

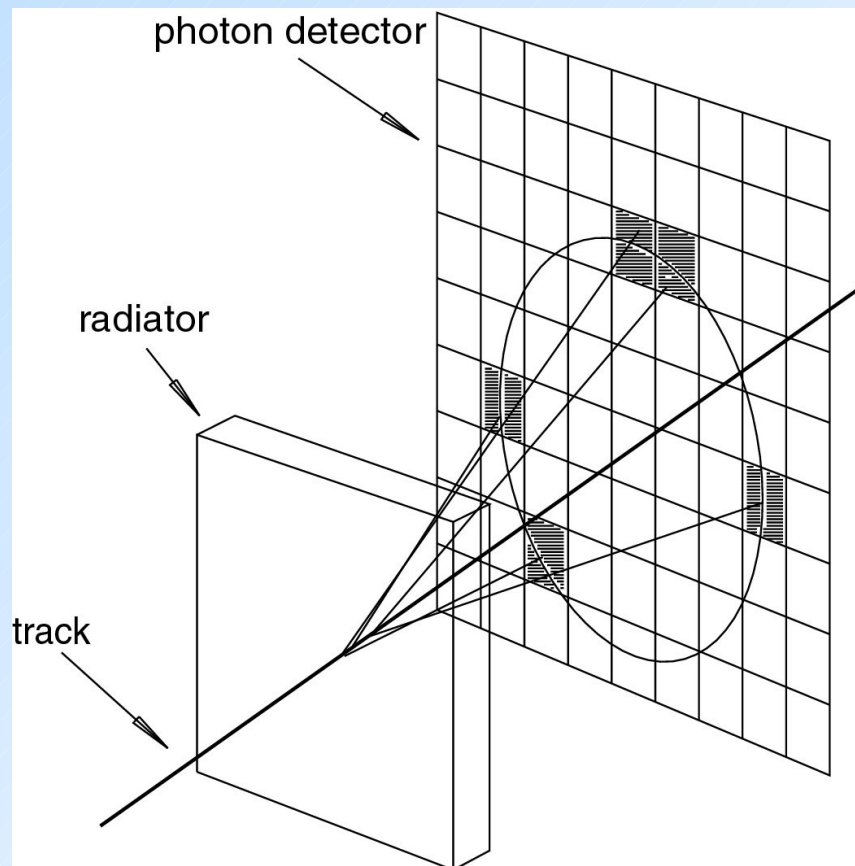
End-cap PID status

(Belle aerogel RICH group)

University of Maribor and Jožef Stefan Institute, Ljubljana
Super KEKB - 2nd Open Meeting, 17-19 March 2009

Outline:

- HAPD progress
- MCP-PMT progress
- Summary - plan



Parallel session contributions for E-PID

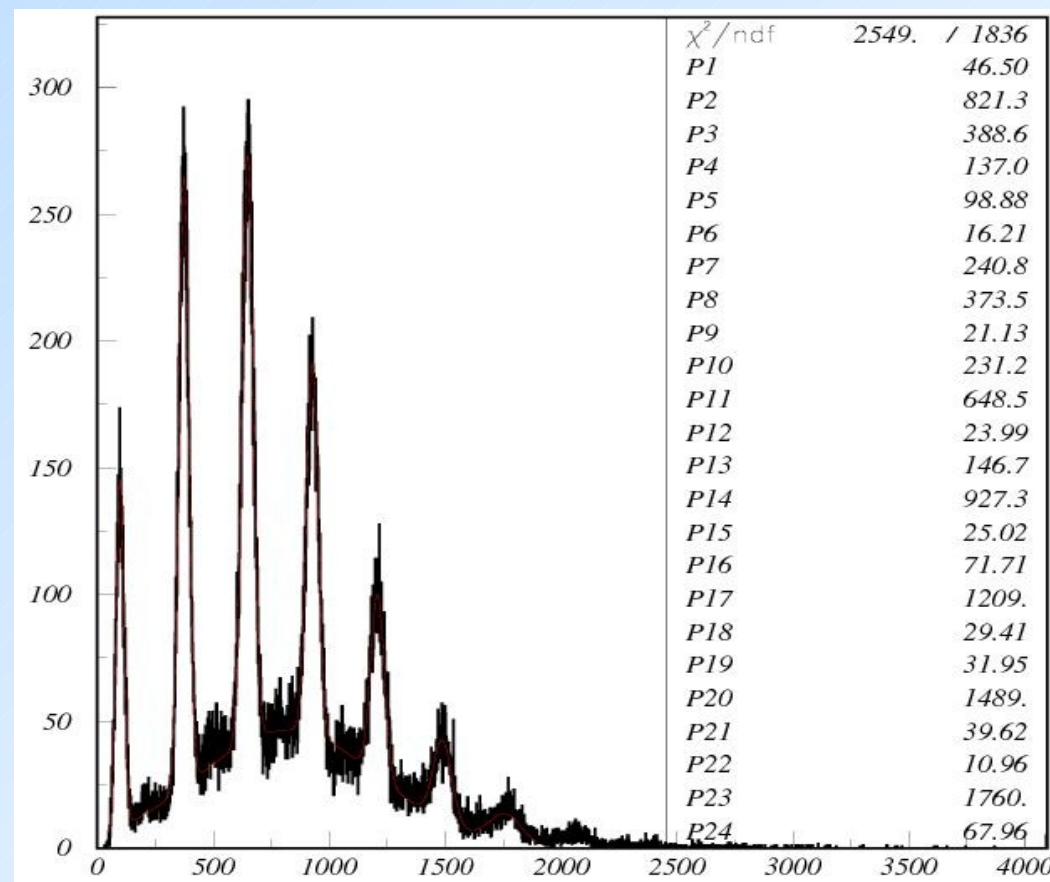
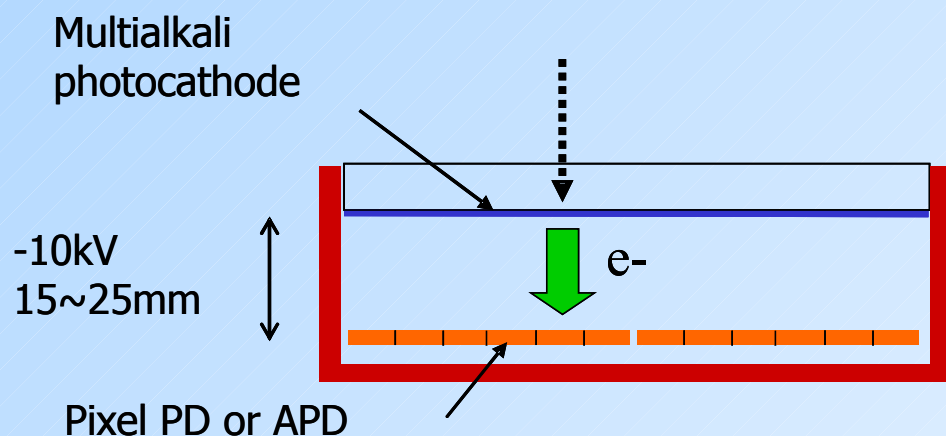
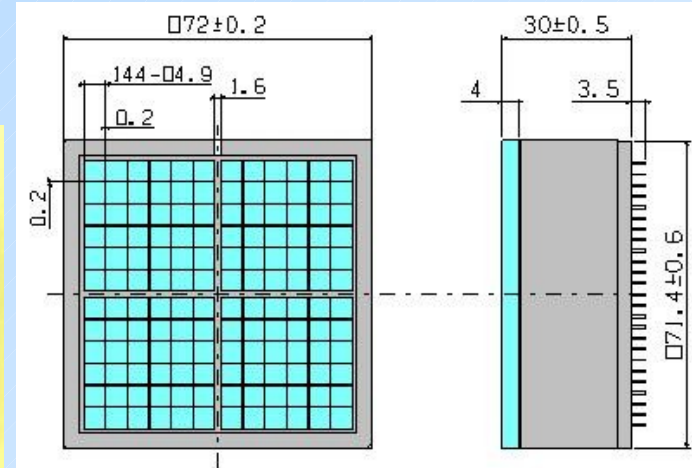
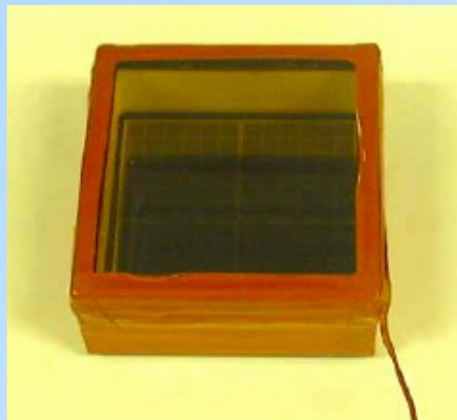
- HAPD status
(I. Adachi)
- HAPD ASIC status
(S. Nishida)
- MCP-PMT status
(S. Korpar)

	HAPD	MCP-PMT	MPPC
N_{ph}	7 (\rightarrow 14)	10 (\rightarrow 15)	30
σ_{ϑ}	14	15	14
B = 1.5T	OK (improved perf.)	OK (improved perf.)	OK
long term stab. (aging)	OK (HV stability?)	OK?	OK
neutron damage	leakage current? \rightarrow signal / noise	OK(?)	X
production	2.5 y	2 y	?
pieces	< 600	< 1000	< 500000
cost / piece	< 7000 €	< 4000 €	< 20 €
electronics	ASIC	WFS	WFS
channels	~ 75k	~ 60k	~ 120k

Photon detector candidate: HAPD

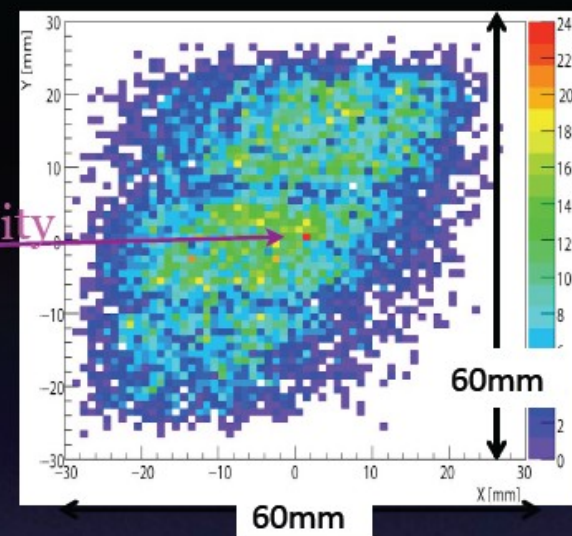
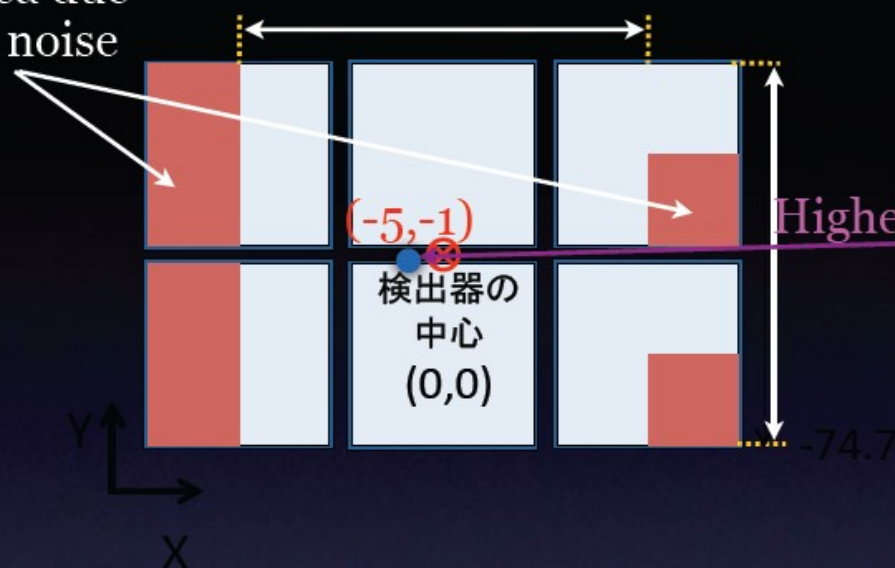
Hybrid avalanche photo diode - proximity focusing configuration:

- 12x12 channels ($\sim 5 \times 5 \text{ mm}^2$)
- size $\sim 74 \text{ mm} \times 74 \text{ mm}$
- $\sim 65\%$ effective area
- total gain $\sim 10^4 - 10^5$
- detector capacity $\sim 80 \text{ pF}$
- peak QE $\sim 25\%$
- works in mag. field perpendicular to the entrance window



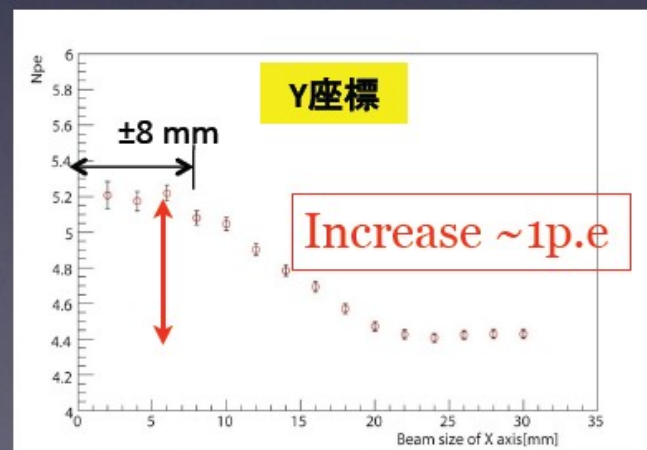
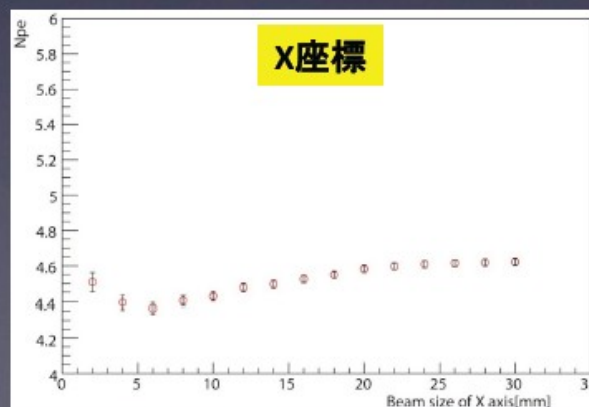
HAPD N photons - beam test

Dead area due to large noise

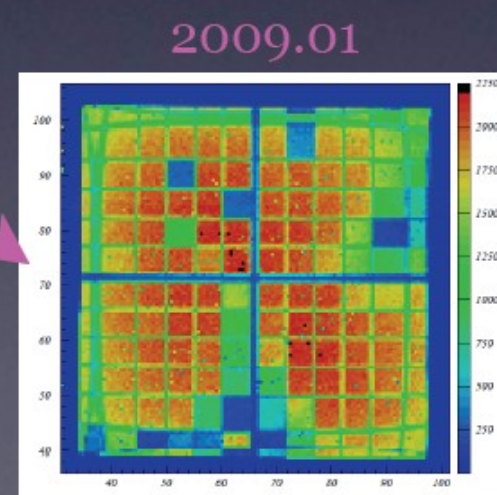
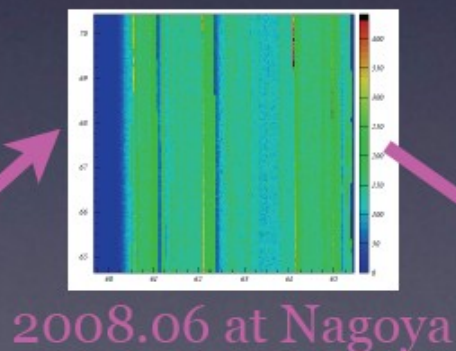
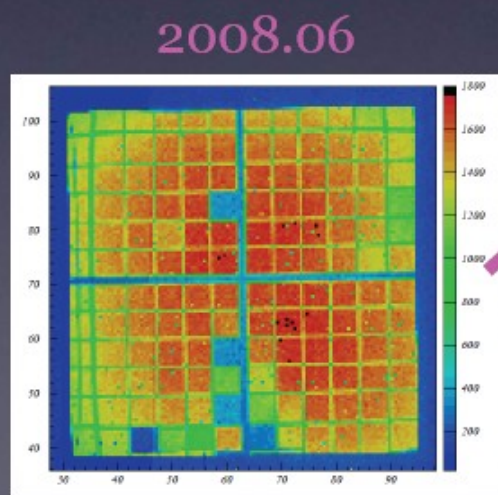


- Large incident beam size
 - 2x3 HAPD array can not cover whole Cherenkov ring area?
 - check Npe by changing beam size cut from the center.

Npe



- History of SHP74
 - Used in 2008 June beam test.
 - Two or three quartz windows added with optical oil to study BG effect
 - After that, large noise found at Nagoya
 - mitigated if lower HV of 4.0kV was applied
 - Disappear noise in 2009.01, however, some dead/insensitive channels observed
 - Guess: noise triggered by optical oil ?, not from vacuum degradation



HAPD neutron damage

● Samples

- 1 HAPD (SHP99)
 - chip-A dead
- 3 types of APDs
 - same as that in HAPD
 - standard
 - CMS-type (rad-hard)

● Irradiation

- “Yayoi” reactor
- 1st day
 - expose 10^{10} neutrons/cm²
 - equivalent to ~1 Belle year
- 2nd day
 - expose 5×10^{11} neutrons/cm²
 - equivalent to ~5 Super Belle year
- Check 1 p.e. signal and leak current

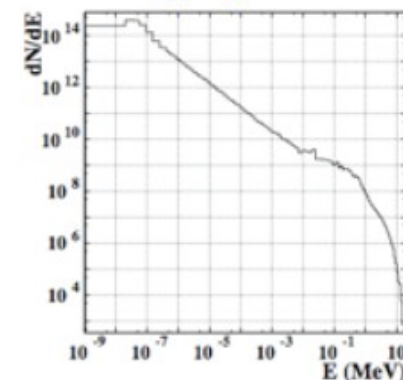
❑ Reactor “弥生(YAYOI)” @Tokai

- Maximum 2kW
- $E_{av} = 370$ keV
- $\sim 4 \times 10^5$ neutron/cm²/Wsec
($\times 0.4$ for 1 MeV convention)

❑ Fluence

- $10^8 - 10^{12}$ /cm²

Energy Spectrum

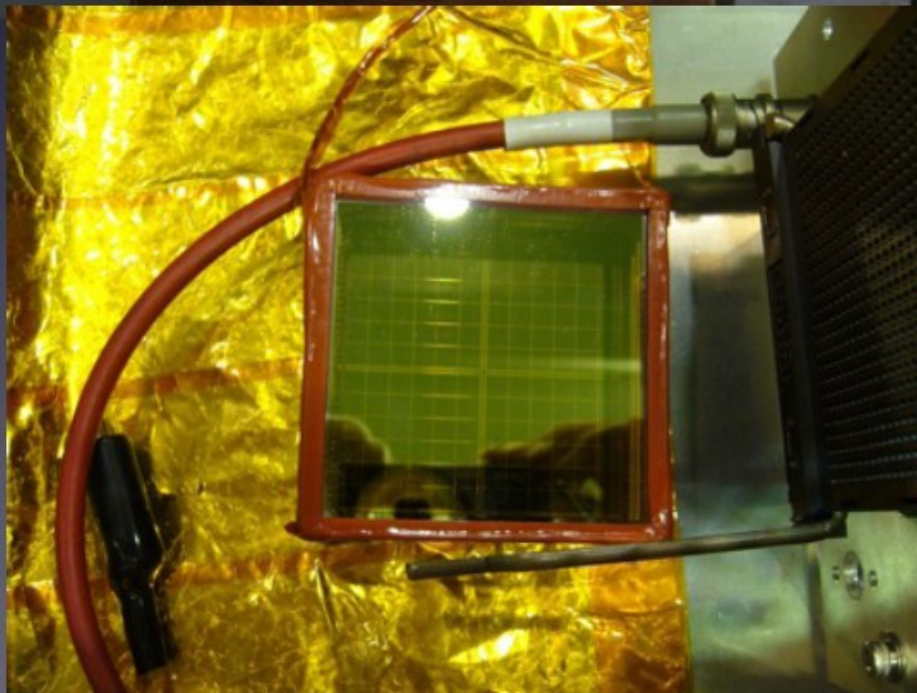


measured in a preparation room

measured on the top of the reactor

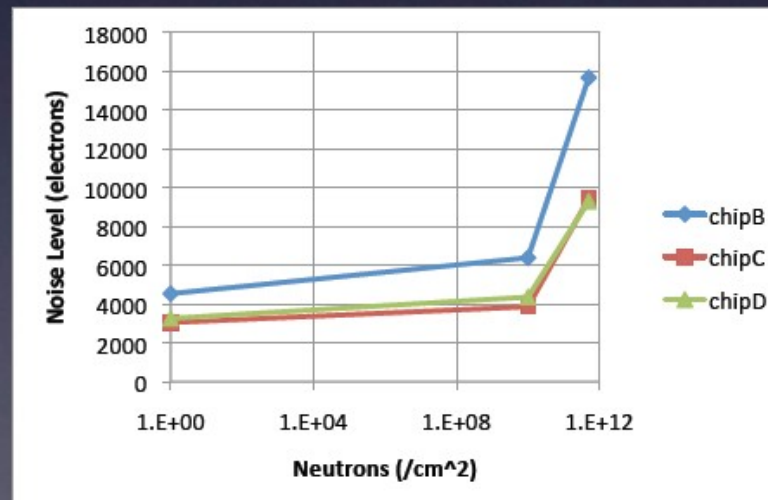
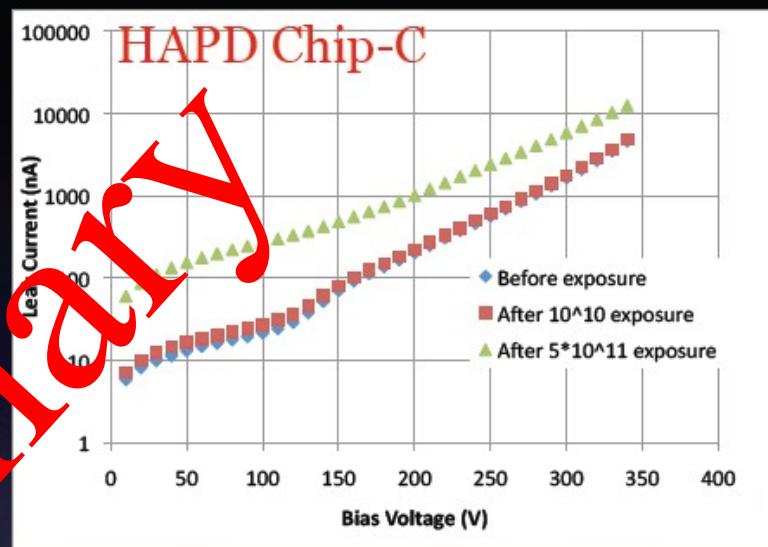
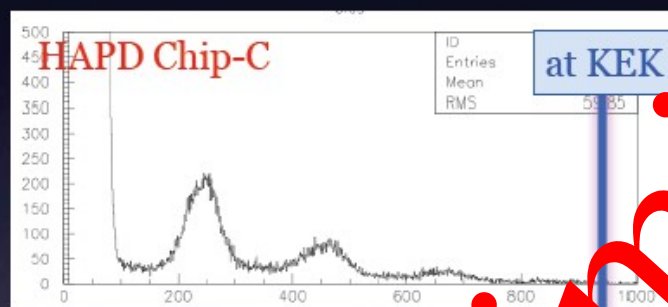
samples highly radio-active
they can not be picked up

Neutron irradiation test



HAPD neutron damage

- Leak current & noise level
 - 2-3 times larger after 5×10^{11}
- Single photon spectrum



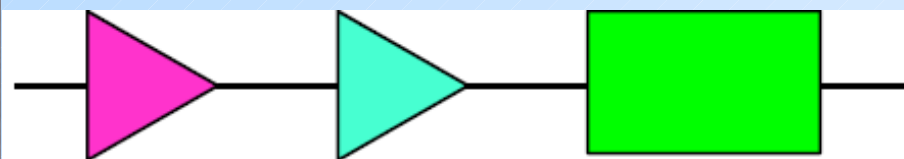
All measurements were done using self-gated mode

Optimization for read-out not yet done

New production facility at HPK

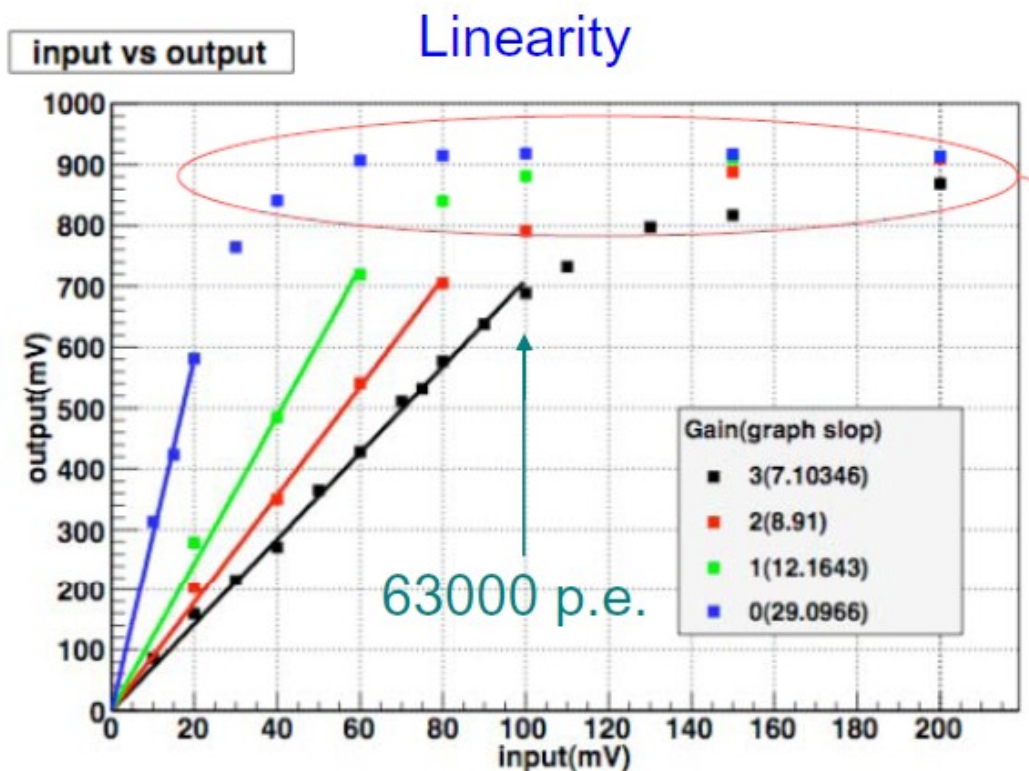
- Facility for HAPD transfer technique has been set up.
- Initial operation is going on.
 - Vacuum pumping & activation for photocathode fabrication
 - First 4 test samples
 - QE ~17-25%... looks good start
- Plan
 - Optimization for higher QE
 - 4 samples/week in April
 - 8 HAPDs by mid of May & 9 HAPDs by mid of June

HAPD ASIC - SA01



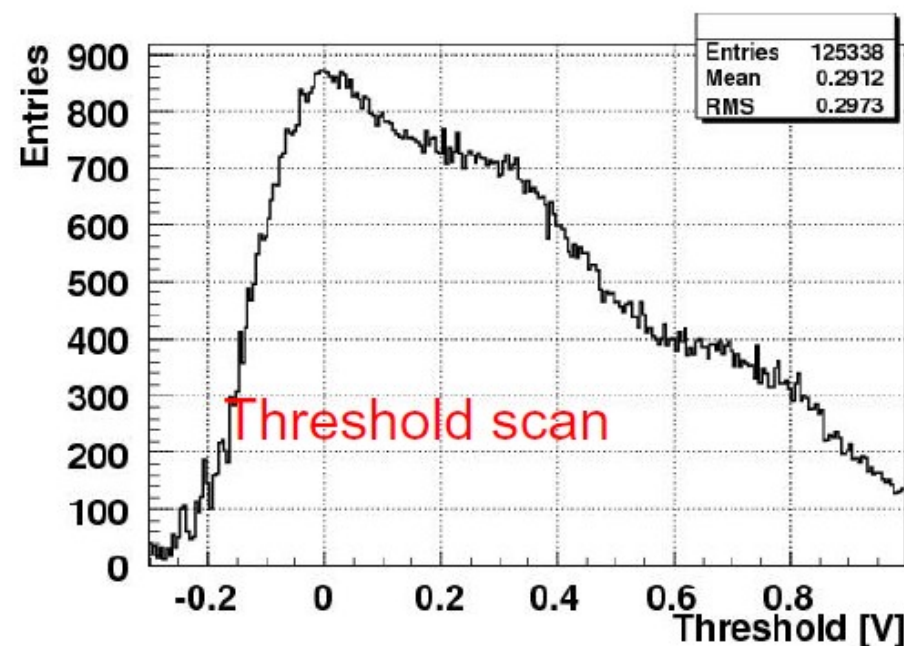
Preamp Shaper Comparator

- Noise ~ 1200 p.e. @ 80pF (better than S04)
- Offset adjustment works fine.



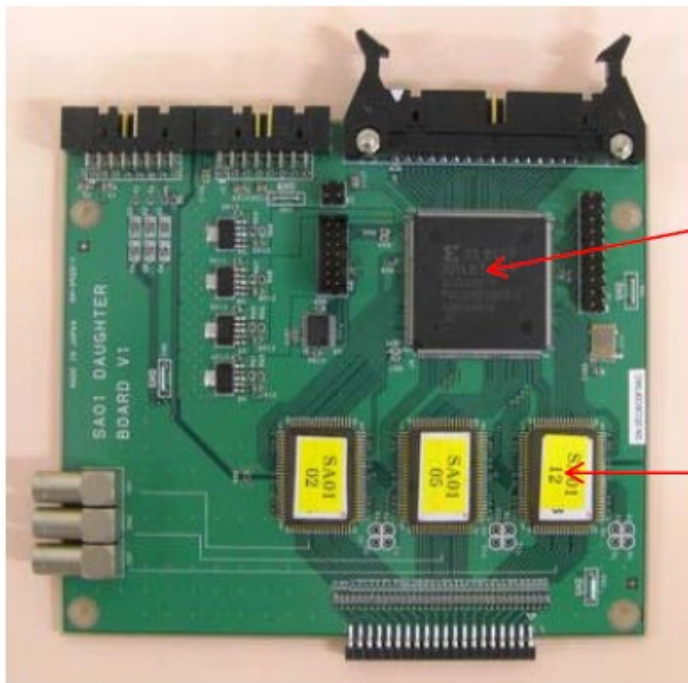
1 p.e. signal is already saturated if we apply full HV and bias voltage to HAPD.

Suffering larger noise than expected when connected with HAPD



HAPD ASIC - SA01 front-end board

- We have produced additional chips ~60 chips (note: 12 chips to readout 144ch)
- New front-end test board is delivered.
 - ✓ read out all of 36 ch (1/4 of HAPD) by one board.
 - ✓ Confirm the scheme to put FPGA in the front-end (development of FPGA logic; effect of noise from digital part (clock etc.))
- Hopefully read out 1 HAPD in the next beam test.



FPGA

ASIC

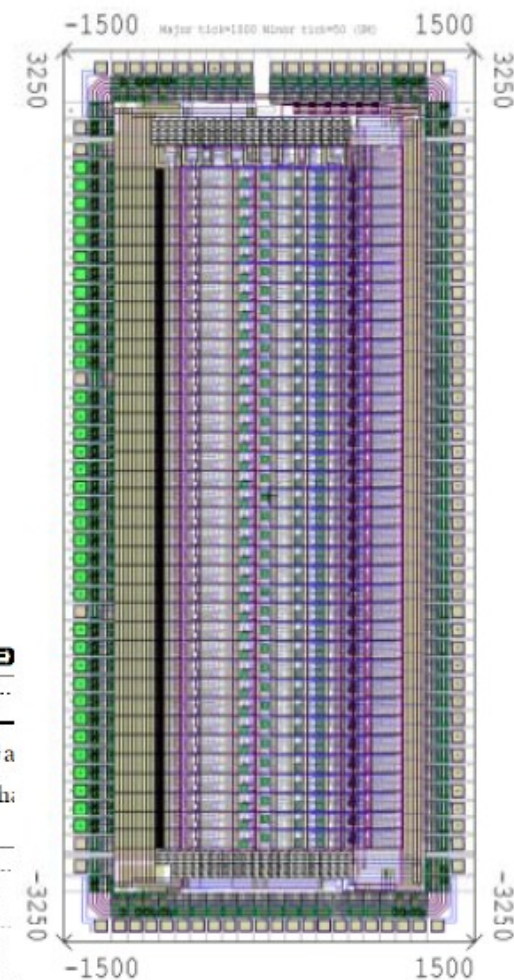
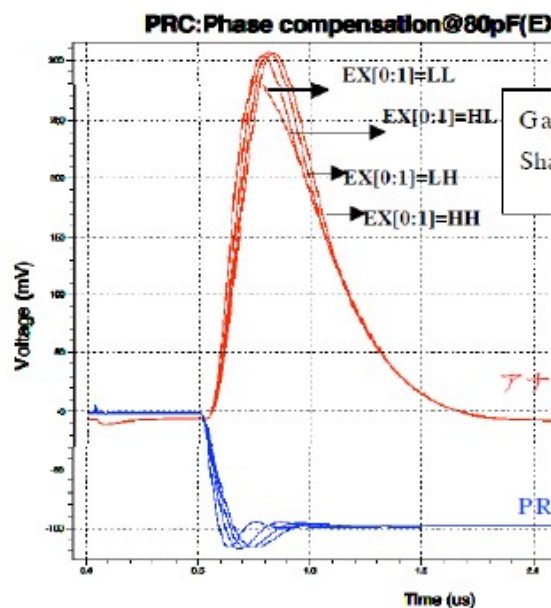
We have just started the test

HAPD ASIC - SA02

- In parallel, we are developing next version of ASIC
 - ✓ 36ch in one chip (i.e. read out 1 APD; need 4 ASICs for 1 HAPD)
 - ✓ gain is decreased by factor 4
- Simulation O.K.
- Chip layout is done (3mm x 6mm).
- Start production in next JFY

Plan

- Test the performance.
- Develop a compact package.
- Target is a small board with 4 ASICs and 1 FPGA to readout 144ch from HAPD.

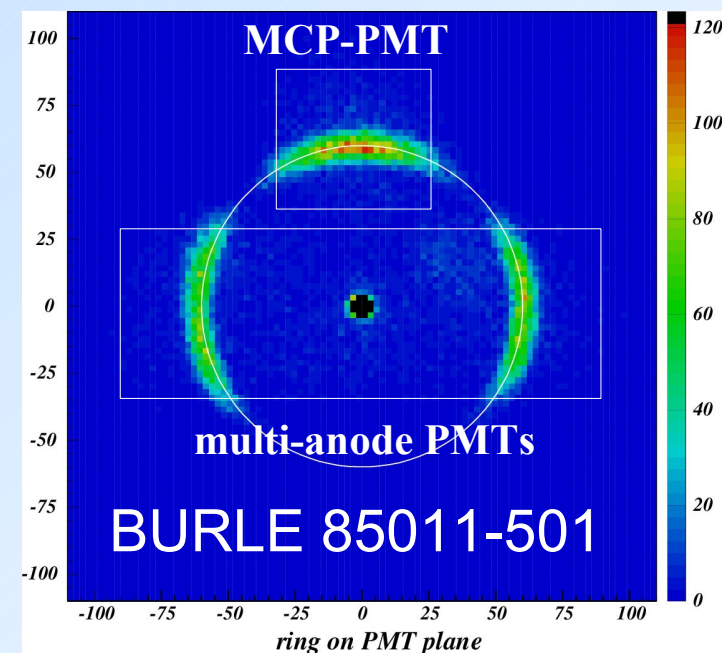
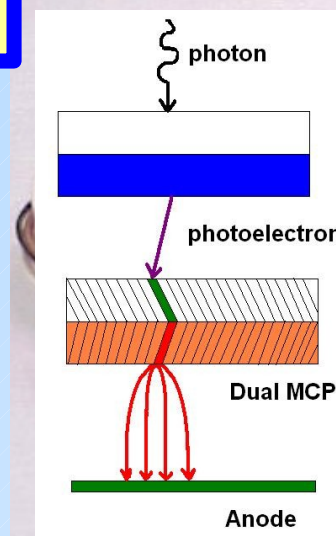


Photon detector candidate: MCP-PMT

Model 85015/A1 (old sample 85011-501):

- two MCP steps - chevron configuration
- 64 (8x8) anode pads @6.5 mm, gap ~ 0.5mm
- bialkali photocathode
- gain ~ 0.6×10^6 (@2400V)
- $10\mu\text{m}$ ($25\mu\text{m}$) pores
- open area ratio ~ 70 % (60 %)
- size ~ $\square 59\text{mm}$ (71mm)
- effective area fraction ~ 80% (52%)
- excellent timing < 40ps (50ps) - single photon
- K-MCP 4.4mm (6.1mm), MCP-A 3.7mm (5.2mm)
- window thickness 1.5mm (2mm)

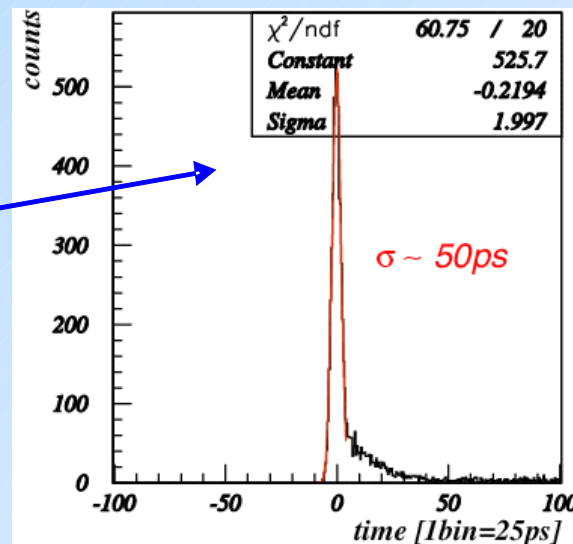
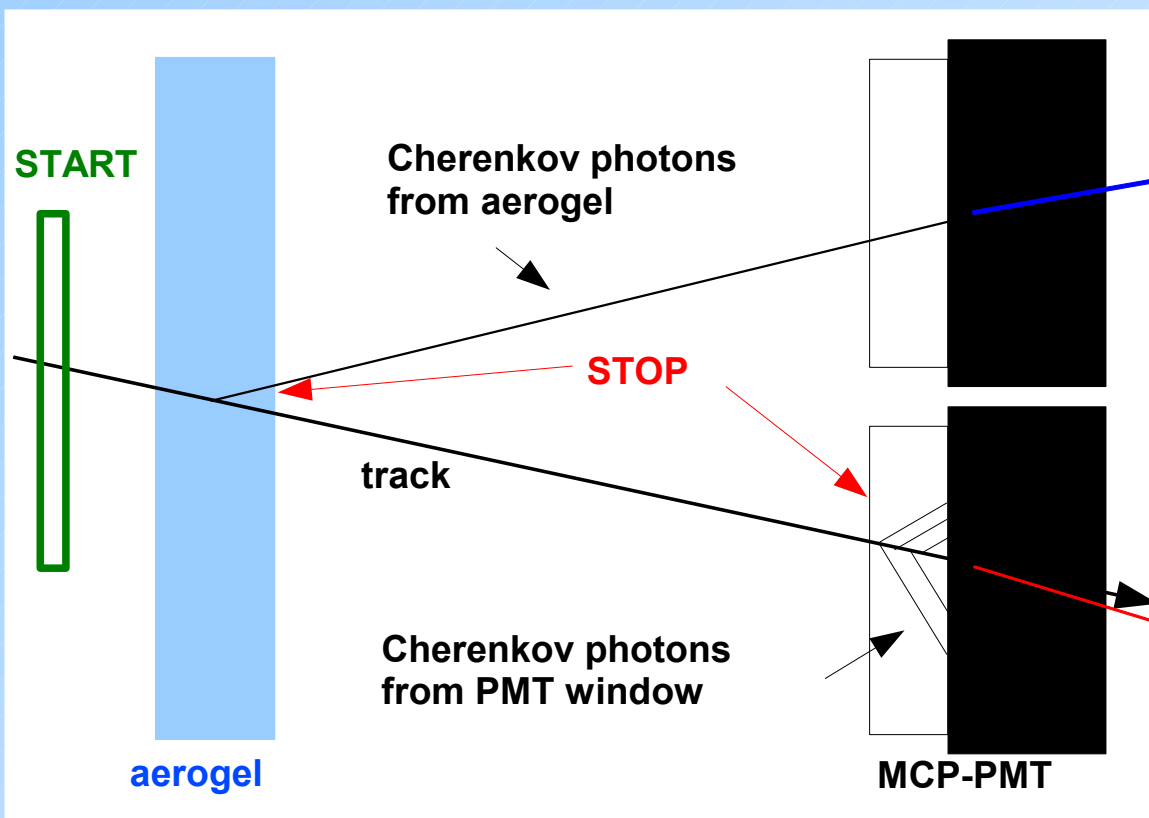
- $\sigma_{\vartheta} \sim 15 \text{ mrad}$ (single photon)
- number of hits per track $N \sim 10$
- $\sigma_{\varphi} \sim 4.7 \text{ mrad}$ (per track)
- $\rightarrow \sim 5 \sigma \pi/K$ separation at 4 GeV/c



- Tested in combination with multi-anode PMTs

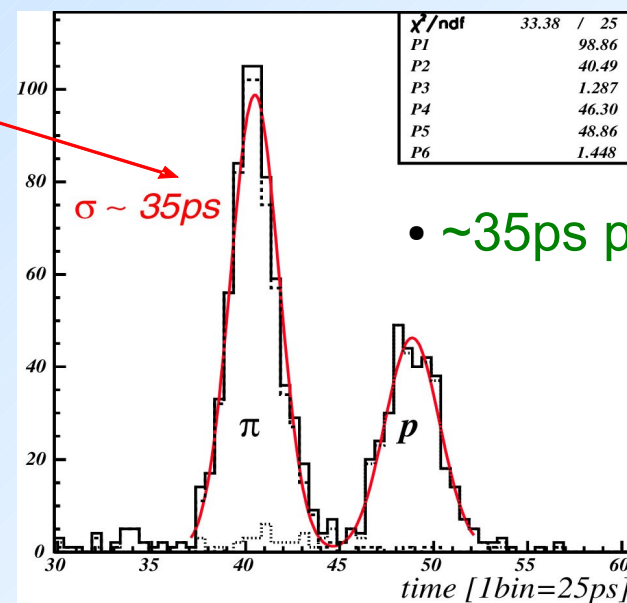
Additional feature: RICH+TOF

Make use of fast photon detectors: measure time-of-flight with Cherenkov photons from **PMT window** and **aerogel**



Beam test:

- 50ps per single photon (~20ps per track)



- ~35ps per track

- Cherenkov photons from the window can be used to positively identify particles below the threshold in aerogel

MCP out timing 1

- 8 anodes

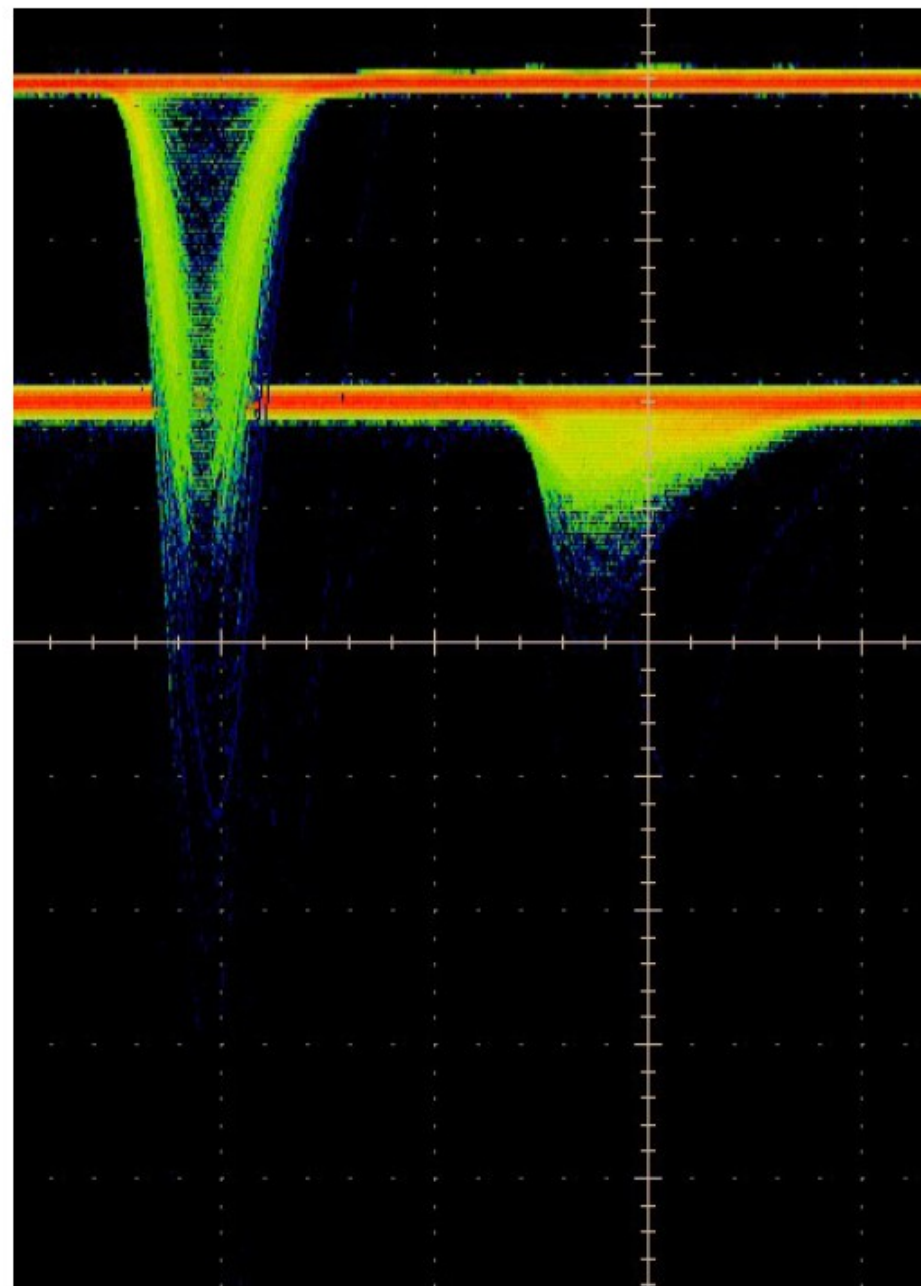
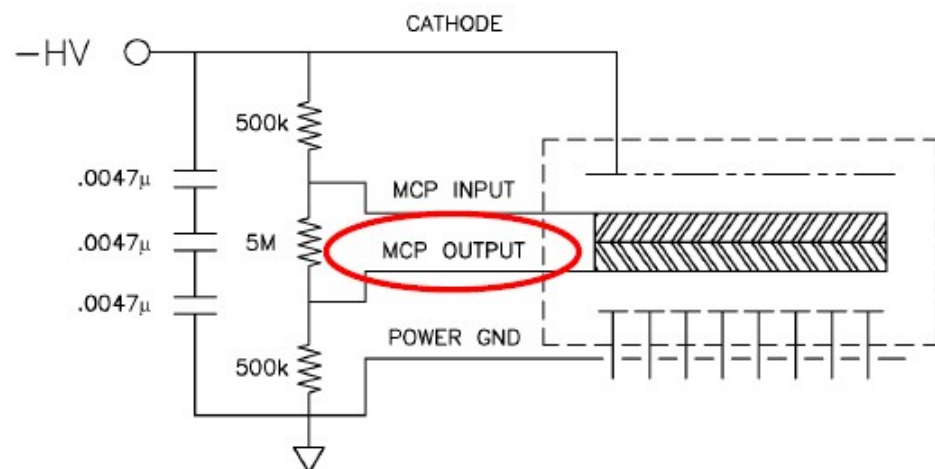
11	12	13	14	15	16	17	18
21	22	23	24	25	26	27	28
31	32	33	34	35	36	37	38
41	42	43	44	45	46	47	48
51	52	53	54	55	56	57	58
61	62	63	64	65	66	67	68
71	72	73	74	75	76	77	78
81	82	83	84	85	86	87	88

200x

- MCP Output

200x, inverted

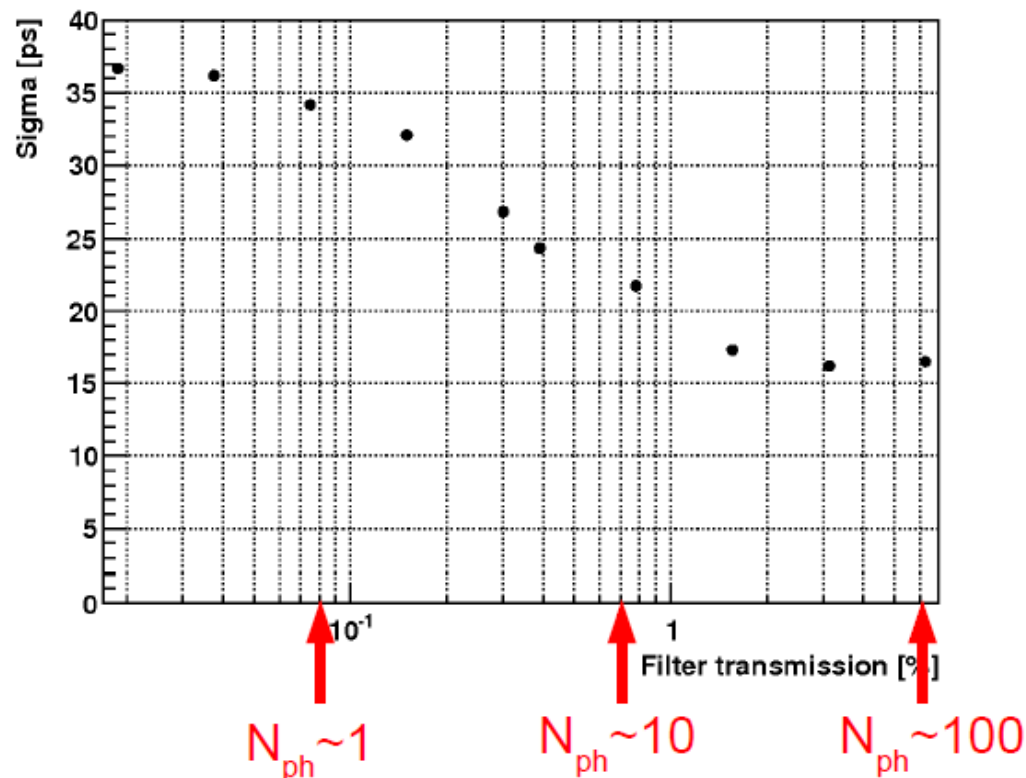
- positive polarity
- signal height $\sim \frac{1}{4}$ of individual anode



MCP out timing 2

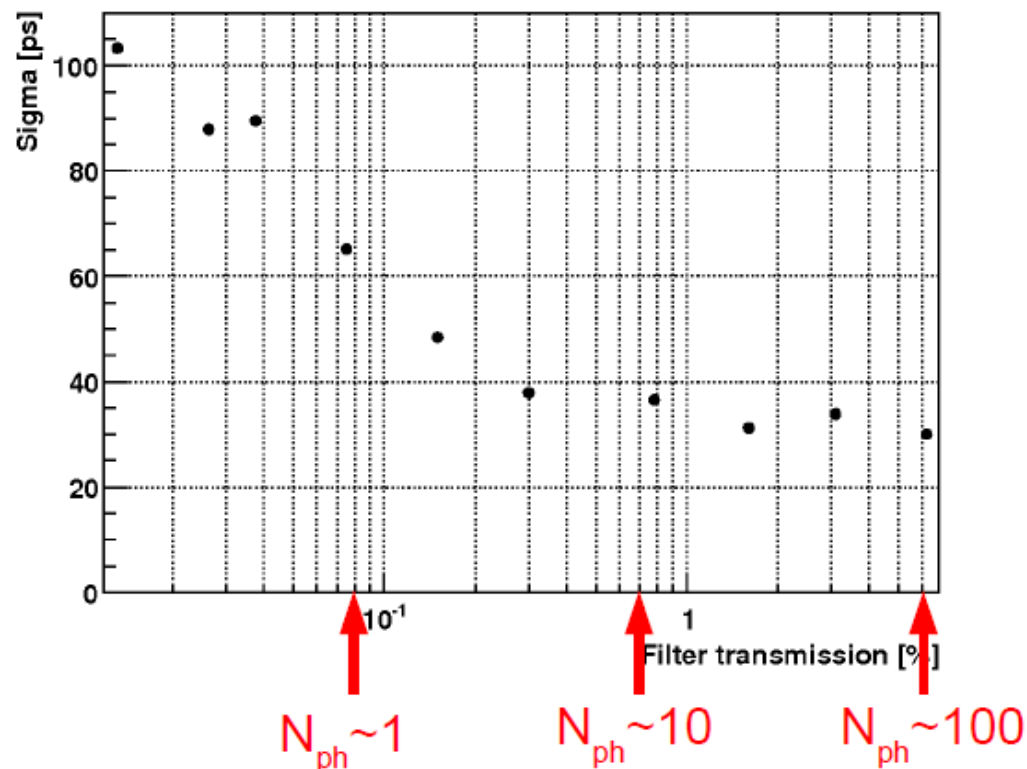
- filters: illumination $\sim 0.1 - 100$ photons an average (N_{ph})

anode TDC sigma



- $N_{ph} \sim 0.1$: $\sigma = 37\text{ps}$
- $N_{ph} \sim 10$: $\sigma = 22\text{ps}$
- $N_{ph} > 10$: $\sigma \rightarrow 16\text{ps}$

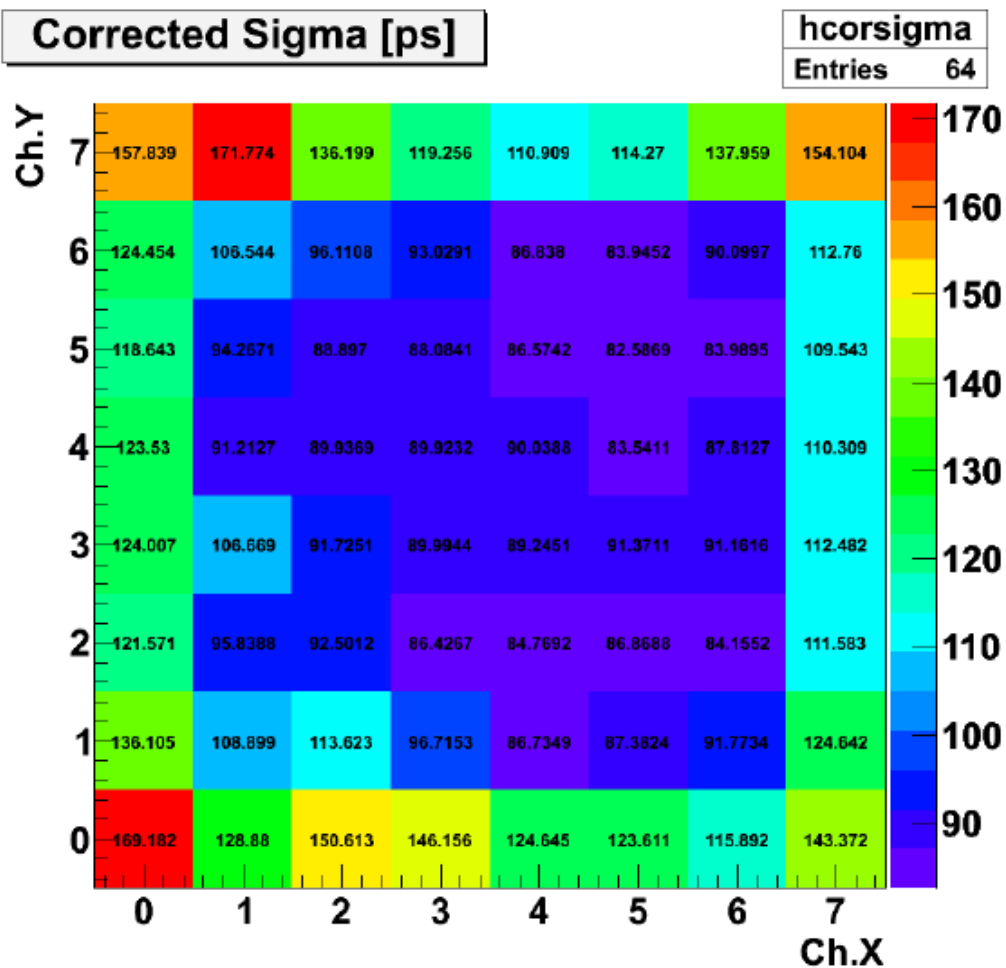
MCP Out TDC sigma



- $N_{ph} \sim 0.1$: $\sigma = 104\text{ps}$
- $N_{ph} \sim 10$: $\sigma = 37\text{ps}$
- $N_{ph} > 10$: $\sigma \rightarrow 30\text{ps}$

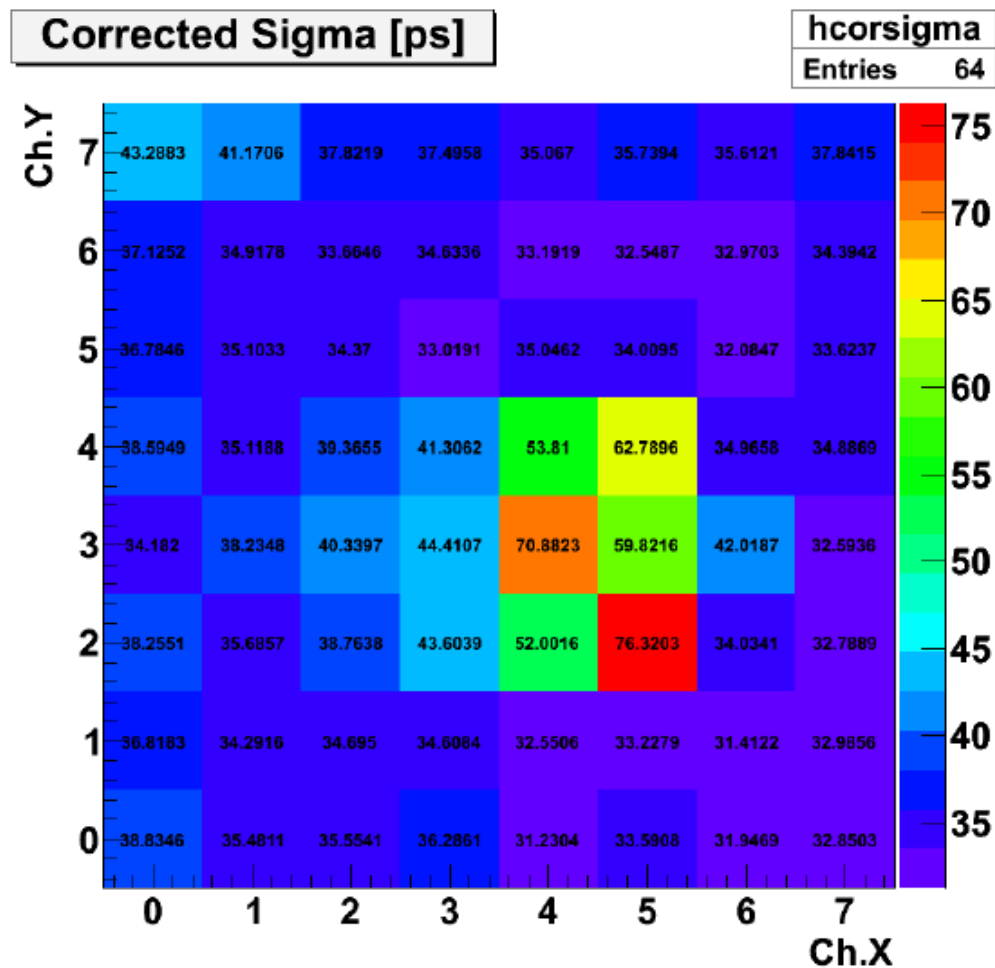
MCP out timing 3

$N_{ph} \sim 0.2$



- $\sigma \sim 100ps$
- worse at edges of device

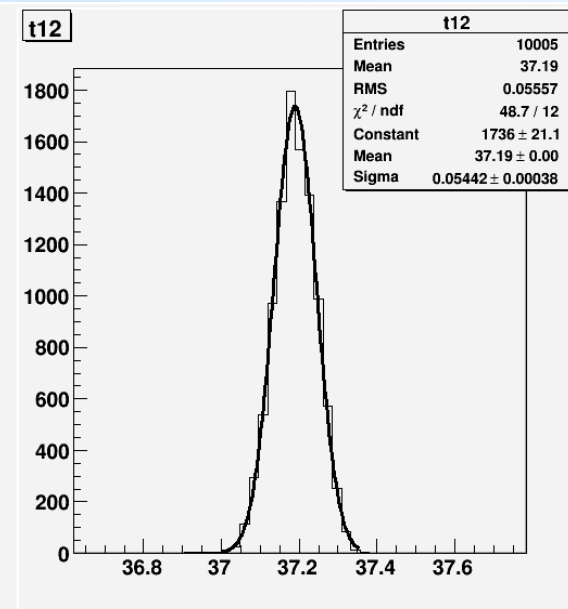
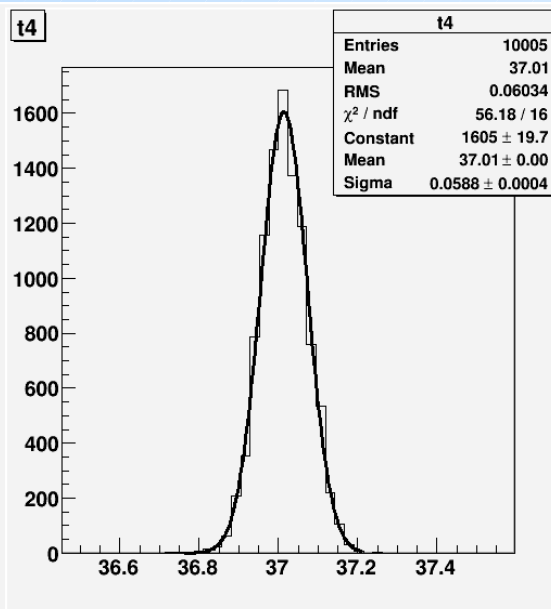
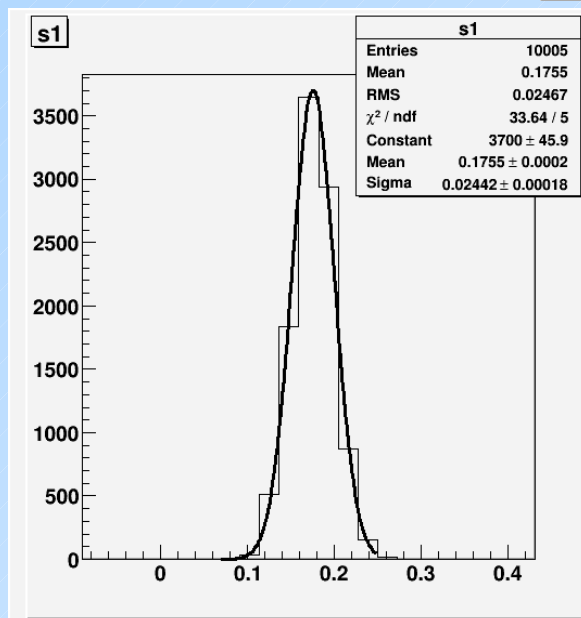
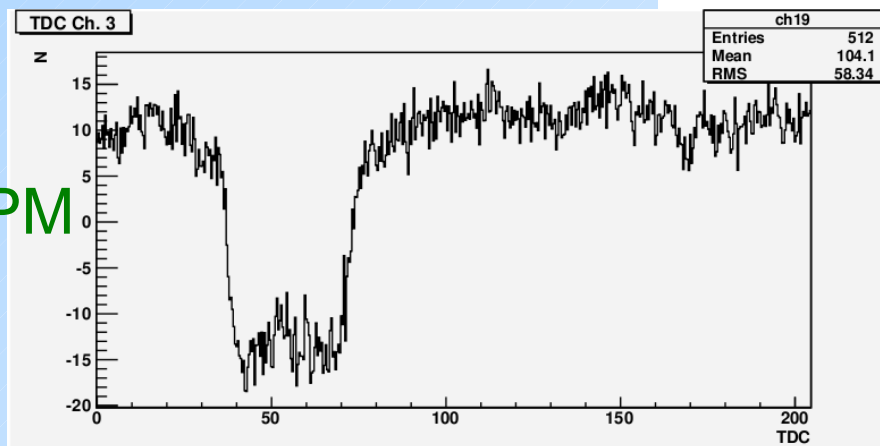
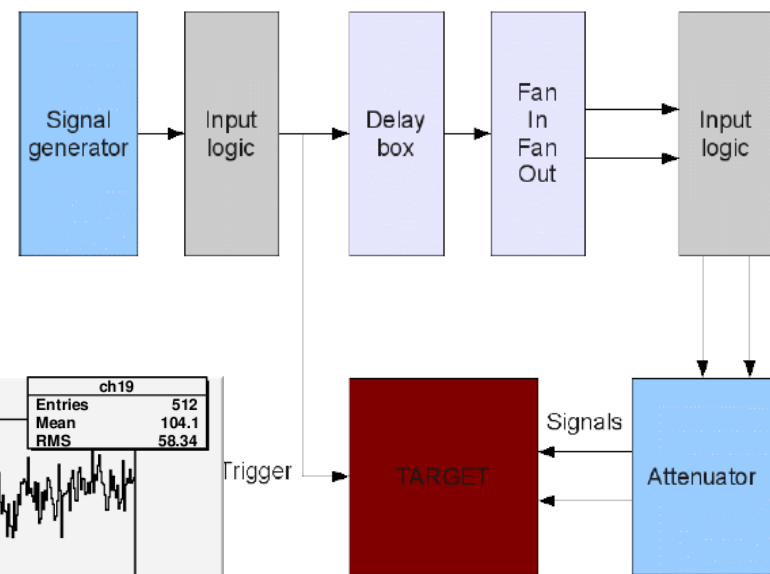
$N_{ph} \sim 10$



- $\sigma \sim 40ps$
- worse for some channels near center

Waveform readout

- readout tested with attenuated NIM signals
- good timing resolution even without calibration
- ready for detectors: MCP-PMT, HAPD, SiPM



Aging test preparation

Setup for aging test of MCP-PMT was prepared:

- monochromator 200nm-900nm
- laser source: 400nm, 630nm
- LED for aging (blue ~470nm)
- reference PMT for QE
- monitoring PMT
- current monitoring
- DAQ with scalers and ADC

Start aging test end of March → results end of April

	HAPD	MCP-PMT	MPPC
N_{ph}	8(+1) (\rightarrow 16)	10 (\rightarrow 15)	30
σ_{ϑ}	14	15	14
$B = 1.5T$	OK (improved perf.)	OK (improved perf.)	OK
long term stab. (aging)	OK (HV stability?)	OK?	OK
neutron damage	leakage current? \rightarrow signal / noise	OK(?)	X
production	2.5 y	2 y	?
pieces	< 600	< 1000	< 500000
cost / piece	< 7000 €	< 4000 €	< 20 €
electronics	ASIC	WFS	WFS
channels	~ 75k	~ 60k	~ 120k

Photon detector summary

Many tests have been performed since last meeting:

- reevaluation of HAPD beam test data
- further magnetic field test of HAPD
- neutron damage tests for HAPD started
- new front-end board with SA01 ASIC and design of SA02
- study of MCP-out timing
- study of WFS electronics, ready to test with sensors

To do list:

- perform aging test of MCP-PMT (→ May)
- neutron damage and long term stability test of HAPD (→ May)
- start periodical monitoring of ion feedback in HAPD samples
- electronics - test detectors with WFS and new ASIC
- check the timing capabilities of HAPD

BACKUP SLIDES

Long term stability - Aging

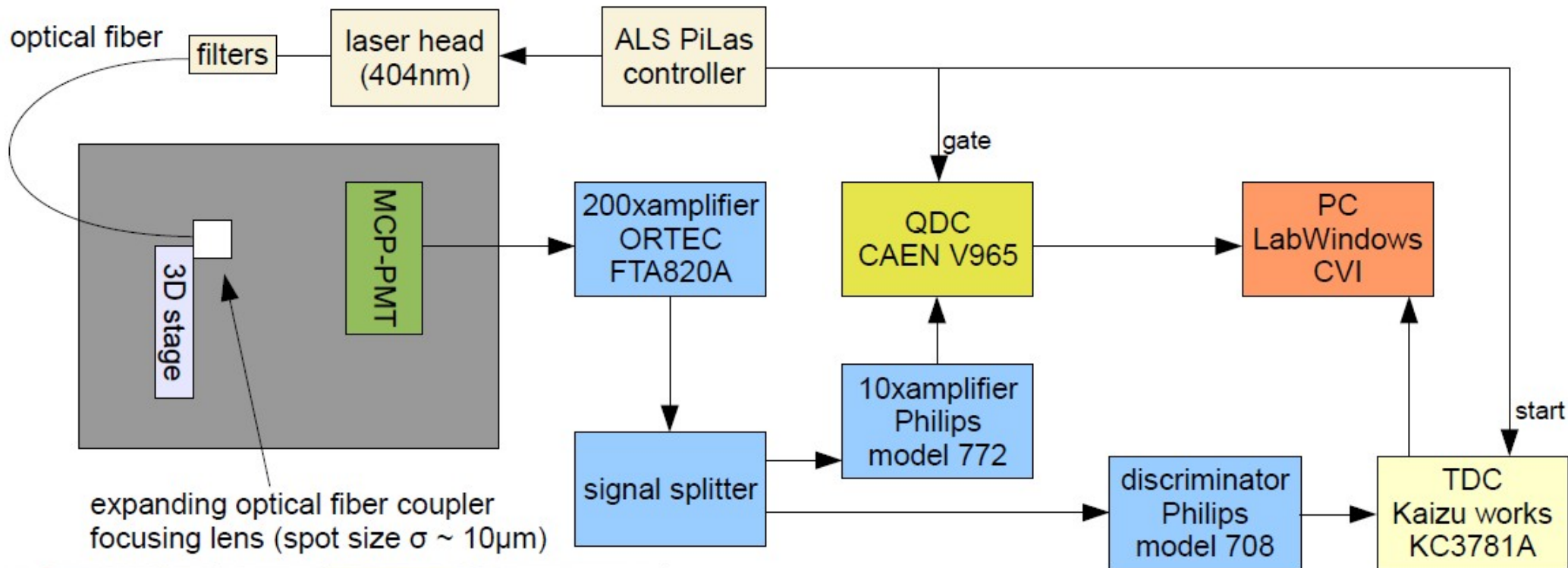
Several discussions with Emile Schyns, Group Product, Manager, Micro Channel Plates (final a good lead to the company)

Current performance (no Al protection layer): → 50% drop of efficiency after 10-15C/tube = 350-540mC/cm²

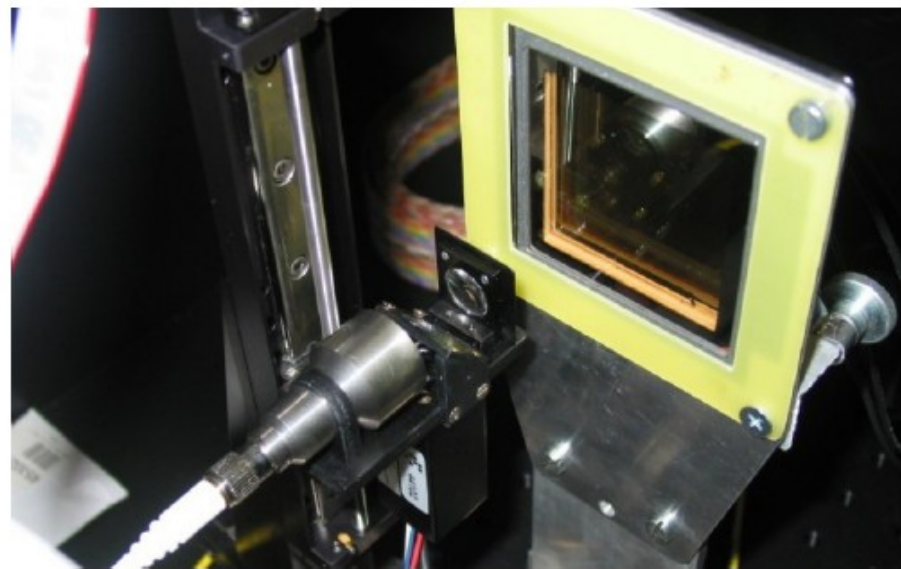
Expect ~ 10 mC/cm²/year on ARICH (scaling the TOP estimate)

Summer 08: move production to Europe, expect to improve the ageing by a factor > 5 (use a different scrubbing technique, deep UV → electrons)

→ Ageing most probably not a problem but need to be tested !

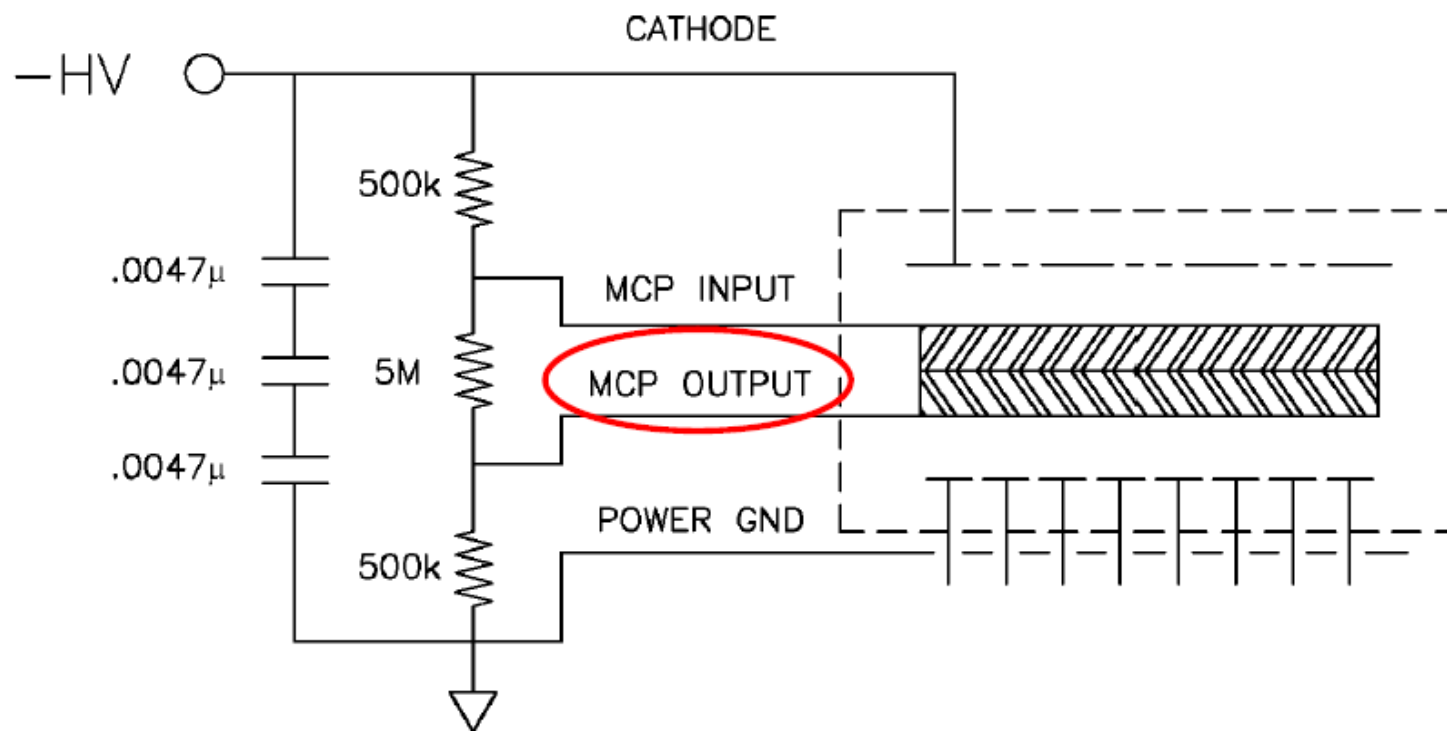


- neutral density filters: illumination $\sim 0.1 - 100$ photons on average (N_{ph}) (amplification modified at higher illuminations/pulse heights)



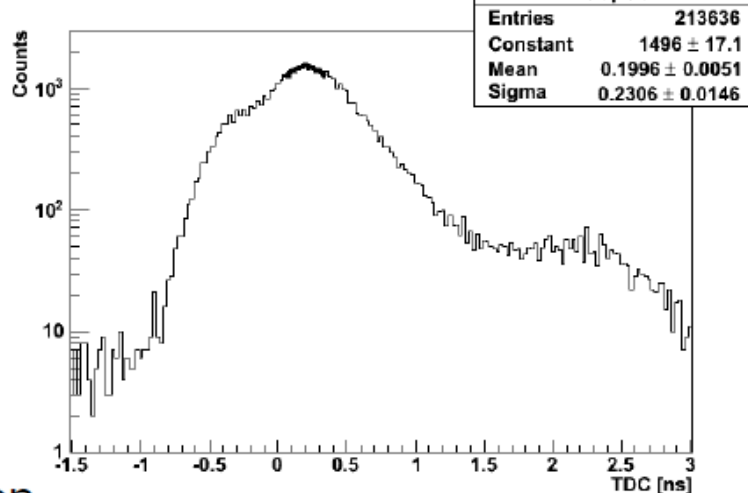
MCP-out timing 1

- output from multi channel plates (common for all channels)
- voltage between cathode and MCP set with resistor chain (external)

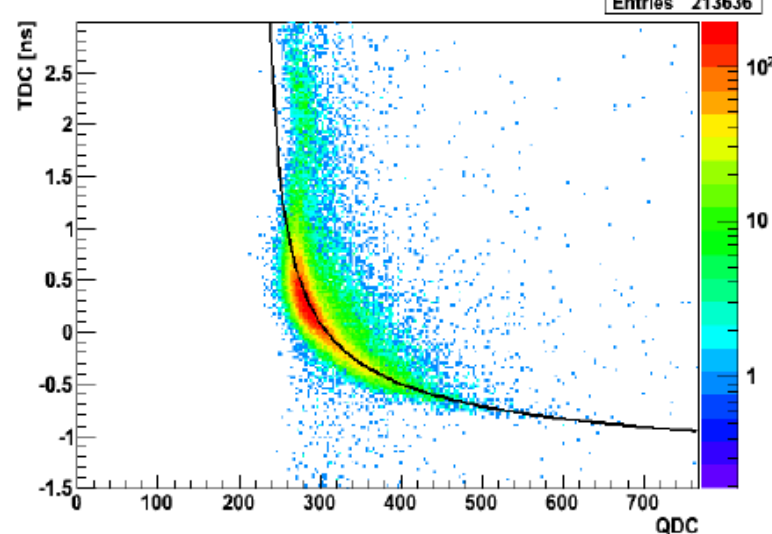


- idea: read timing for whole device from 1 channel
- 64 channels \rightarrow position
- MCP Out timing?

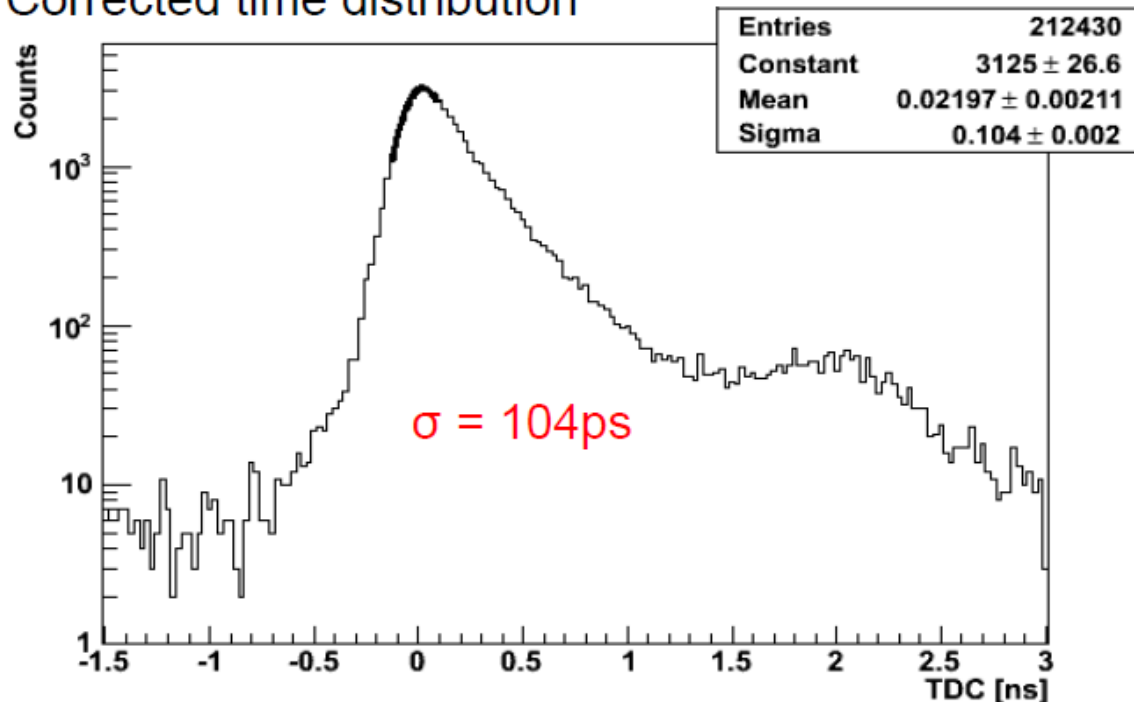
Time distribution



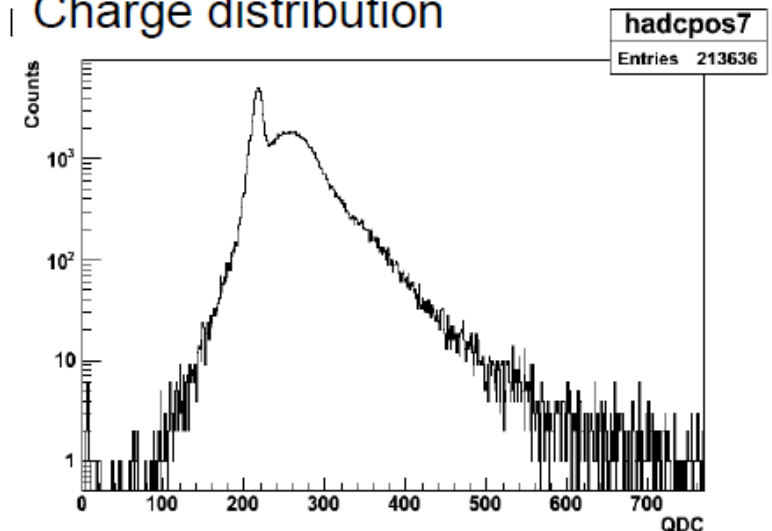
Time-walk correction

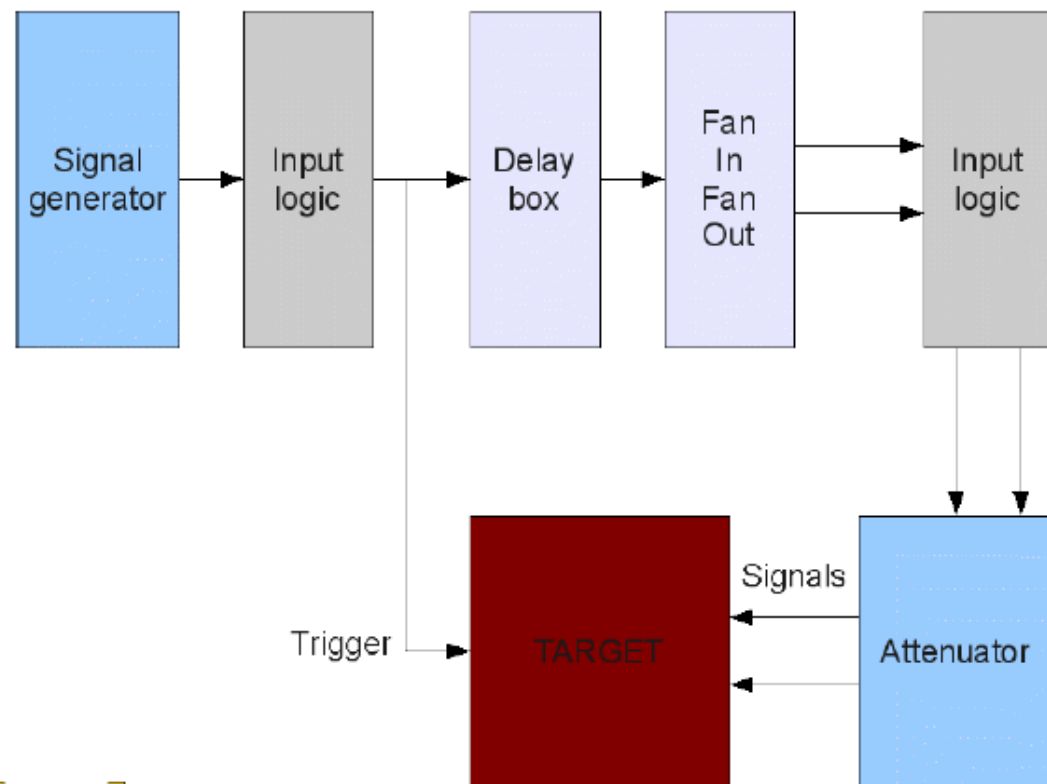


Corrected time distribution



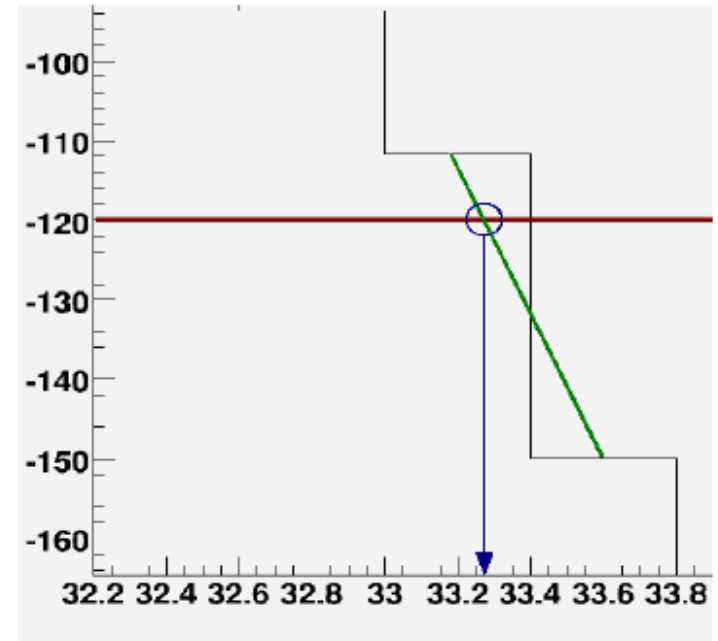
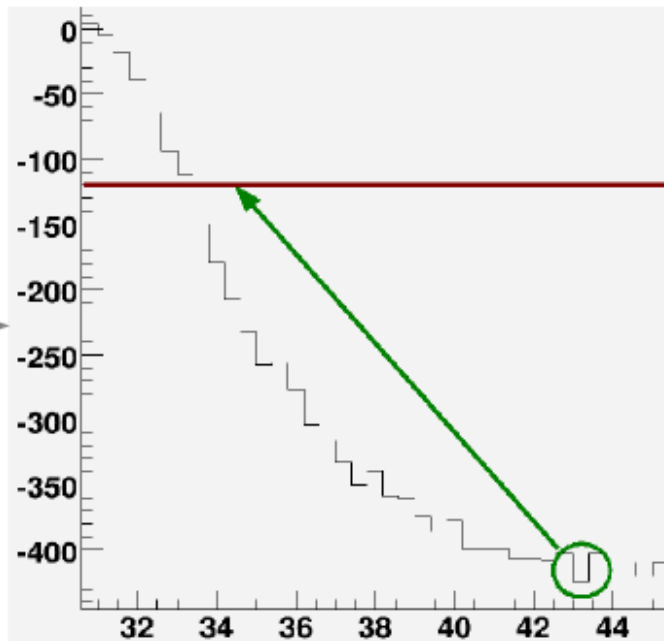
Charge distribution





- Dual timer in a 'feedback' loop acts as a signal generator
- Signal transformed into logic pulse
- One logic pulse is send to trigger input of TARGET
- Second logic pulse is send to delay box
- After delay if gets split by a fan in fan out (FIFO)
- FIFO sends 2 copies to input logic
- 2 logic pulses get attenuated
- Attenuated pulses act as input signals

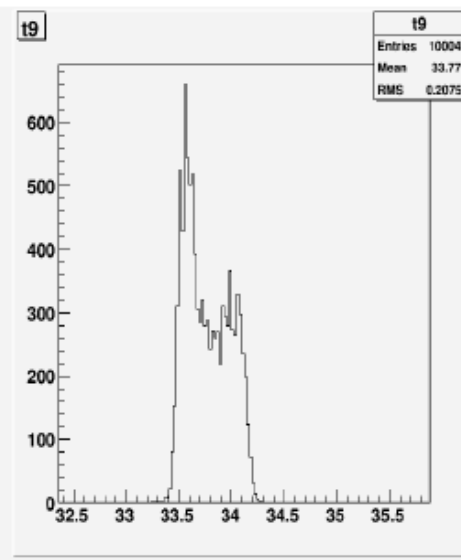
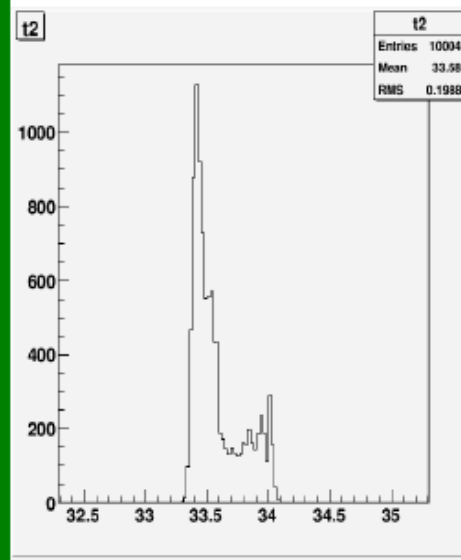
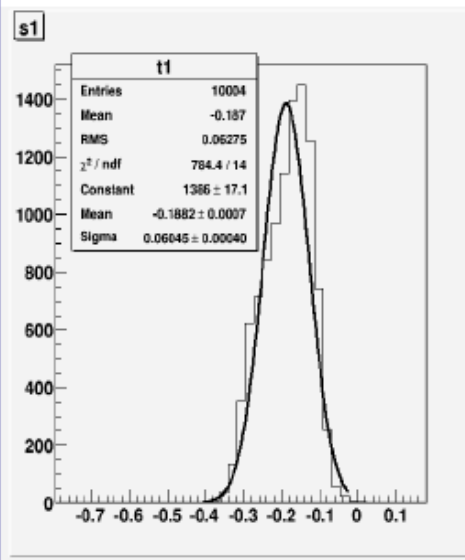
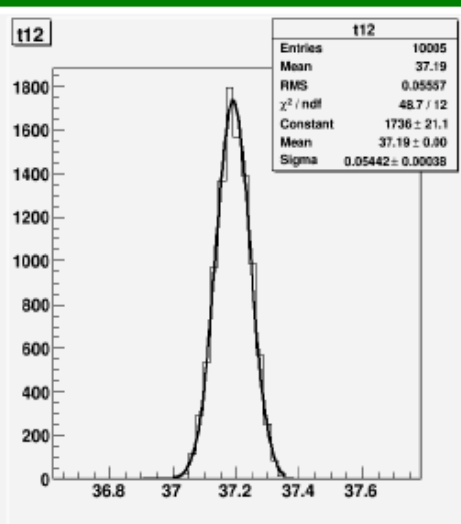
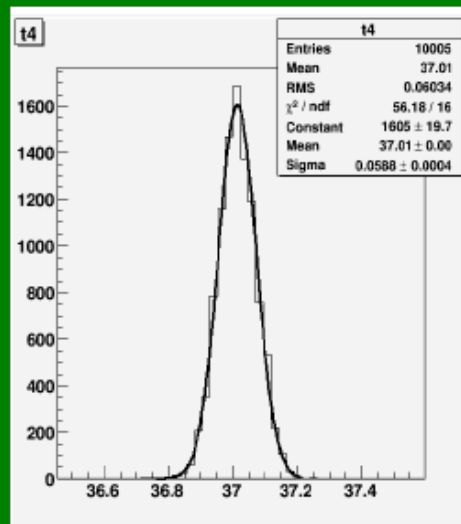
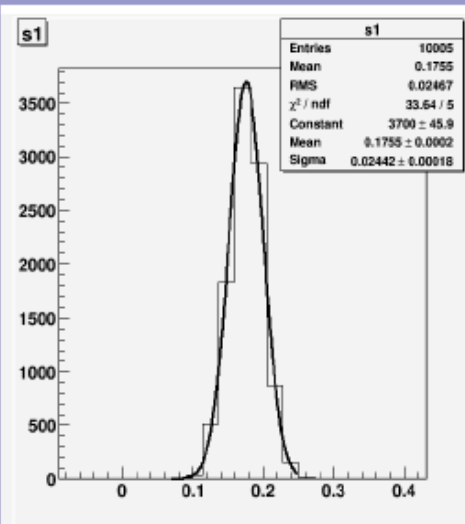
Connectors used for
50 Ω termination



- Every calculation happens per event
- Get minimum => y
- Set threshold => $y = t * y$ ($0 < t < 1$ & change to needs/best result)
- Look for signal $< y$ and 'memorize' time bins before and after crossing.
- Linear interpolation to find 'real' time of threshold crossing!

- Right → single channel timing.
- Left → Time difference between 2 signals on different channels.
- All signals have the same origin and go through same electronics (see setup slide).

Single channel:
 top → channel 4-12
 bot. → channel 1-9

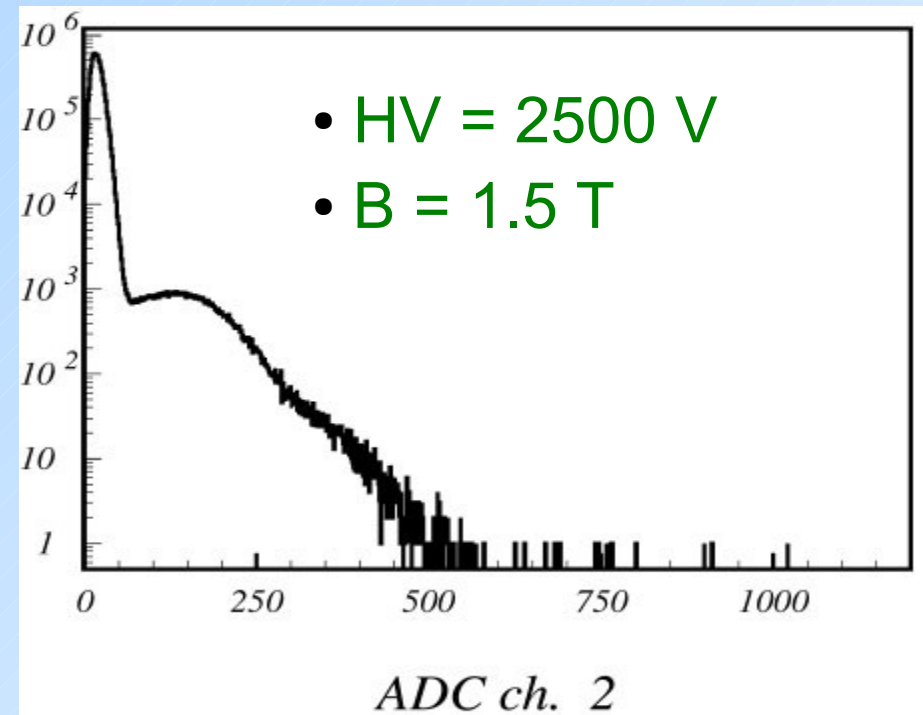
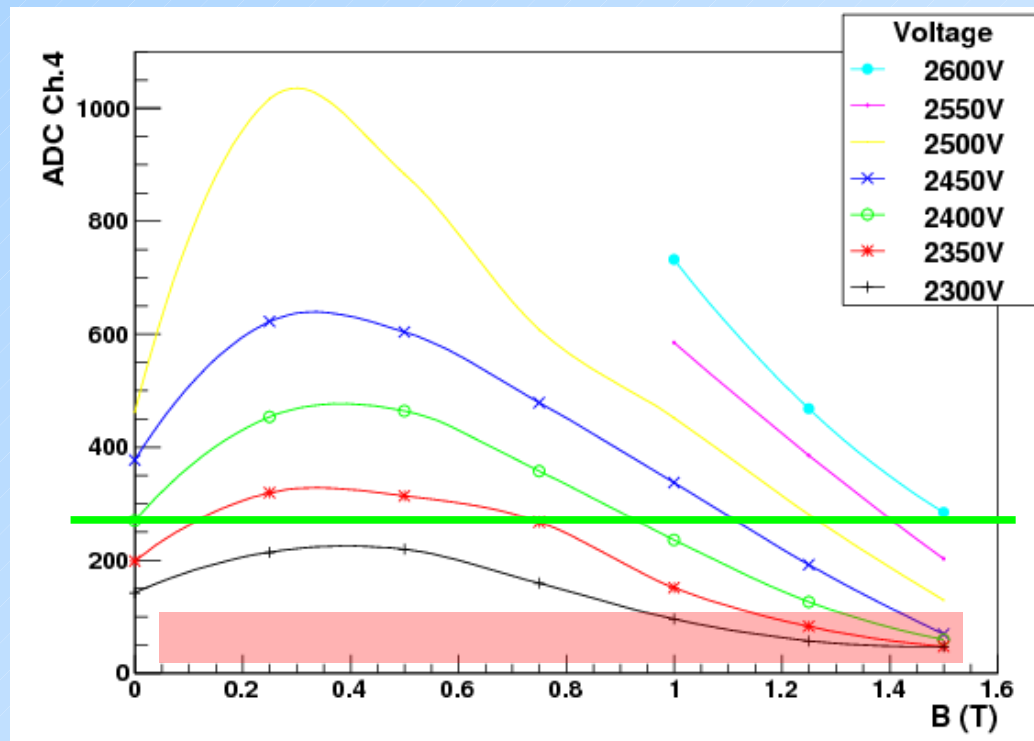


Double channel: top → channel 4-12
 Bottom → channel 1-9

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cost / piece	< 7000 €	< 4000 €	< 20 €
electronics	ASIC	WFS	WFS
channels	~ 75k	~ 60k	~ 120k
material	?	?	?

Tests in magnetic field: ADC vs B

- gain drop observed in magnetic field 1.5T
- increase HV for ~200V to reach the same amplification as in B=0T

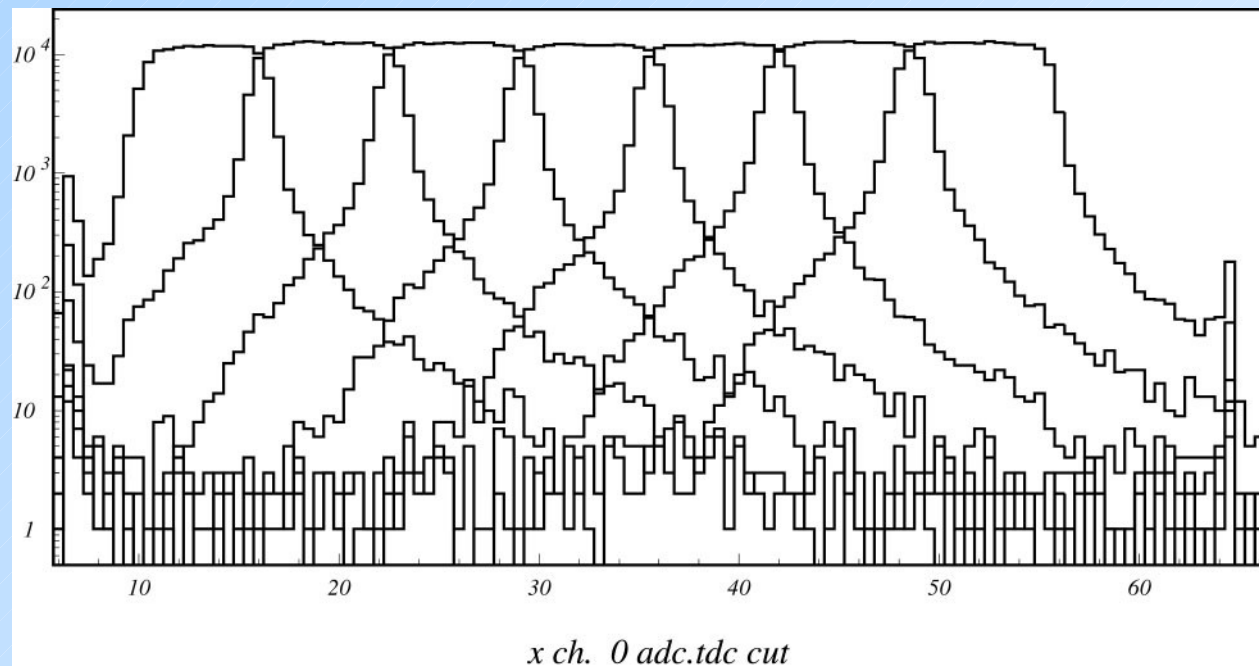


- single photon ADC distribution measured in magnetic field
- gain as a function of magnetic field for different operation voltages.

Tests in magnetic field: charge sharing

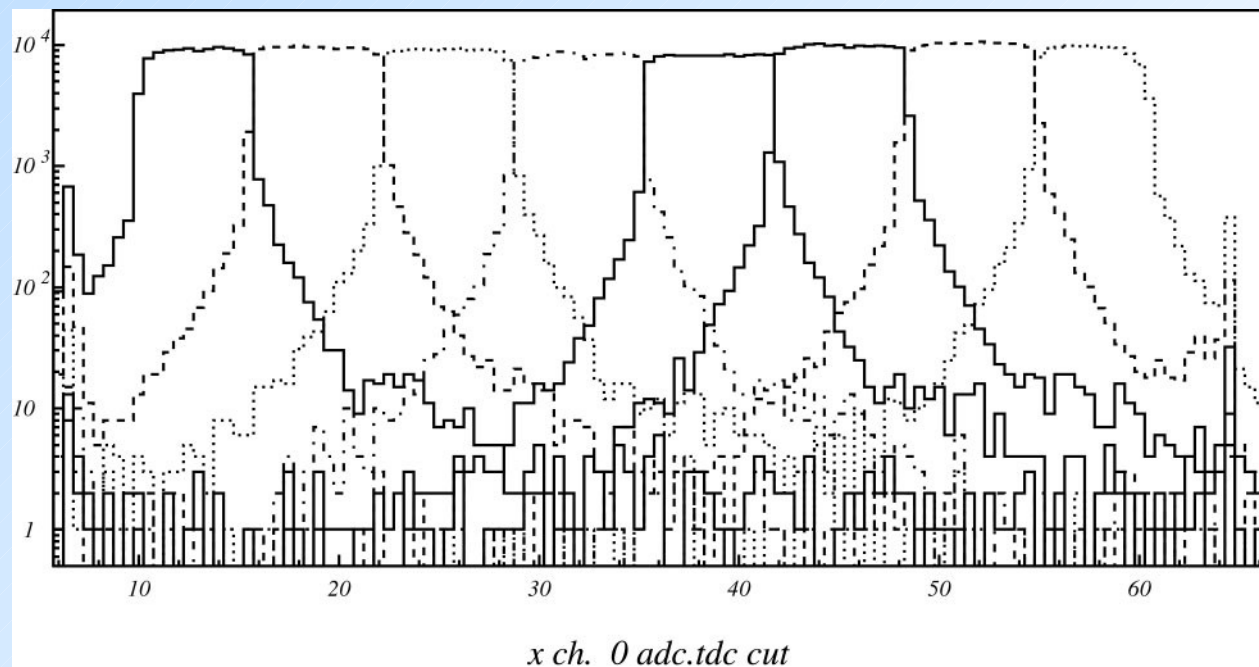
Number of detected hits on individual channels as a function of light spot position.

- HV = 2400 V
- B = 0 T



- HV = 2500 V
- B = 1.5 T

Reduced effects of charge sharing and photo-electron backscattering are

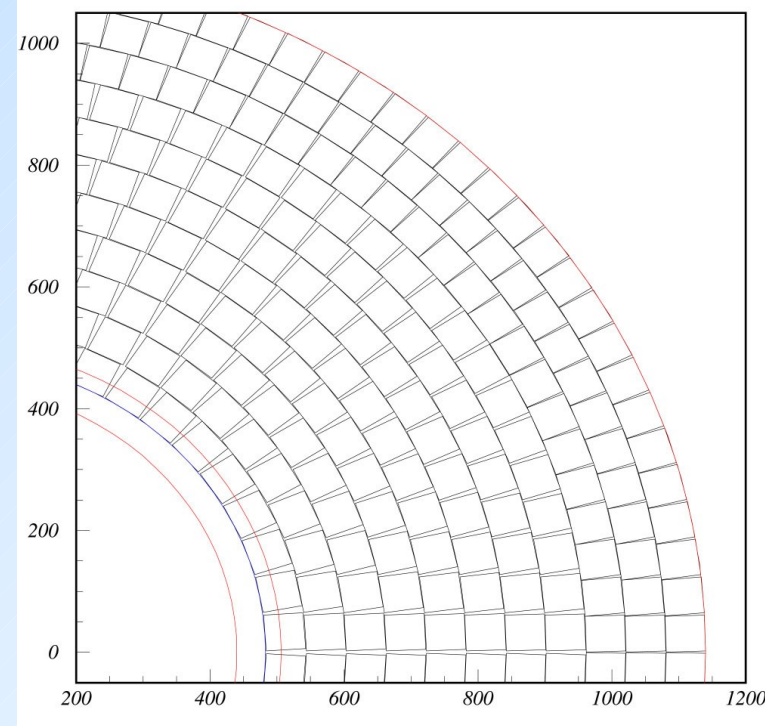
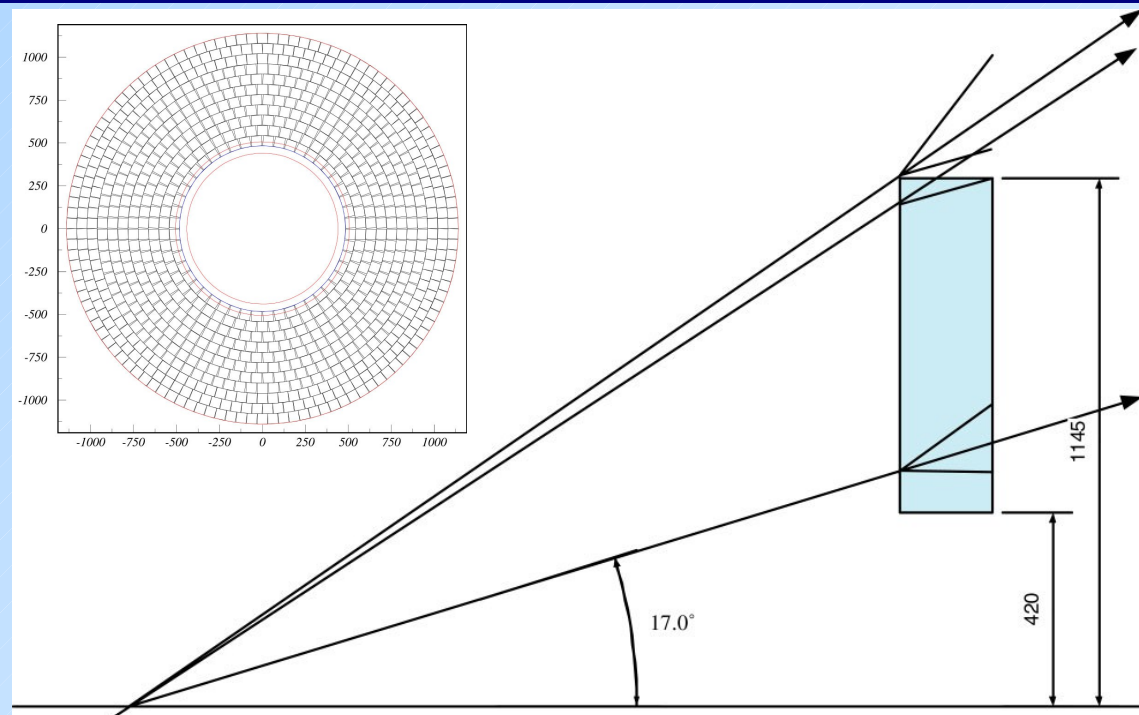


Tiling scheme

- Number of MCP-PMTs and covered area fraction

ring	# PMTs	fraction
1	48	86%
2	54	87%
3	60	88%
4	66	88%
5	72	89%
6	78	89%
7	84	89%
8	90	90%
9	102	96%
10	108	96%
11	114	95%
all	876	91%

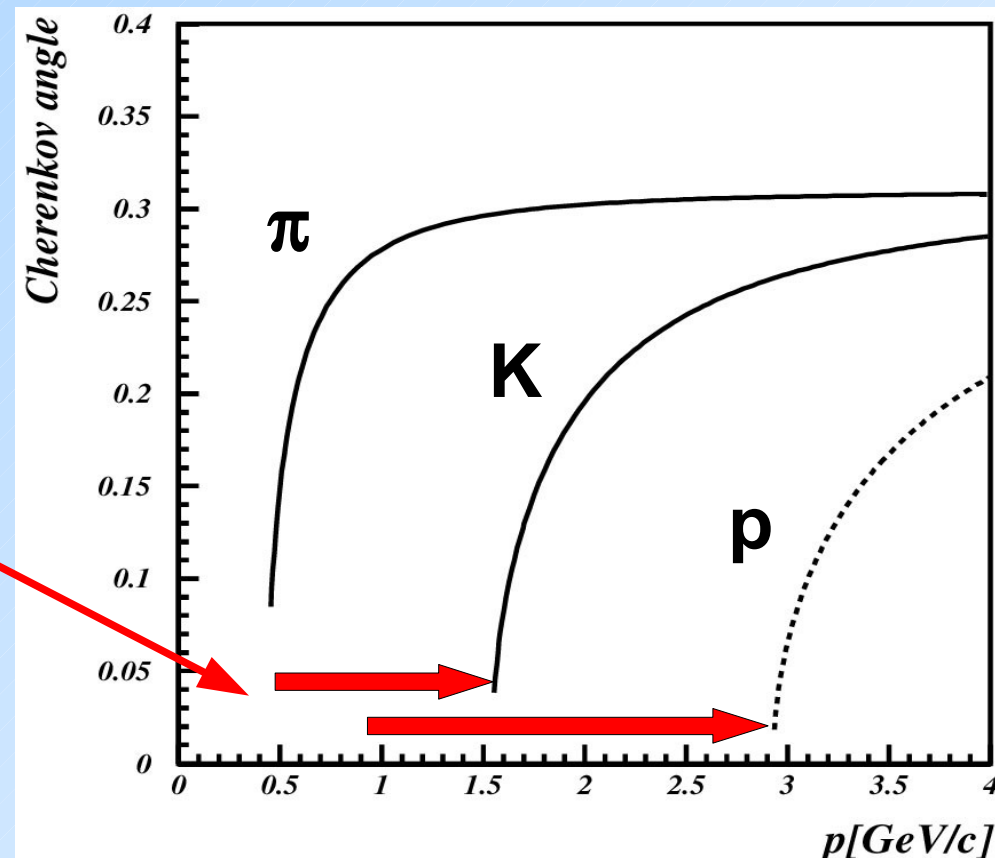
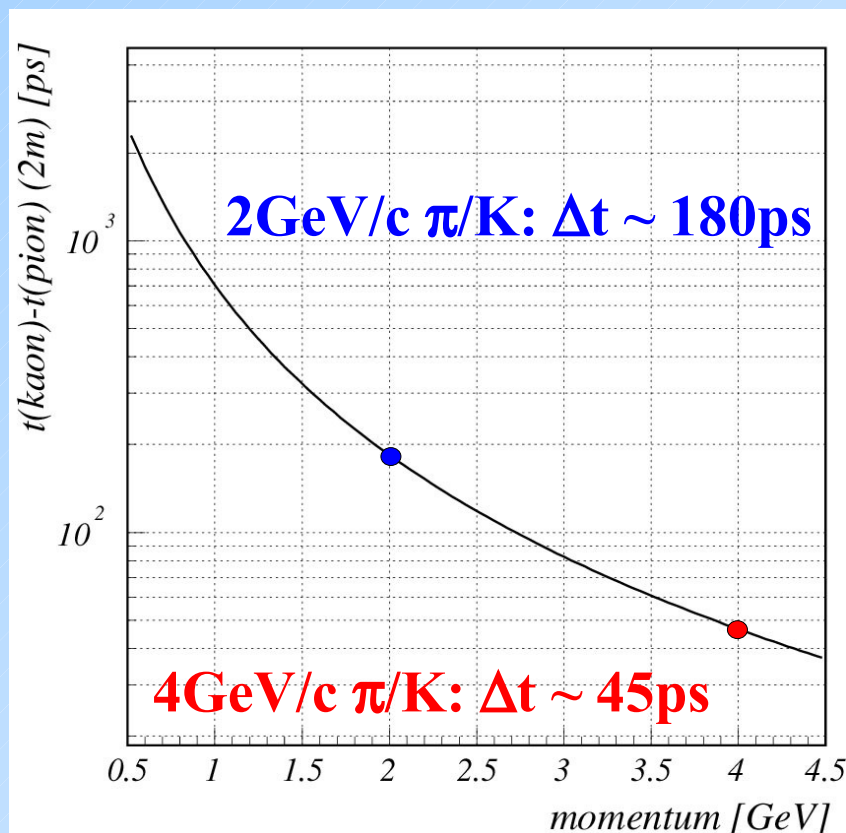
Total number <1000 and rough estimate for price < 4M€ (upper limit)



TOF capability

Using Cherenkov photons emitted in the PMT window ($n \sim 1.46$) PID can be extended into the lower momentum region:

Kaons and protons can be positively identified below the Cherenkov threshold in aerogel ($n \sim 1.05$).



Cherenkov angle in aerogel ($n=1.05$) for pion, kaon and proton.

Time-of-flight difference for pions and kaons from IP to forward PID (2m).

Summary and plan

- XXX

Plan:

- XXX