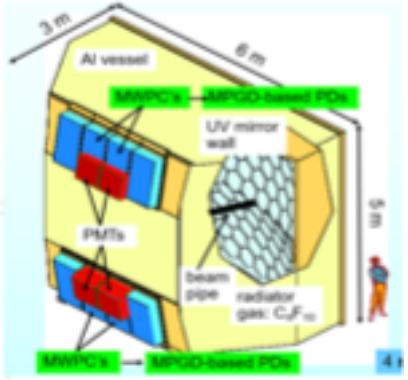
DLC photo-cathode and its initial trial in fast-timing MPGD

Yi Zhou[1], You Lv[1], Xu Wang[1], Lunlin Shang[2], Guangan Zhang[2], Zhiyong Zhang[1], Jianbei Liu[1]

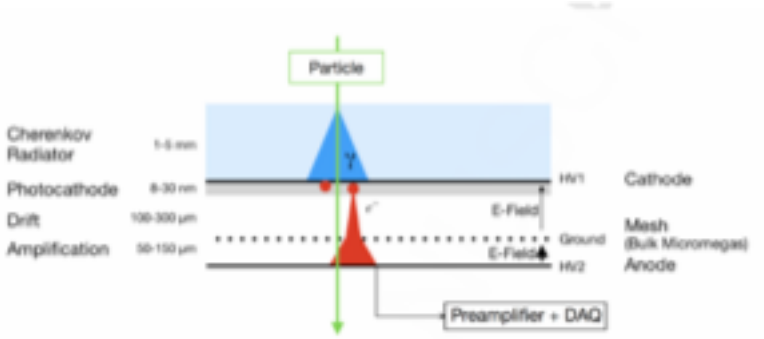
1. State Key Laboratory of Particle Detection and Electronics, University of Science and Technology of China
2. State Key Laboratory of Solid Lubrication, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences

Photo-cathode in a gaseous environment

- Gaseous photon detectors have lots of advantages over other photon detection techniques.
- They are a viable option for large-area photon detection
  - Successfully employed in RICH detectors of many nuclear and particle physics experiments.
- A new exploration: fast-timing with MM (PIC-SEC)
- Photo-cathode is extremely crucial to gaseous photon detectors
  - It has to work stably and robustly in a gaseous environment.



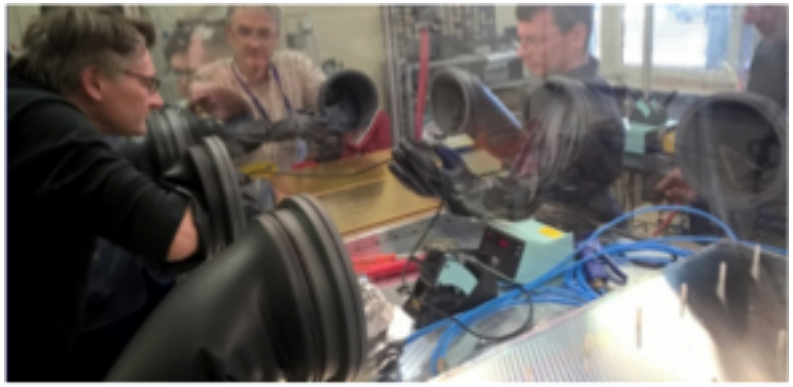
RICH @ COMPASS



PIC-SEC

Available photo-cathode

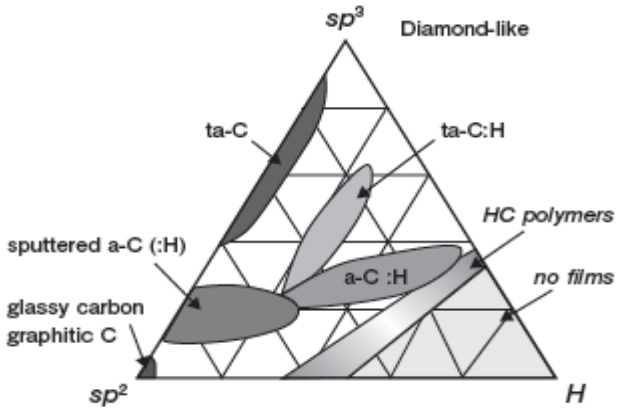
- CsI is the standard photo-conversion material for gaseous photon detectors so far. However, it is susceptible to exposure to air (H2O and O2) and ion bombardment.
  - Complicated fabrication and operation of detectors
  - Limited radiation hardness and rate capability
- Finding alternative photo-cathodes for gaseous photon detectors is highly desirable and demanded.

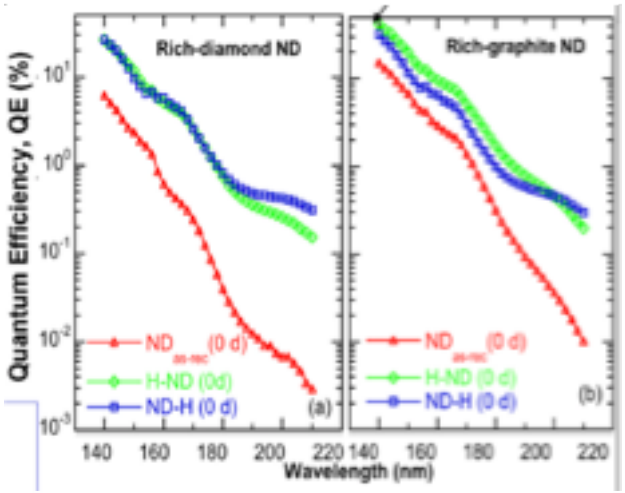


Talk on COMPASS RICH by Silvia Dalla Torre at Elba2018

DLC as an photo-cathode ?

- DLC – Diamond-like carbon
  - Widely used in industry as a solid lubricant
  - Recently introduced to the MPGD field as excellent resistive electrodes
- A very robust material. Could it make a photo-cathode?
  - Graphite-enriched (sp2)?
  - ta-C , a-C or somewhere else?

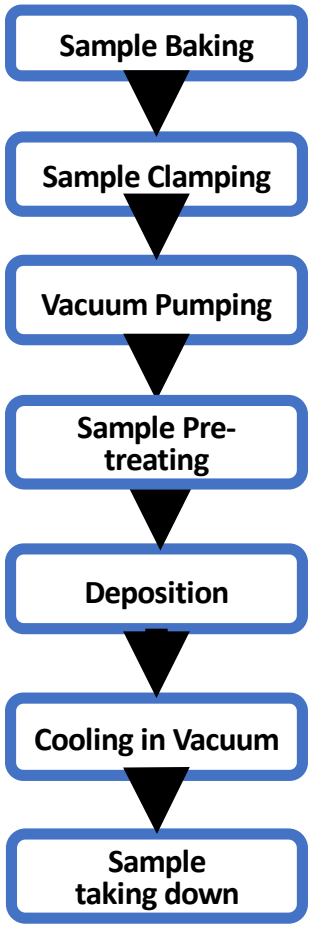




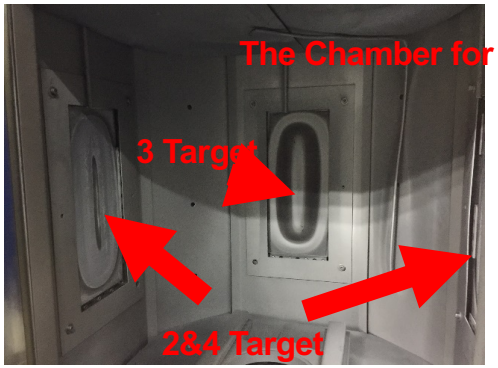
L.Velardi, A.Valentini, G.Cicala al.,
Diamond & Related Materials 76 (2017) 1

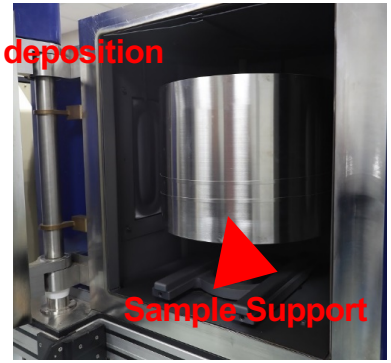
Talk on COMPASS RICH by Silvia Dalla Torre at Elba2018

DLC deposition procedure and devices



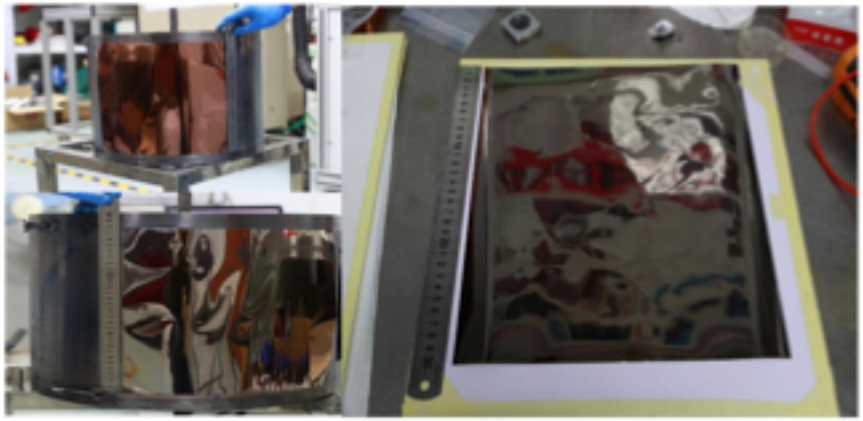
1. Baking base material at 70 degrees for 12 hours.
2. Vacuum pumping to remove the air from the chamber.
3. Start procedure to coat DLC on the pre-treated sample.
4. Cooling in vacuum to release the inner stress uniformly of the sample.





DLC samples and quality control

- Started with making resistive coating
- Found out a way to well control resistivity of DLC films and produced resistive samples of quality.
- DLC resistivity may provide access to “graphite (sp2) content” ?
- To Modify the composition of DLC (sp2:sp3) by adjusting sputtering parameters



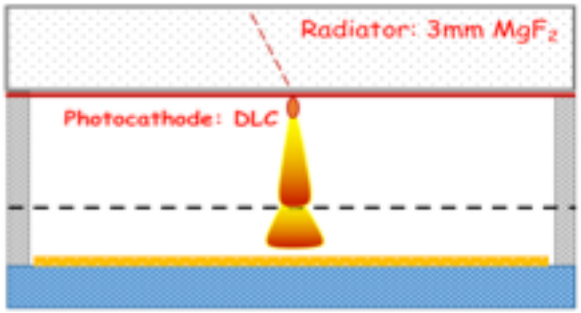
Sample	Current	Deposition Time	Resistivity
#1	0.5 A	160 min	Outrange
#2	1.0 A	125 min	~50 MΩ/□
#3	2.0 A	40 min	~300 MΩ/□

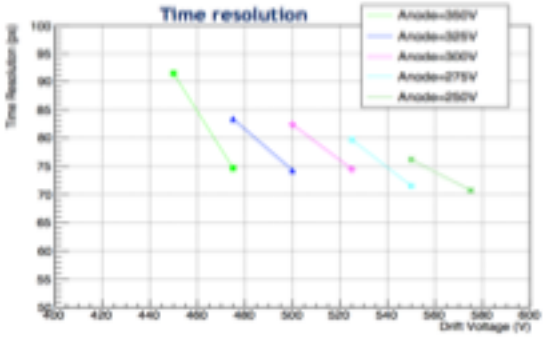
Sample	Initial vacuum degree	Resistivity
#1	1.7×10^{-5}Torr	~80 MΩ/□
#2	1.2×10^{-5}Torr	~50 MΩ/□
#3	0.3×10^{-5}Torr	~8 MΩ/□

DLC photo-cathode samples

- First tried on quartz plane and observed signals with a PIC-SEC for cosmic-rays.
- Then made two DLC photo-cathodes on 3mm MgF2
  - Sputtered for 10 mins (so called 20 nm)
  - Sputtered for 20 mins (so called 40 nm)

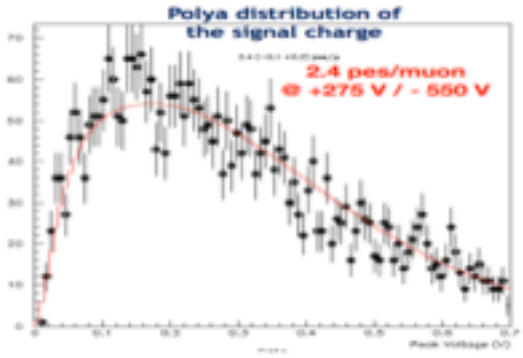
PIC-SEC with DLC photo-cathode





"10-min" DLC

MgF_2	Substrate	Nphe	Res (ps)
3 mm	6 nm Al	1.69 ± 0.01	71.4 ± 1.8
5 mm	10 nm Al	2.20 ± 0.05	57.6 ± 0.6



With the "10-min" DLC:

- Time resolution down to 70ps
- 2.4 PEs/3mm, better than Al (2.2 PEs/5mm).
- Efficiency: ~85%

Performance of "20-min" DLC worse than the "10-min" one.

"Recent results of PIC-SEC" by Lukas Sohl at this meeting

Robustness of DLC photo-cathode

- Evidence for DLC being robust
  - Transported to CERN in atmospheric environment without any extra protection.
  - Tested for two weeks at CERN
  - No ageing effect observed

Plans

- Make DLC films with different thicknesses (from 5nm – 30nm)
- Investigate how to make “graphite-like” carbon in a controlled way
- Make DLC photo-cathode samples (MgF2 + Cr + DLC) with different graphite content.
- Test quantum efficiency for these samples
  - Collaborate with Xi’an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences
- Engage with material and electro-optics experts for guidance

Outlook

- Robust photo-cathode compatible with detector gas is a R&D topic of great interest to lots of applications
- DLC might be a potential candidate
- A breakthrough in this area could revolutionize gaseous photon detection
  - Fast-timing gaseous detectors based on Cherenkov radiation
  - RICH detectors for PID for future NP/HEP experiments
    - CEPC, STCF, EIC …
  - …