Thoughts about the Sensor Options for the PANDA DIRCs

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- Challenges to photon sensors
  - Barrel DIRC
  - Endcap DIRCs
- Pros and cons of different sensors
- Conclusion

Challenges to Photon Sensors

	Barrel DIRC	Focussing Endcap DIRC	TOP Endcap DIRC
Magnetic Field magnitude [T]	0.5 – 1.0	0.5 – 1.0	1.0 – 1.5
orientation vs PMT axis	?	?	?
Time resolution [ps]	< 100	~300	< 50
Photons after QE per track	?	?	?
Rate [MHz/cm^2]	0.2	1	2
Lifetime [C/cm^2/y] at 10^6 gain	~1	~5	~10

Sensor Candidates

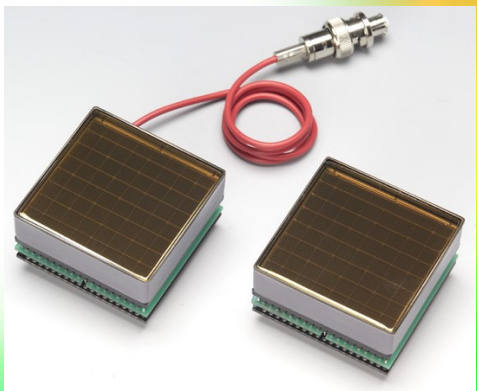
allowing an efficient detection of single photons

- multi-anode photomultiplier tubes (MaPMTs)
- fine-mesh photomultiplier tubes
- hybrid photo diodes (HAPDs)
- **Geiger-mode avalanche photo diodes** (SiPMs)
- **micro-channel plate photomultipliers** (MCPs)
- diamond dynode photomultipliers ?

MaPMT

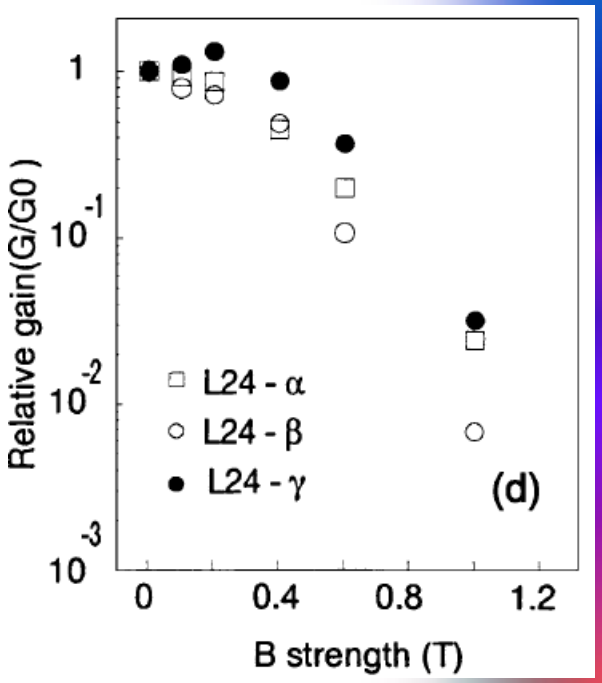
- H6568 (and R7600)
  - used for COMPASS RICH and SciFis
  - operable in fields up to 100 mT (with 3mm shielding)
  - TTS = 400 ps (σ) for single photons (= s.ph.)
  - 36% geometrical efficiency (G.E.); ~20% Q.E.
- R8900
  - rather poor time resolution (TTS ~ 300 ps)
  - ~80% G.E.; super alkali cathode (~30% Q.E.)
  - cross plate anodes (position resolution for s.ph.?)

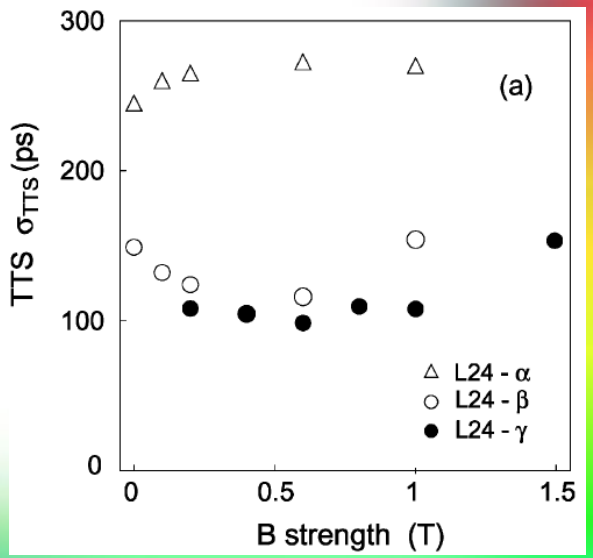
- H8500
  - fair time resolution (~140 ps for s. ph.)
  - 8x8 pixels and **89% G.E.**
  - up to **35% Q.E. with special photo cathode**



Fine-Mesh PMT

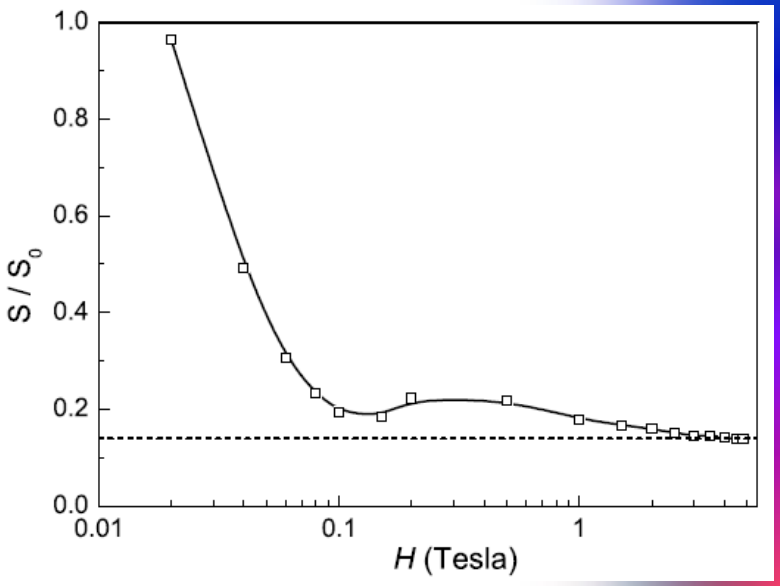
- usable in magnetic fields up to ~1 T
  - conventional dynodes replaced by 15-19 stages of a very thin grid (~10µm pitch)
  - massive gain drop in high magnetic field
  - hardly usable for s.ph. detection
- no multi-anode tubes available
  - development work of Nagoya group in collaboration with Hamamatsu (L24 for s.ph. detection) was abandoned
- moderate time resolution
  - ~100 ps for s.ph. with L24
  - TTS(m.ph.) = 150-200 ps for other tubes



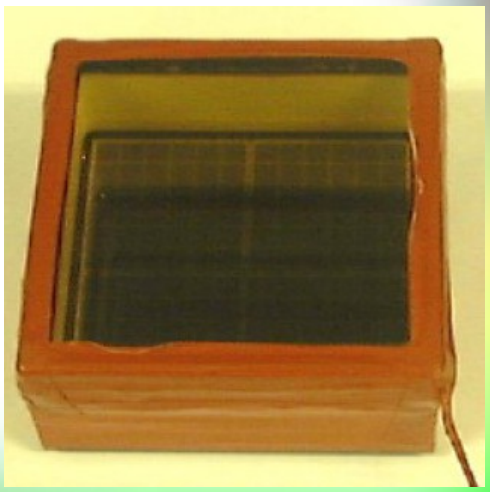


Hybrid photo diode

- Electrostatic focussing HAPD
  - 10-20 kHz operation voltage
  - field should be homogeneous and parallel to HAPD axis
  - problems with G.E. inside B-field
  - also problems with ion feedback
    → aging of photo cathode ??

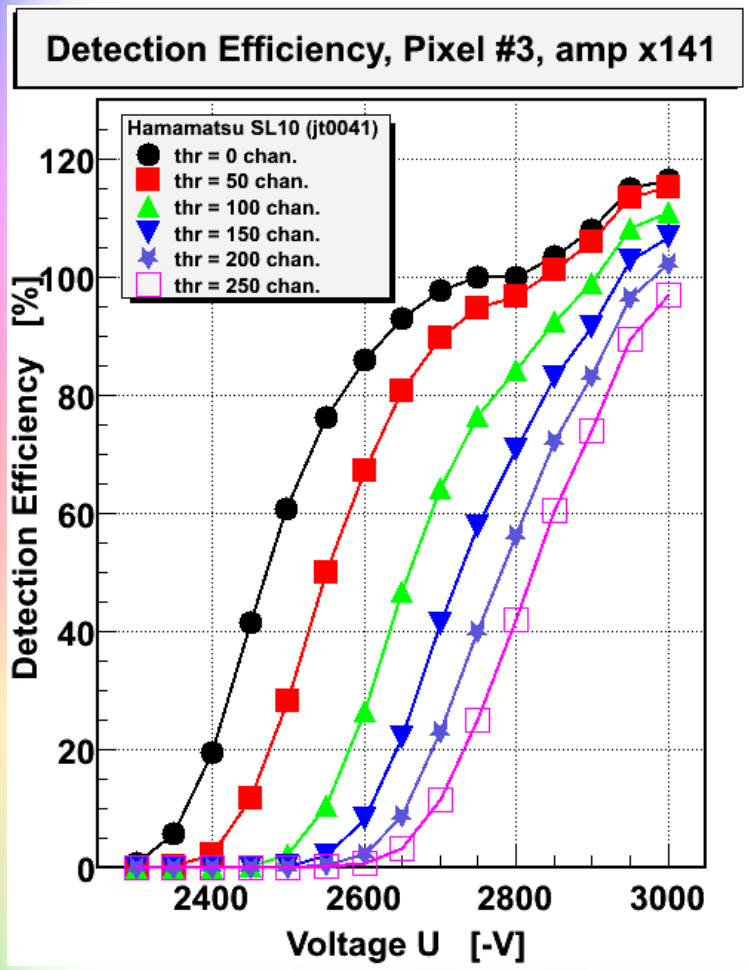


- Proximity focussing HAPD
  - Hamamatsu development for Belle
  - 144 chan.; effective area ~65%
  - what about time resolution? (typical time resolution of HAPD >>100 ps)
  - what about p.c. aging?

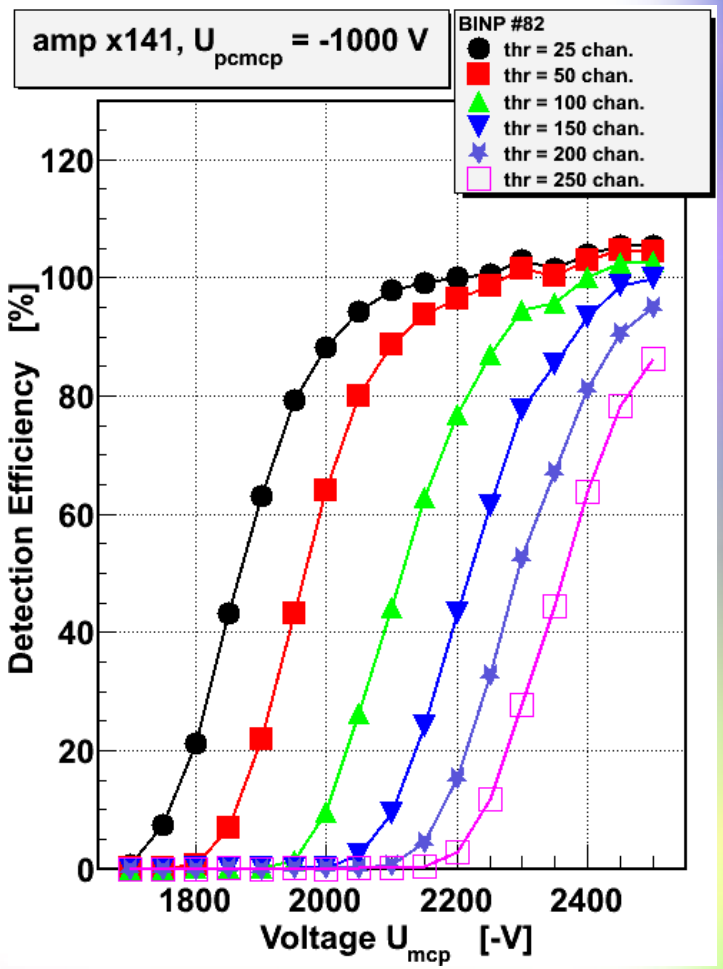


Detection Efficiency of MCP-PMTs

Hamamatsu SL10



BINP #82



Detection efficiency depends heavily on gain (= HV) !!

Conclusions (Realistic Sensor Options)

- Barrel DIRC
  - MaPMTs (if outside magnetic field)
  - MCP-PMTs (Burle Planacon with 10μm pore size)
- Focussing Endcap DIRC
  - MCP-PMTs (10μm Burle Planacon or Hamamatsu SL10)
  - Cooled SiPMs
- TOP Endcap DIRC
  - Most likely SiPMs or HAPDs will not give sufficient time resolution (<50 ps) for single photons
  - Diamond dynode PMTs ??
  - **MCP-PMTs (SL10 with Al protection layer)**