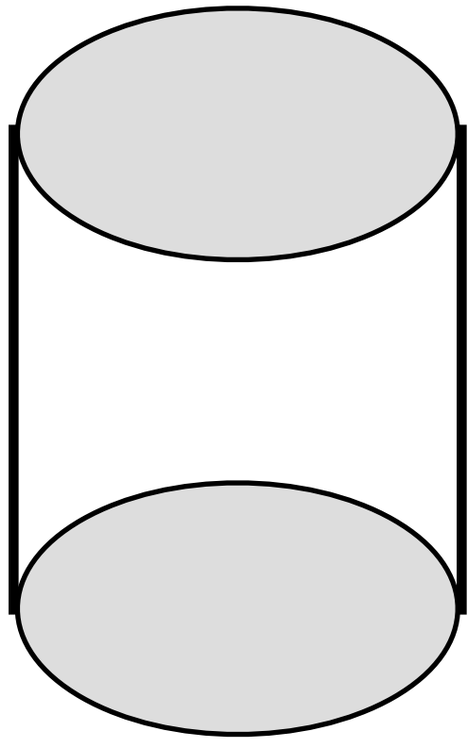


2 orthogonal strips (narrow)



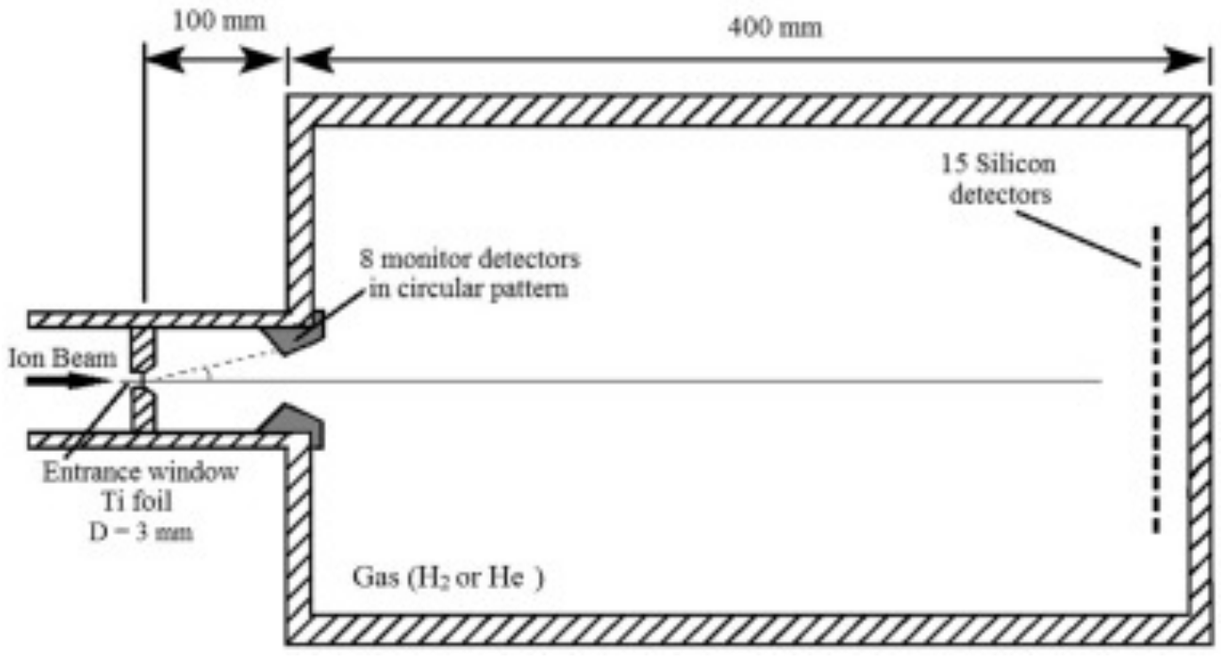
2-dim granular pads (coa

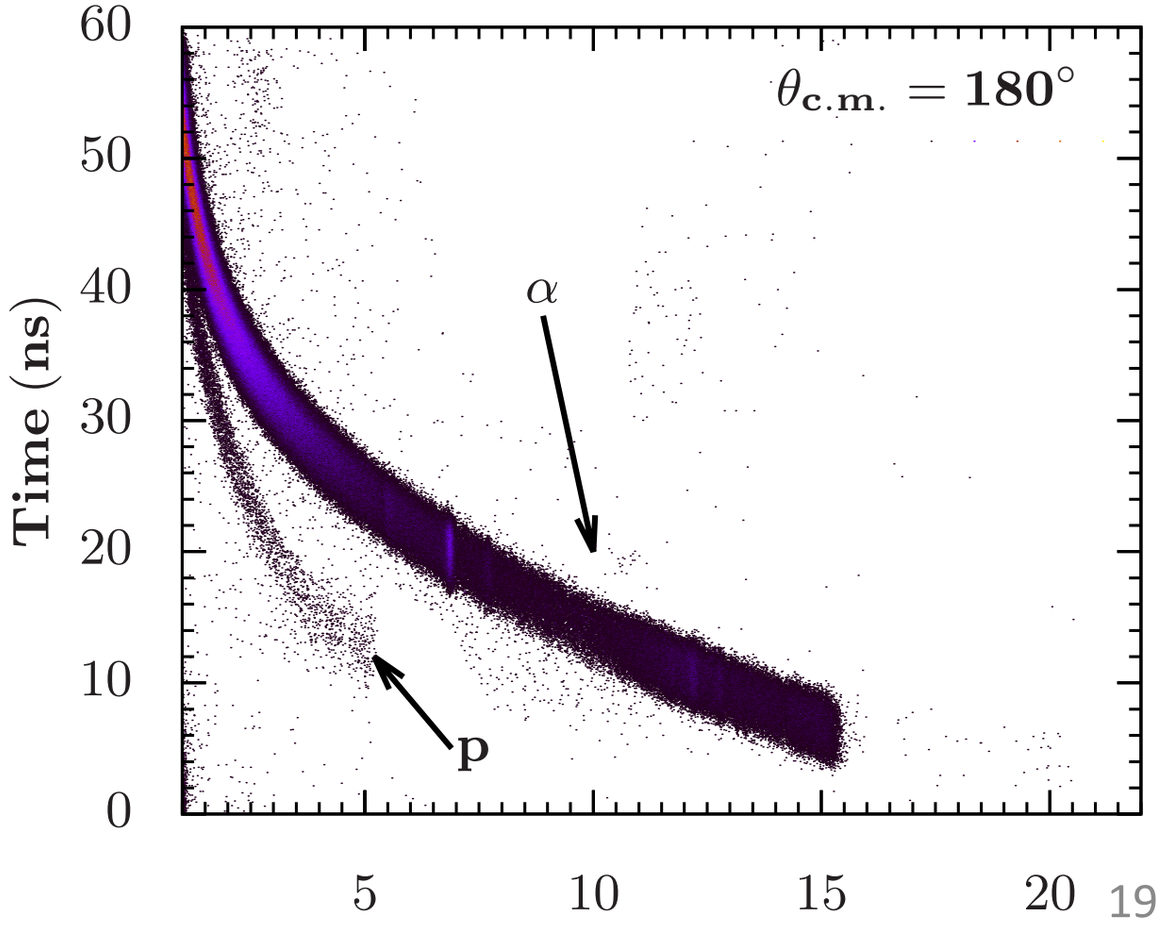




2. TTIK (Thick Target Inverse Kinematics) method

- **TTIK in DC-60 cyclotron (Astana)**
  - 99.99% of He gas
  - Beam stops in the gas chamber
- Study of ^{20}Ne resonances via alpha + ^{16}O elastic scattering
  - E up to 1.9 MeV/A
- Scattered α is detected by Si-array
- Calibrated with α from ^{226}Ra and ^{218}Po
  - Energy resolution ~ 30 keV





2. TTIK (Thick Target Inverse Kinematics) method

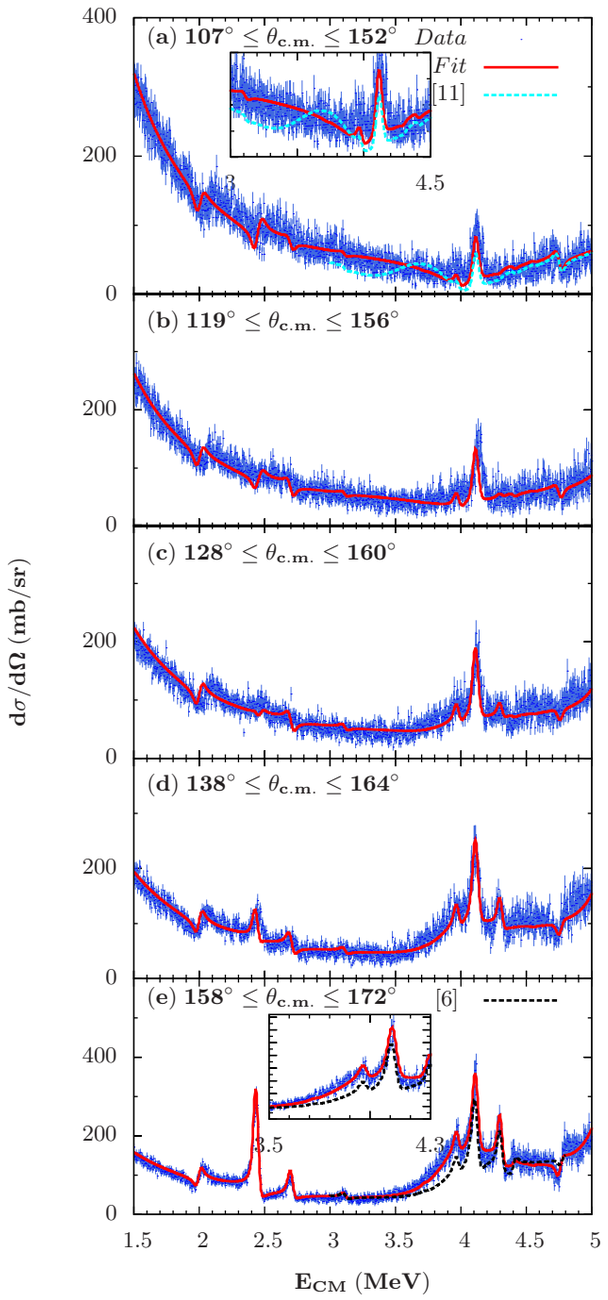


TABLE I. ^{20}Ne levels

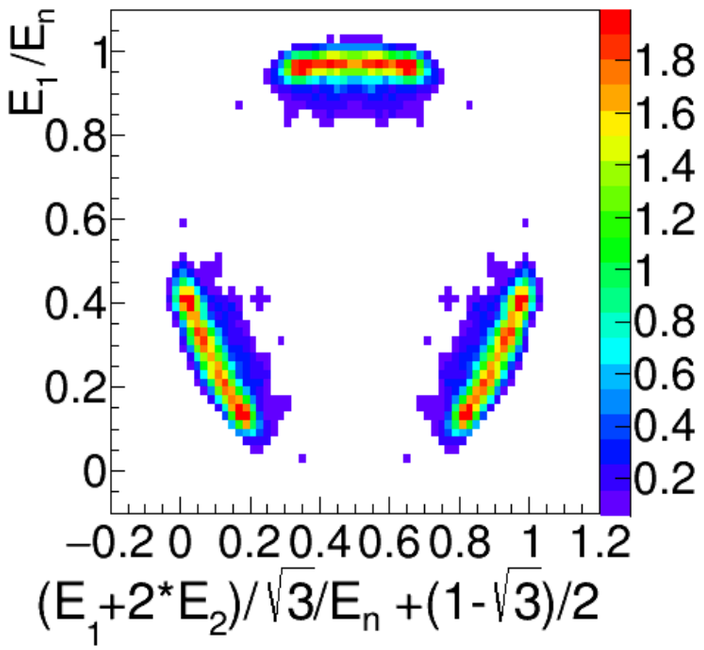
N	TUNL data [6]			H. Shen et al. [9]		This work			CNCIM			
	E_x (MeV)	J^π	Γ_α (keV)	E_x (MeV)	Γ_α (keV)	E_x (MeV)	Γ_α (keV)	γ_α	E_x (MeV)	J^π	SF_p	SF_α
1	0	0_1^+		-	-	0		Large	0	0^+	0.36	0.73
2	1.63	2_1^+		-	-	1.63		Large	2.242	2^+	0.41	0.67
3	4.25	4_1^+		-	-	4.25		Large	4.58	4^+		0.62
4	5.78	1^-	$(28\pm3)\text{x}10^{-3}$	-	-	4.45	0.03	1.4				
5	6.73	0_2^+	19±0.9	6.72	11	6.78	20.6	0.47	6.94	0_3^+	0.55	0.46
6	7.16	3^-	8.2±0.3	7.16	10	7.18	8.3	1.37				
7	7.19	0_3^+	3.4±0.2	7.19	5	7.20	3	0.019	6.27**	0_2^+	0.055	0.44**
8	7.42	2_2^+	15.1±0.7	7.43	7	7.44	14.3	0.19	7.39	2_3^+	0.01	0.12
9	7.83	2_3^+	2	7.83	1	7.85	3.68	0.01	7.15**	2_2^+	0.12	0.18**
10	8.45	5^-	0.013±0.004	8.45	0.02	8.45	0.013					
11	8.71	1^-	2.1±0.8			8.71	3.5					
12	≈8.7	0_4^+	>800	8.62	1470	8.77±0.15	750±220	∼0.25	9.66**	0_4^+	0.002	0.18**
13	8.78	6_1^+	0.11±0.02	-	-	8.78	0.14	0.5	9.49	6^+		0.51
14	8.85	1^-	19	8.84	27	8.85	18.0					
15	9.00	2_4^+	≈800	8.87	1250	8.79±0.10	695±120	0.86	8.36**	2_4^+	0.02	0.02**
16	9.03	4_3^+	3	9.02		9.03	1.9	0.03	9.0	4^+		0.09
17	9.12	3^-	3.2	9.09	4	9.13	4.1					
18	9.19	2^+		-	-	(9.29)	≤10					
19	9.48	2^+	29±15	9.48	46	9.48	65±20	0.02?				
20	9.99	4_4^+	155±30	10.02	150	9.97	157	0.38	9.5	4^+		0.009
21*	10.26	5^-	145±40	10.26	190	10.26		1.9				
22	10.41	3^-	80	10.40	101	10.41						
23	10.58	2^+	24	10.56	15	10.58			10.2	2+	0.005	0.04
24	10.80	4_4^+	350	10.75	400	10.80			10.7	4^+		0.04
25	10.97	0_5^+	580	10.99	700	10.97			11.9	0^+		
26	11.24	1^-	175	11.19	85	11.24						
27	11.95	8^+	$(3.5\pm1.0)\text{x}10^{-2}$			11.95		0.35	11.50	8^+		0.40

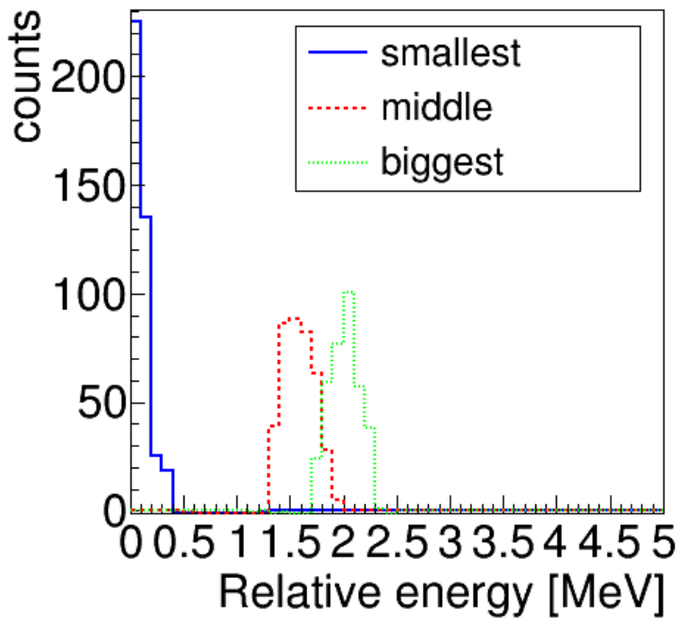
* For the levels with numbers 21-27 the parameters of the present fit were fixed as in [6]
** Calculated in *psd* space. SF is to the first excited state in ^{16}O; SFs for the ground state in ^{16}O are ≤ 0.1

- Results in the range of E = 5 - 6 MeV suggested to modify the R-matrix fit
- Argues that fp shell and higher oscillation must be included in the model to describe the strong clustering features, the

3. TTIK at Texas A&M

- TTIK experiment using K150 cyclotron beam in Texas A&M
  - 20Ne + α at E_{max} = 13 MeV/u
  - $4x10^{10}$ particles used for analysis
- Check hypothesis of BEC states of ^{12}C
  - 3α would decay symmetrically
  - Not found. Γ(3α) / Γ(α + 8Be -> 3α) ~ 10^{-4}
- Search for Hoyle-like states in ^{16}O and ^{20}Ne
- Similar momentum resolution with DC-60

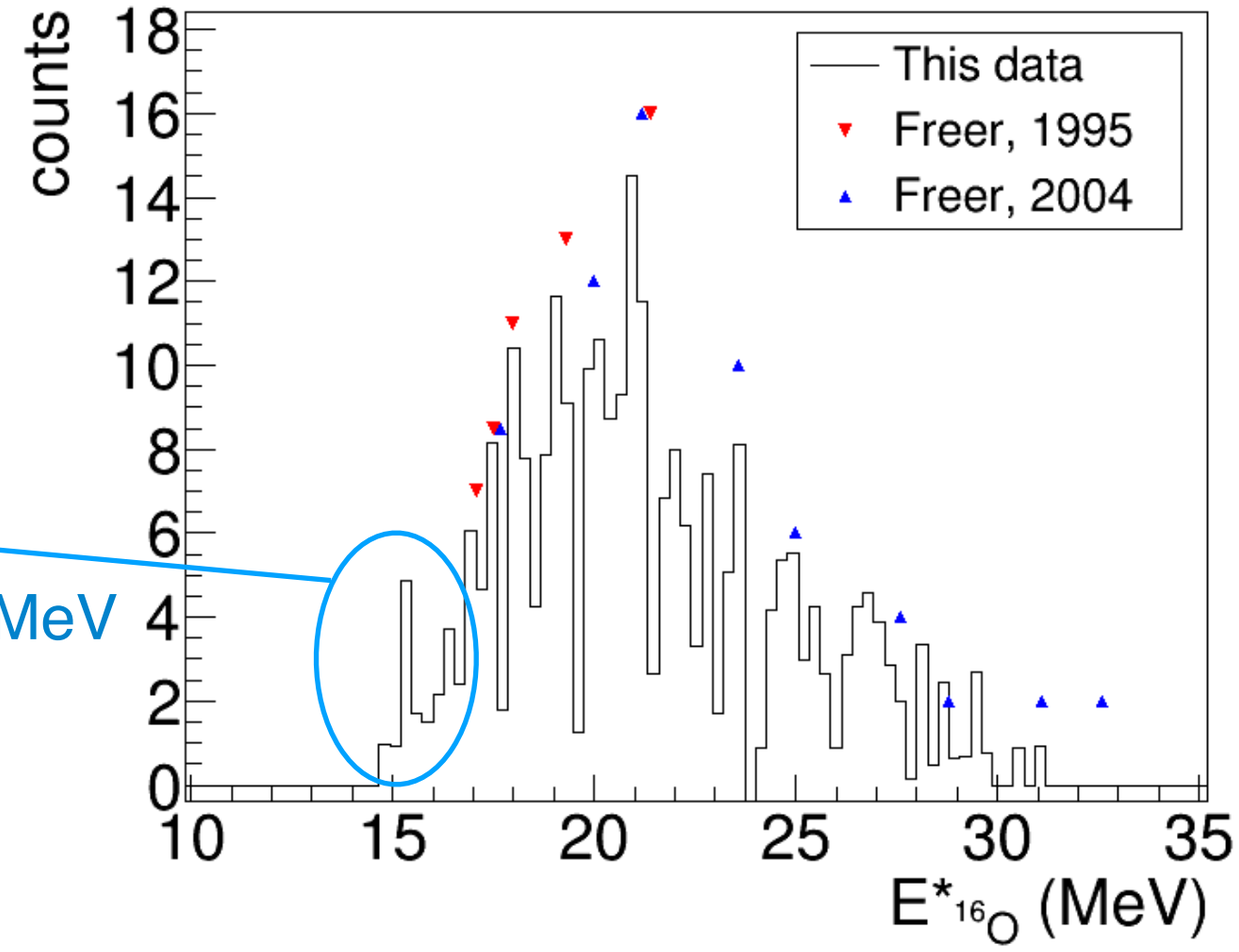




3. TTIK at Texas A&M

Quadruple α events

- α + ^{20}Ne -> ^{16}O + ^{8}Be -> 6α
- 659 events found
- Candidate for Hoyle-like state of ^{16}O (Funaki)



In the summary section

MeV above the 6 alpha particles threshold or 33.42 MeV

In the future we plan to use this same experimental method to collect larger statistics data on ^{16}O and later to explore heavier systems. We are also considering the possibility to insert an active TPC volume at the end of the chamber in the region after the point where the beam is stopped and before the silicon detector array. This will help to reduce the energy threshold and to trace the trajectories back to the interaction point.

LAMPS can be the great chance for this study!