Study of DLC photocathode for PICOSEC detector

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Outline

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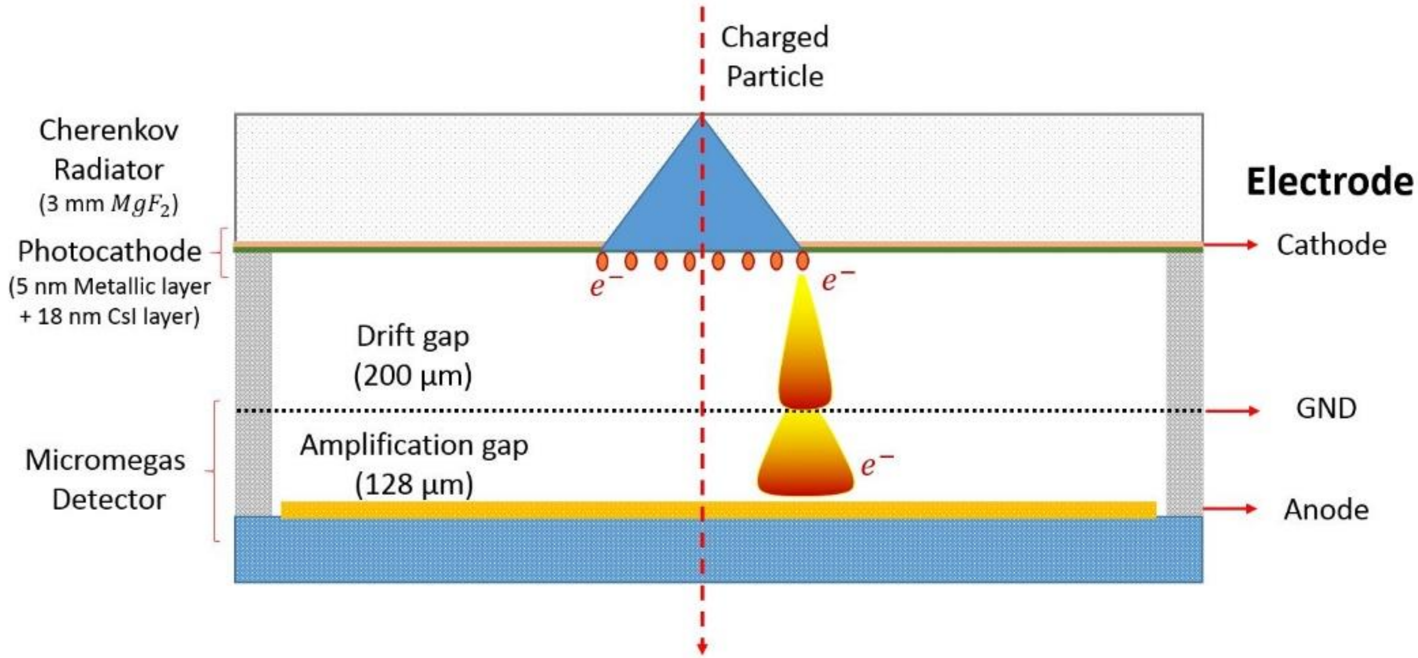
  - Beam test with CsI photocathode
- Diamond-Like Carbon (DLC) Photocathode
  - Manufacture
  - Quantum Efficiency test with laser
  - Preliminary results of Beam test
- Conclusion and Future work

Detector Concept

PICOSEC detector

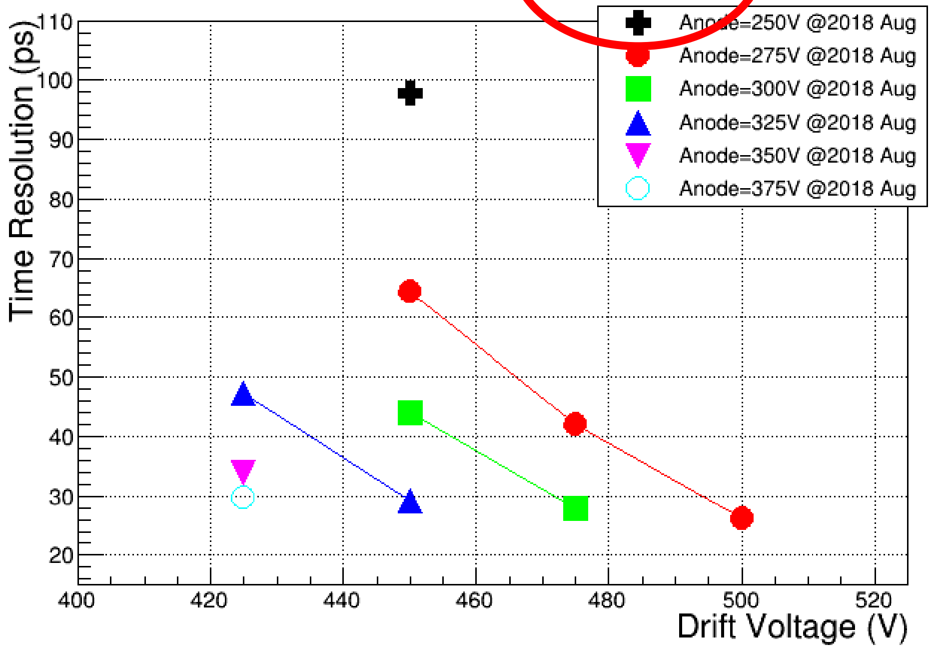


Novel fast timing Micromegas detectors: **Photon detect**

- Cerenkov Radiator & Photocathode
- Smaller drift gap
- Higher electric field

Beam test results

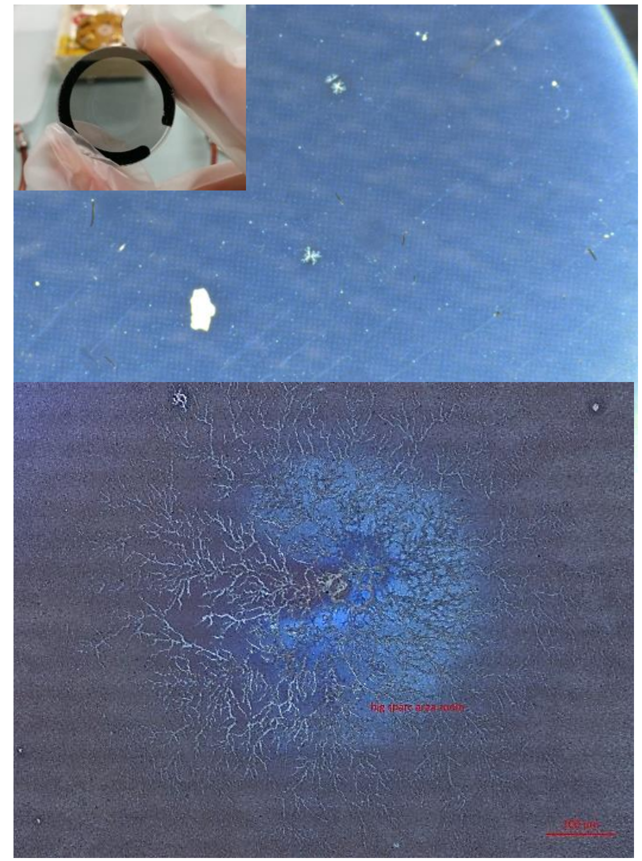
USTC PICOSEC detector (18 nm CsI)



CsI aging problem

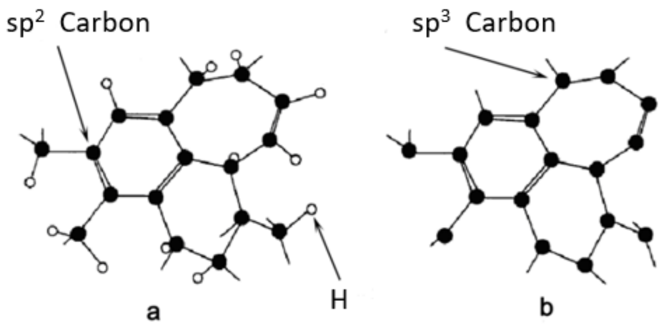
Sparks

High IBF

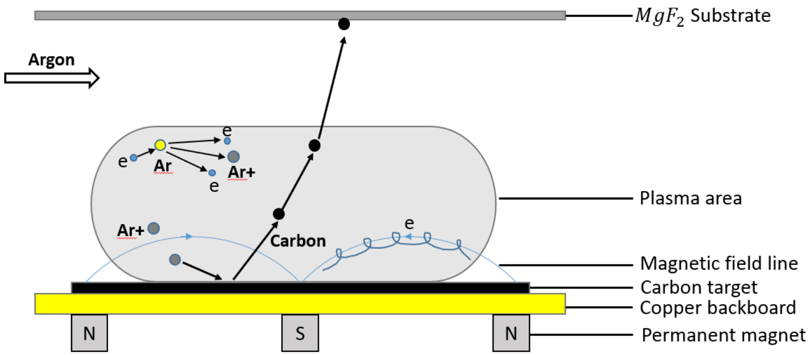


- Time resolution reaches: 28 ps
- Mean number of photoelectrons per muon: 7.4
- Detection efficiency for muons: 100%
- Ion back-flow (IBF) ratio: 42.7% @ -475V / +300V

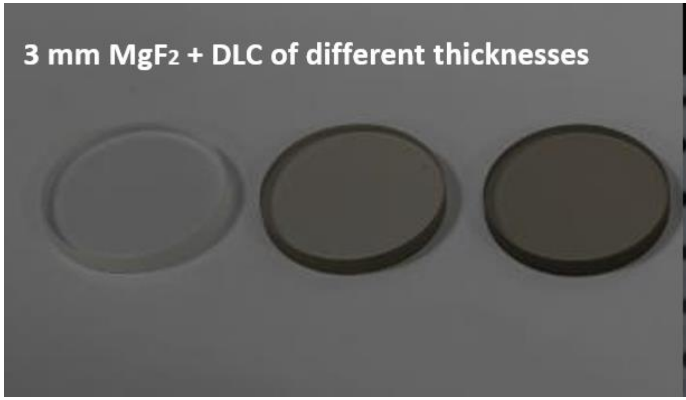
Diamond-Like Carbon (DLC)



Structure of the DLC,
sp^2: graphite-structure
sp^3: diamond-structure



Schematic of DLC deposition by
magnetron sputtering technology

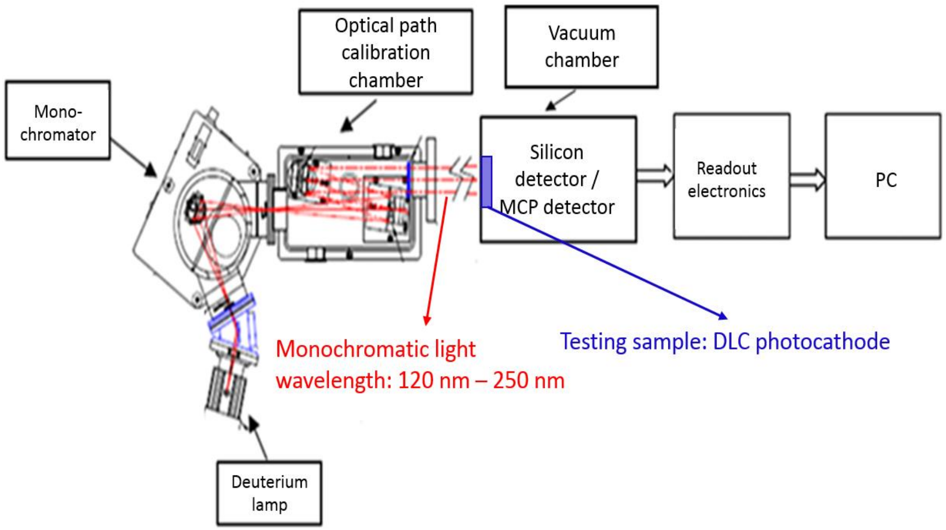


DLC samples we made
Thicknesses: 1 nm, 2.5 nm, 5 nm, 7.5 nm, 10 nm

Fixed MgF2 crystal in the vacuum chamber of the coating machine

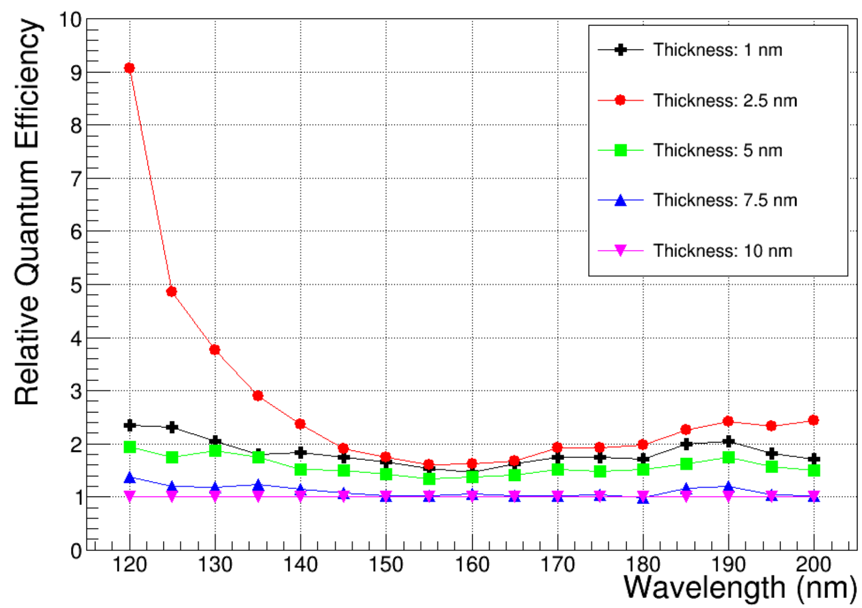
QE test with Laser

Quantum efficiency test system in laboratory



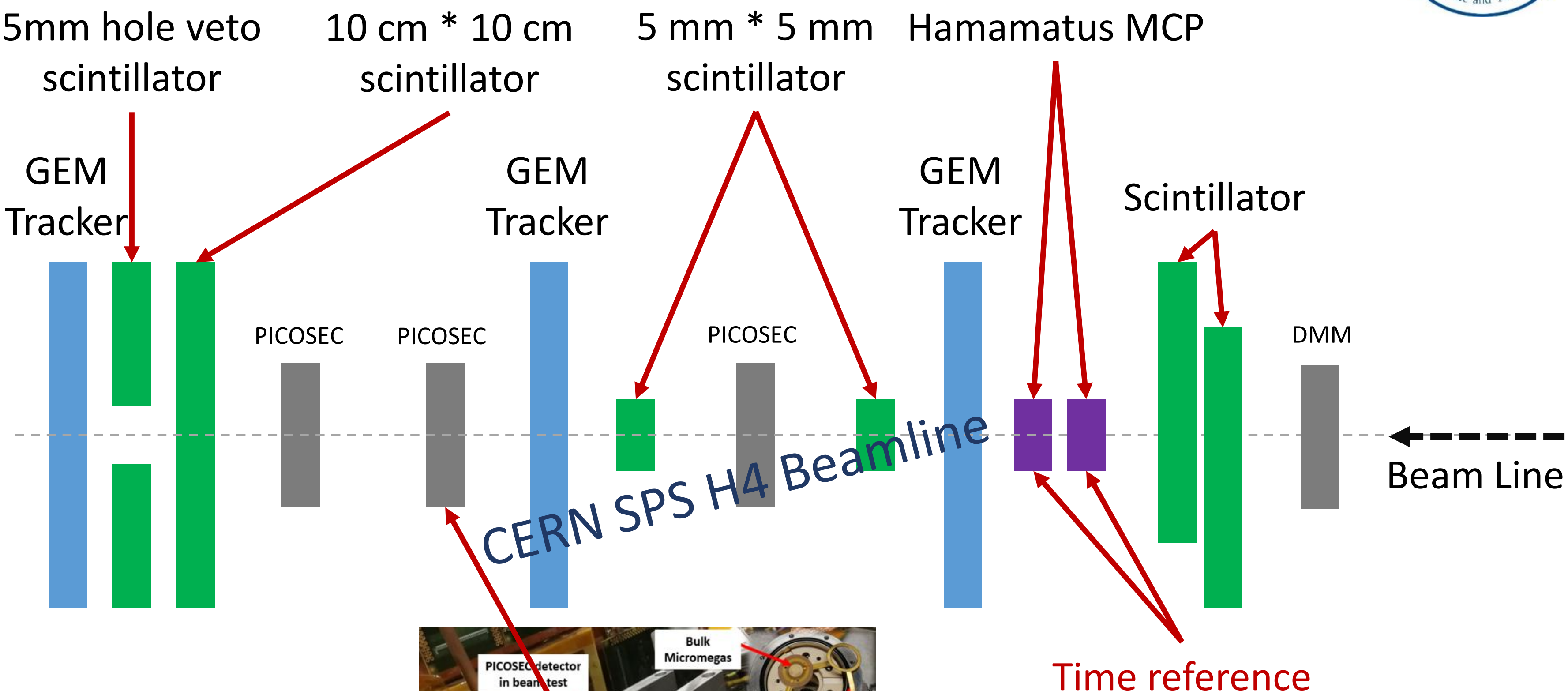
- Silicon detector (No DLC sample)
  Incident photons flux
- MCP detector (DLC sample)
  Photoelectrons generation rate

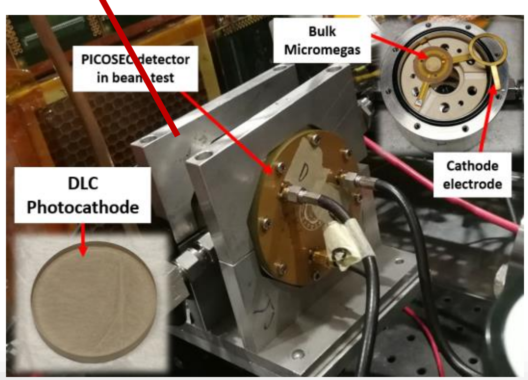
Relative QE of DLC with different thicknesses



- Absolute QE is not very high (< 1 %)
- 2.5 nm samples shows the best performance
- 10 nm DLC photocathode has been tested by
  muons: 2.4 Pes/3mm MgF_2; 85% efficiency

Beam test of DLC photocathode

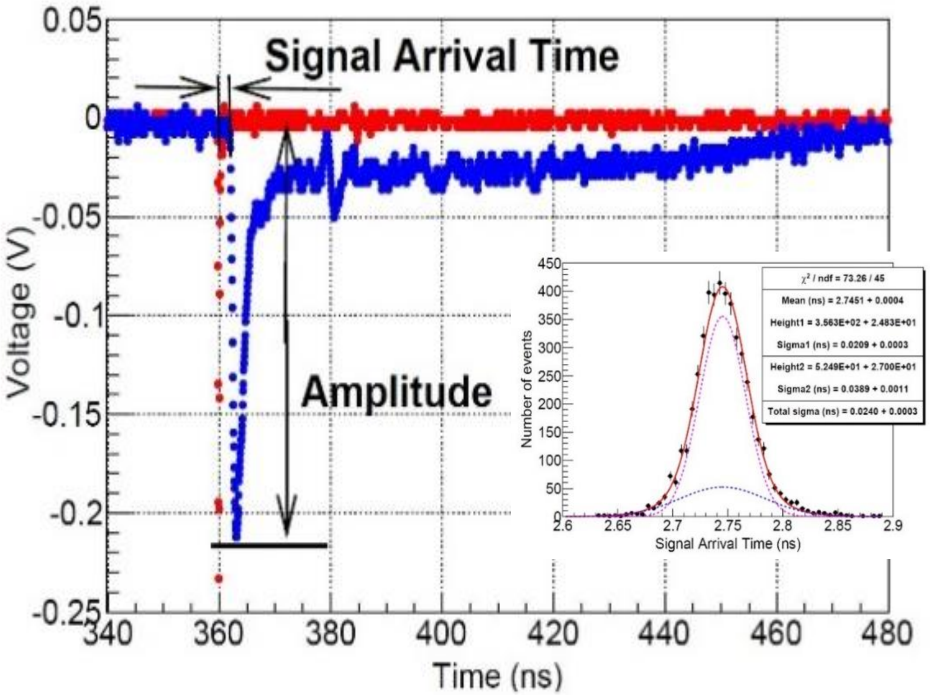




PICOSEC detector in beam test
Active area: Φ1 cm

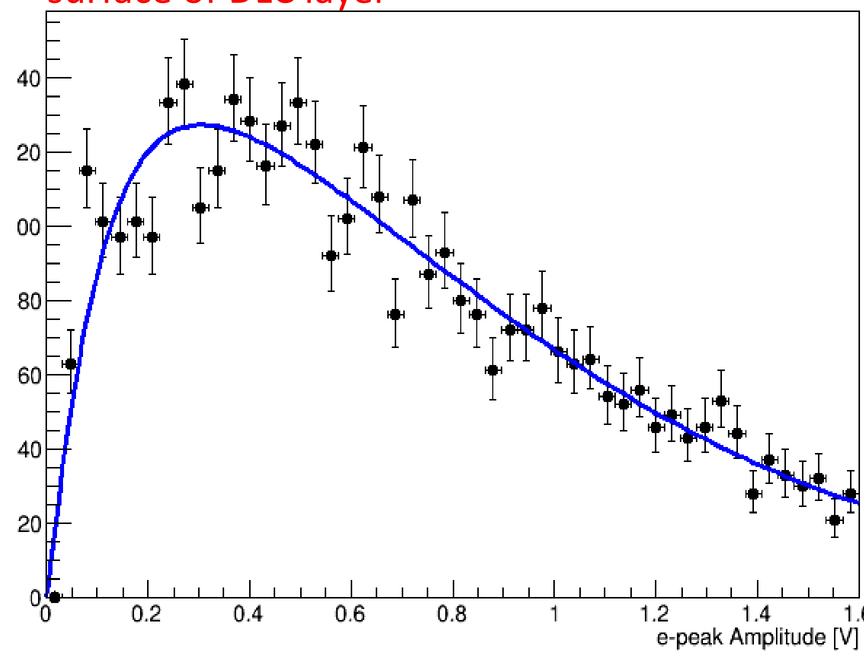
Data analysis

Time Response



- Blue : Sample waveform of PICOSEC detector generated by 150 GeV muon
- Red : Related MCP PMT signal
- Signal Arrival Time: time difference between PICOSEC and MCP (Constant Fraction Timing)

Npe: mean number of photoelectrons generated by Cherenkov light on the surface of DLC layer



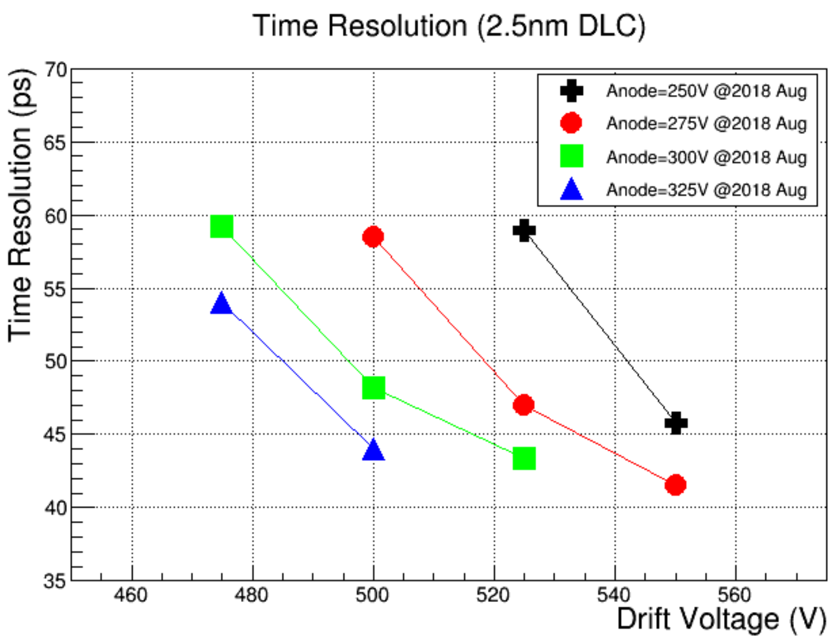
- Single photoelectron calibration: UV lamp
- Negative log Like-hood

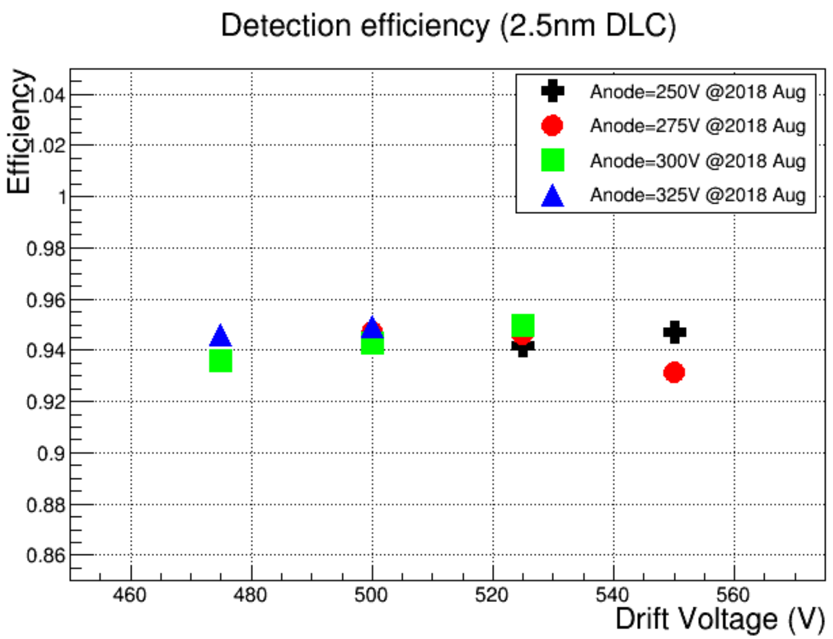
Npe results of different samples

Thickness of DLC film (nm)	Npe/per muon	Detection efficiency for muons
1	Bad	Bad
2.5	3.7	97%
5	3.4	94%
7.5	2.2	70%
10	1.7	68%
5 nm Cr + 18 nm CsI	7.4	100%

- 2.5 nm sample is currently the optimal one , with 3.7 Npe/per muon and 97% efficiency (the best results of several 2.5 nm samples)
- These results are repeatable:
  - two independent beam tests
  - different samples in same condition

Timing results of DLC photocathode





- The best time resolution reaches 42 ps with 2.5 nm DLC photocathode
- Npe: 3.5/per muon
- Detection efficiency for muons: ~ 95% (the best is 97%)

Aging of DLC photocathode

- Durable DLC photocathode
  - Stored in atmospheric environment for a few months, without any extra protection
  - Worked stable during beam period
  - No performance degradation by muons for a few days

- Pions irradiation
  - 2.5 nm DLC photocathode was placed in a Resistive PICOSEC detector (-525/+275)
  - 11 hours (voltage on 3.5 hours)
  - 3.5 h: pions trigger $\sim 1.4 \times 10^7$

	Npe/per muon	Detection efficiency
Before pions	3.5	95%
After pions	3	94%

Conclusion

- Laser test: 2.5 nm sample shows best performance
- Beam test: 2.5 nm sample is also the best one
  3.7 Npe / per muon 97 % detection efficiency
- PICOSEC detector timing response with DLC photocathode
  42 ps by muons,3.5 Npe / per muon, 95% detection efficiency
- Npe reduced form 3.5 to 3 after 11 hours (voltage on 3.5 hours) of pions irradiation

Plans

- Find a suitable thickness of DLC layer which is robust enough, as well as suitable QE
- Optimize the process of DLC deposition:
  doping, heating… …
- Improve quantum efficiency test system
- Aging research in lab with laser (213 nm):
  Figure out the impact of IBF
- … …