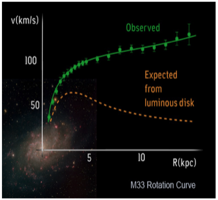
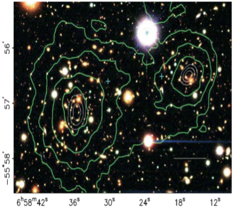
3rd 地下和空间粒子物理与宇宙物理前沿问题研讨会

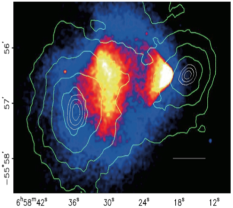
用于暗物质探测的液氦时间投影室研究进展

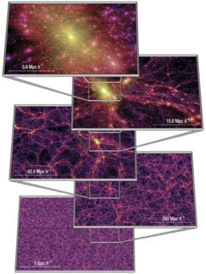
Astronomy V.S. High energy physicis

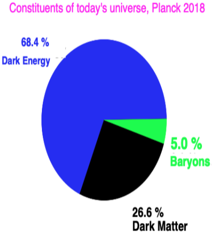
Astrophysical and cosmological evidence of DM existence.

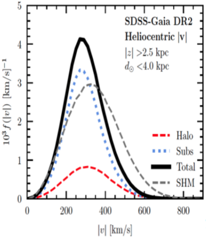




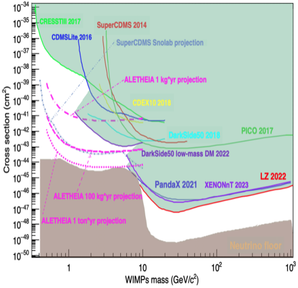




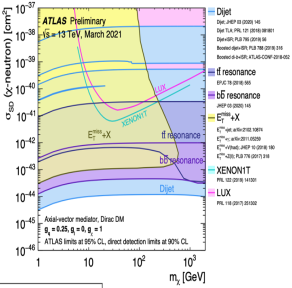


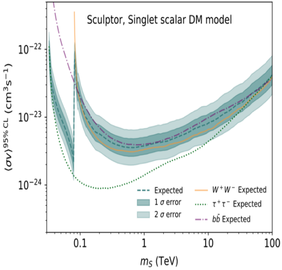


No any convincing DM signal from HEP searches.



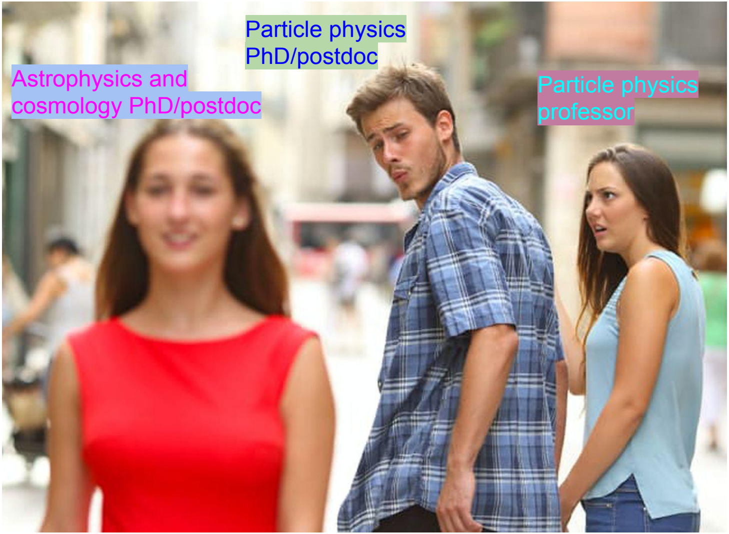
arXiv: 2210.01220





ATL-PHYS-PROC-2022-003

Particle physicist professors working in DM: completely frustrated.



Experimental efforts worldwide (might have missed some efforts)

- EU: Direct detection of dark matter – APPEC committee report, arXiv: 2104.07634.

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- China: CEDX 50 kg HPGe, CDEX-100/1T (?), PandaX-xT (?), DS-1ton for low-mass DM (?);
  ALETHEIA, R&D stage

Outline

1. ALETHEIA Introduction
2. The progress of the ALETHEIA project
   - ALETHEIA prototype detector R&D on the 30g-V1 LHe
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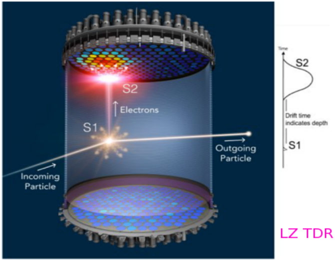

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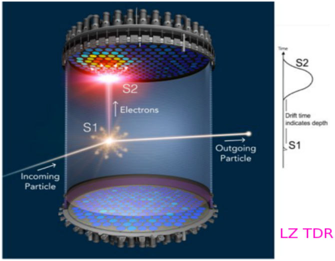

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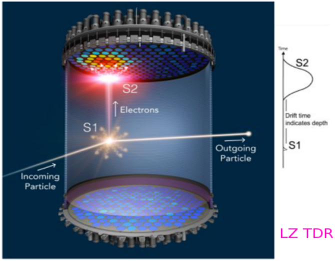

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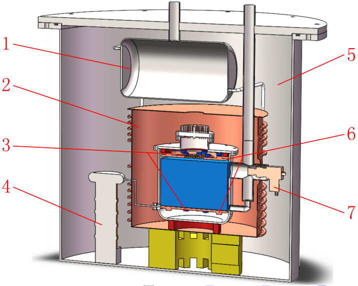

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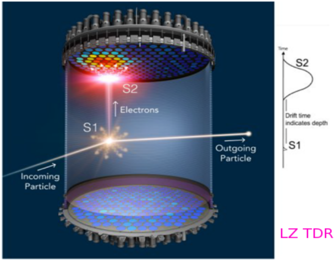
- For details: Eur. Phys. J. Plus (2023) 138:128.



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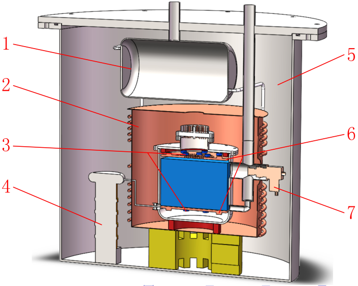
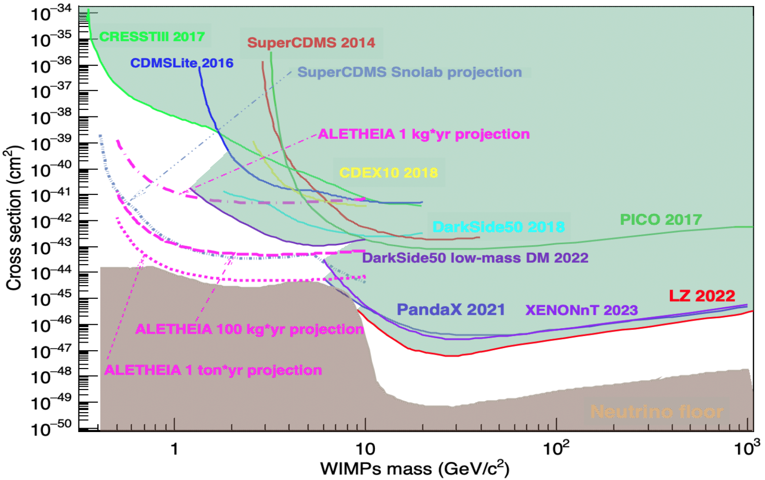


ALETHEIA NR channel: Projected sensitivities

- 1 ton*yr ALETHEIA can "touch down" the ^{8}B solar ν fog (Assuming IBF, 50% Eff.).



ALETHEIA review, Oct 2019.

ALETHEIA review, Oct 2019.

- *"It is possible that liquid helium could enable especially low backgrounds because of its powerful combination of intrinsically low radioactivity, ease of purification, and charge/light discrimination capability."*

ALETHEIA collaborators so far

5 institutions (increasing), ~ 20 members

- CIAE (China Institute of Atomic Energy), ~ 10 researchers.
- Peking University, 1 + 2 (?) researchers.
- University of South China, 1 + 1(?) researchers.
- China Southern Power Grid Electric Power Research Institute, 5 researchers.
- SCRI (Shanghai Cable Research Institute), 3 researchers.

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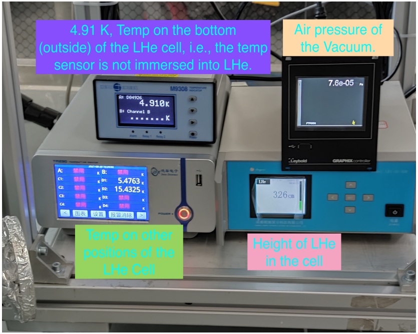
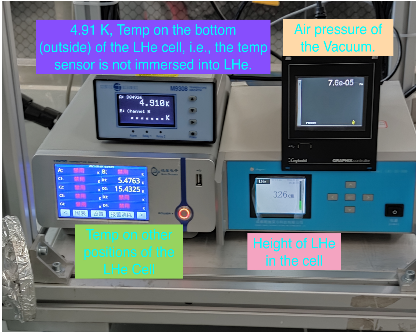
The R&D of the 30g-V1 LHe prototype.

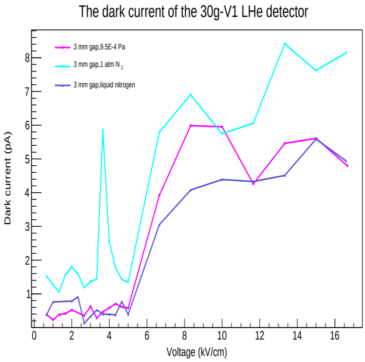
- Left picture: the detector successfully cooled to 4 K.



The R&D of the 30g-V1 LHe prototype.

- Left picture: the detector successfully cooled to 4 K.
- Right plot: dark current is less than 10 pA under several circumstances.

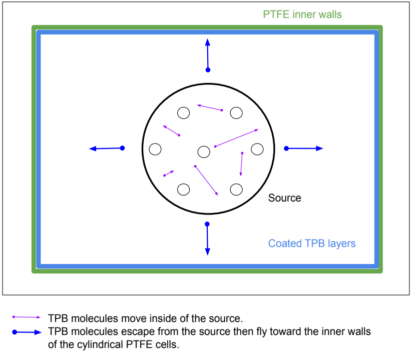




Outline

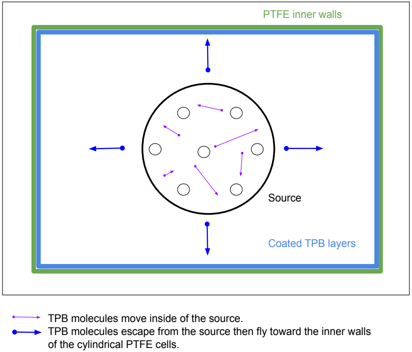
LHe light peaked 80 nm, TPB to convert into visible light.

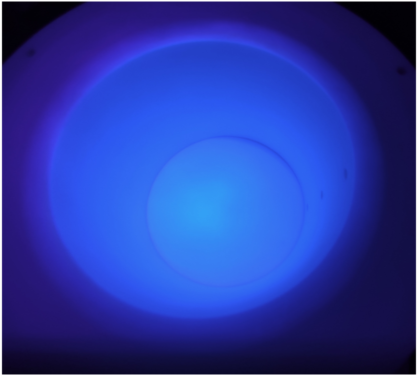
- Left picture: the principle of TPB coating.



LHe light peaked 80 nm, TPB to convert into visible light.

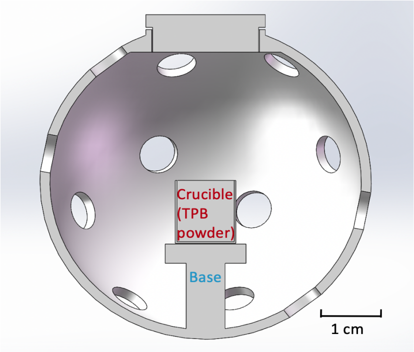
- Left picture: the principle of TPB coating.
- Right plot: top view of the coated 10-cm size PTFE chamber.
- Published: Acta Phys. Sin. Vol. 71, No. 22 (2022) 229501





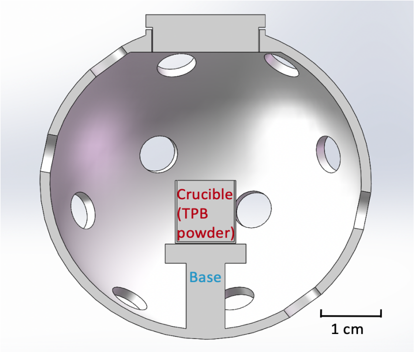
The coating source.

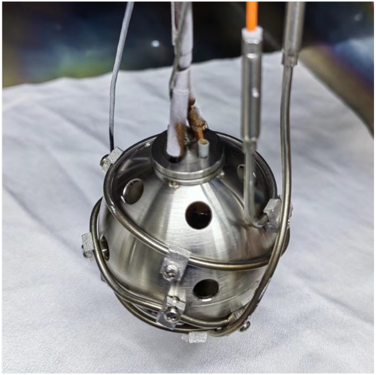
- Left picture: The source's drawing.



The coating source.

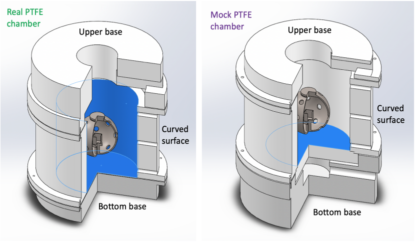
- Left picture: The source's drawing.
- Right plot: The image of the source.





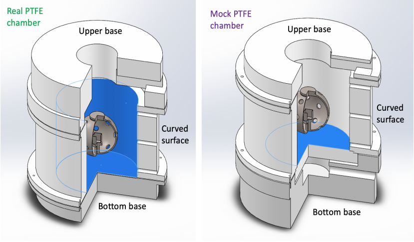
Coating process.

- Left picture: Coating into steps.



Coating process.

- Left picture: Coating into steps.
- Right plot: real time monitoring on TPB thickness.



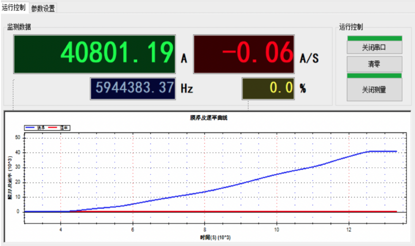
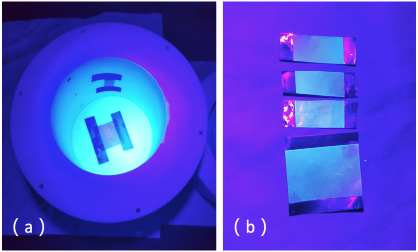


Figure out the TPB coating thickness.

- Left picture: sample films inside of the chamber.



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- Right plot: calculate TPB's thickness based on the mass difference.

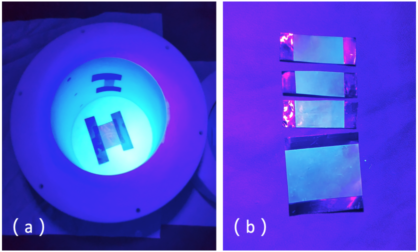
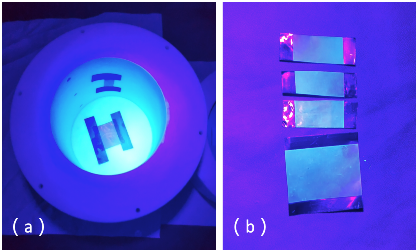


Table 1. TPB coating thickness calculation based on the mass difference before and after coating on the aluminum plates

Sample #	Plate area (cm^2)	Plate position	Mass increase (mg)	thickness (μ m)
1	2	Chamber top	0.75±0.02	3.48±0.11
2	2	Chamber top	0.46±0.04	2.13±0.17
3	2	Curved surface	0.87±0.04	4.03±0.16
4	6	Chamber bottom	2.54±0.02	3.92±0.03

Figure out the TPB coating thickness.

- Left picture: sample films inside of the chamber.
- Right plot: calculate TPB's thickness based on the mass difference.
- The third method to figure out TPB's thickness is based on the TPB mass consumed, 0.2 g.
- All of the three methods returned consistent thickness.



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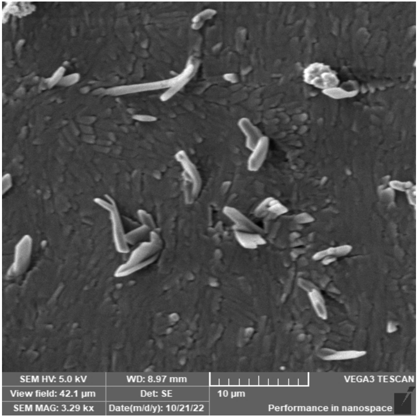
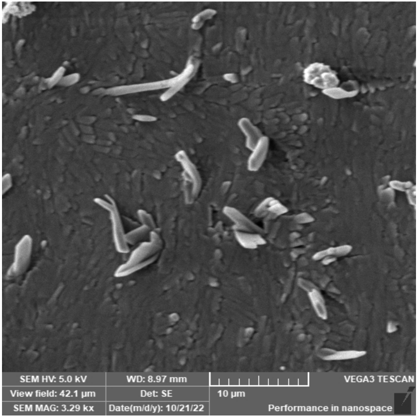
TPB coating film, exposed at 4 K.

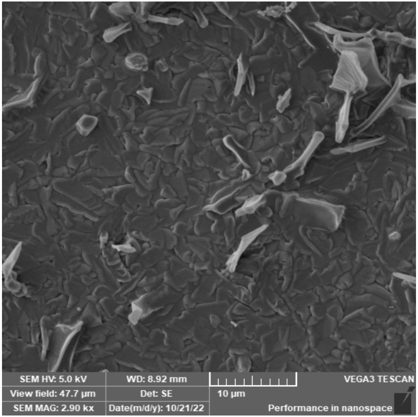
- Left picture: SEM scanning imagine on TPB coated film experienced at 4 K.



TPB coating film, exposed at 4 K.

- Left picture: SEM scanning imagine on TPB coated film experienced at 4 K.
- Right plot: SEM scanning imagine on TPB coated film W/O cryogenic experience.
- Published in JINST, 2022 JINST 17 P12001.

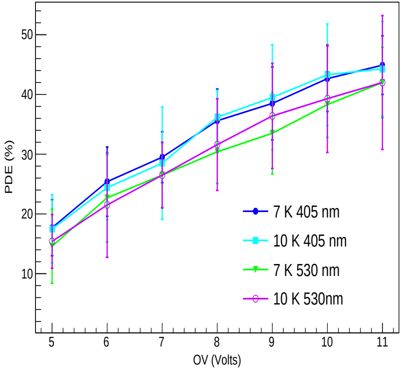




Outline

FBK SiPMs PDE @ 10 K and 7 K, 405 and 530 nm.

- FBK NUV-HD-Cryo SiPMs, ~ 100 mm^2.
- Lowest temperature being measured.
- 更详细的介绍，5月10号下午15:40马梅月楠报告。



FBK SiPMs after-pulse @ 10 K and 7 K (measured in dark).

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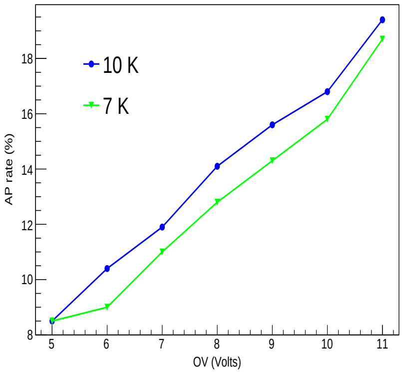

FBK SiPMs cross-talk @ 10 K and 7 K, 405 and 530 nm.

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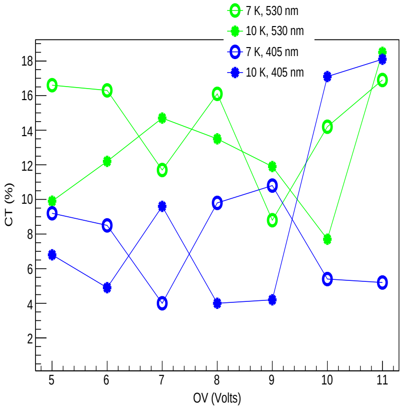

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Concept introduction

Traditional NR calibration implement fast neutrons

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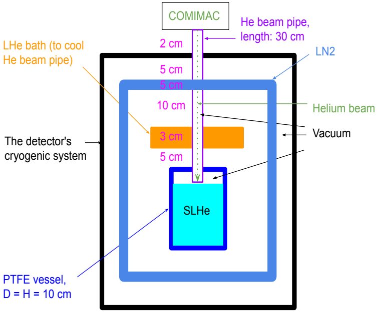

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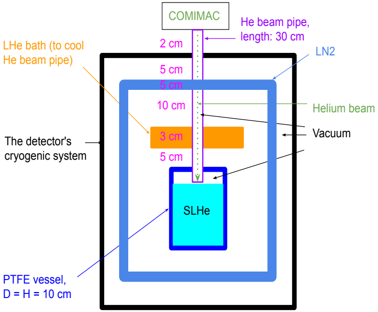
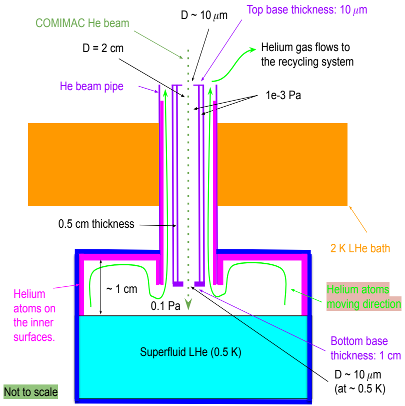
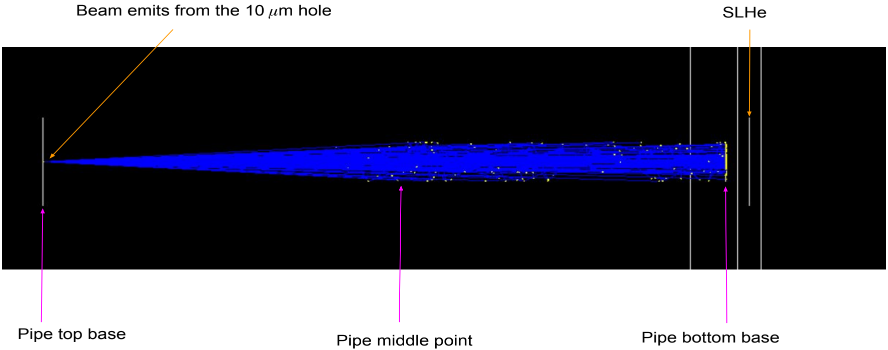




Beam introduction

- G4 simulation shows a typical beam tracjectory



Beam energy deposition in the journey before hitting SLHe

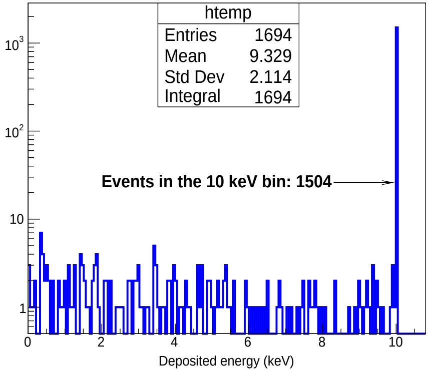
G4 simulation shows beam energy deposition in the journey is ignorable

- ~ 1 / 1000 of beam energy

Medium	**2 keV α**			**10 keV α**			**50 keV α**		
length (cm)	**G4** (keV)	**NIST** (keV)	**SRIM** (keV)	**G4** (keV)	**NIST** (keV)	**SRIM** (keV)	**G4** (keV)	**NIST** (keV)	**SRIM** (keV)
30.0 (1e-3 Pa air)	5.0e-5		9.6e-5	1.2e-4		1.4e-4	2.8e-4		2.6e-4
0.5 (0.1 Pa He_2)	1.7e-3	2.2e-3	2.3e-3	2.5e-3	2.6e-3	2.6e-3	5.2e-5	5.4e-3	5.4e-3
1.0 (0.1 Pa He_2)	3.2e-3	4.3e-3	4.7e-3	5.0e-3	5.2e-3	5.3e-3	1.0e-2	1.1e-2	1.1e-2
2.0 (0.1 Pa He_2)	6.2e-3	8.7e-3	9.3e-3	9.9e-3	1.0e-2	1.1e-2	2.1e-2	2.2e-2	2.2e-2
SLHe	1.6			9.2			50		

The events rate

- Events rate = (α particles in the beam) / (recorded meaningful events) ≅1.5 E-4
- The beam rate can go up to 100 kHz ⇒ ~ 10 Hz events rate.
- Paper already accepted in EPJP, suppose to come online this week.



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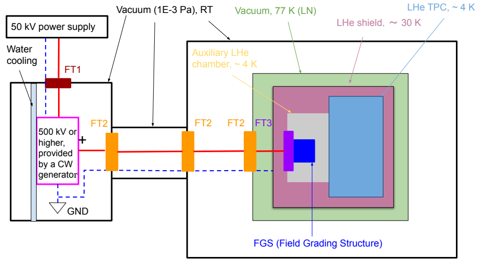
Transmitting ~ MV (Million Volts) into an LHe TPC, 2310.12504

- 10 kV/cm drift field is trade-off to get reasonable drift speed (2 m/s) and fraction of ion-e separation (~50%); 1m size TPC (~ 100 kg LHe) requires 1 MV.



FT1: 50 kV, RT, one side is air, another is vacuum.

FT2: 500 kV or higher, both sides are RT or 77K and vacuum, no need to seal.

FT3: 500 kV or higher, one side is vacuum and ~ 30 K, another is LHe and 4 K, seal vacuum from LHe.

FGS: Immersed in 4 K LHe.

—— : Thin wall tubing (304 SS); - - - - : Grounding cable or cathode.

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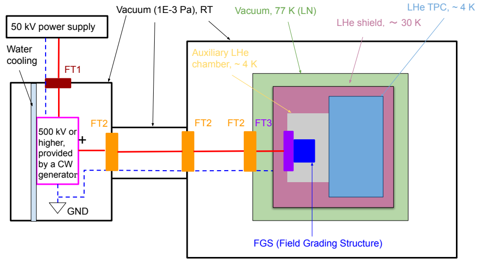
- Left plot: the preliminary scheme. Right plot: an electrode capable of delivering 100 kV is house-made at CIAE. Testing underway.



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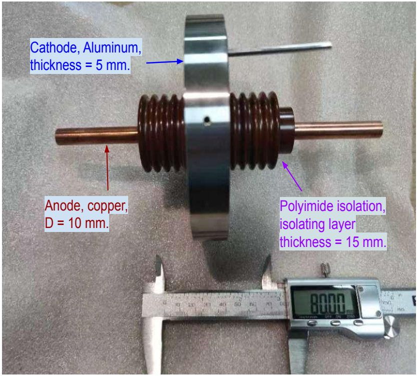

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- (a) detector assembly,
- (b) wavelength-shifter TPB coating,
- (c) FBK SiPMs are capable of working near LHe temperature.
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