# Scintillating Fiber Detector for its use as Off-Momentum detector

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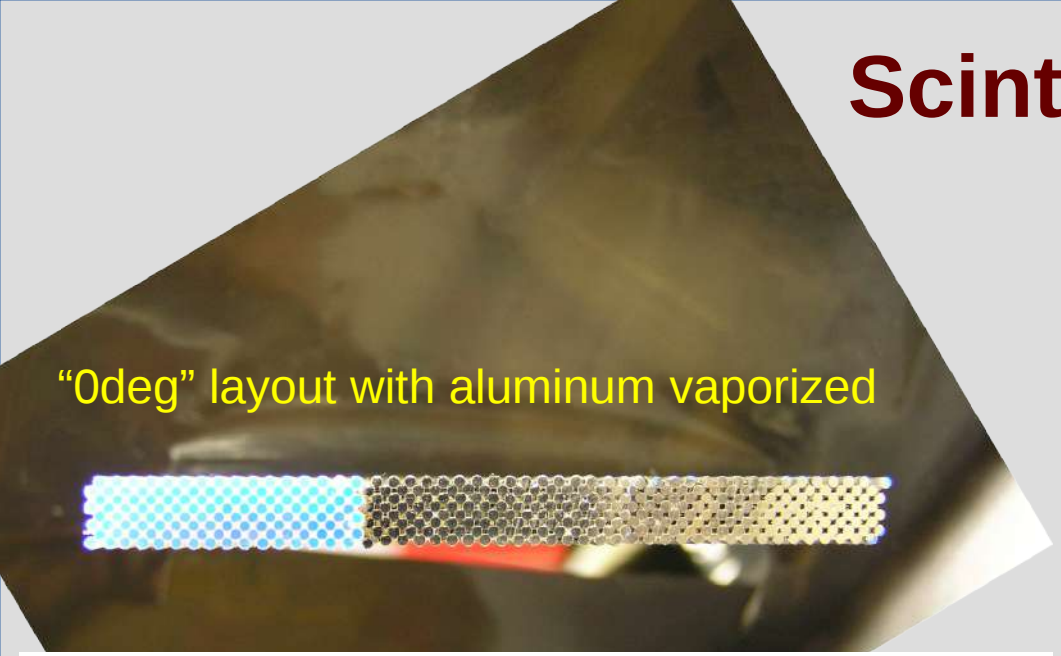
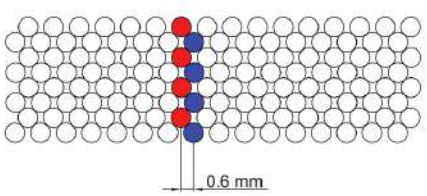
# Scintillating fiber detector



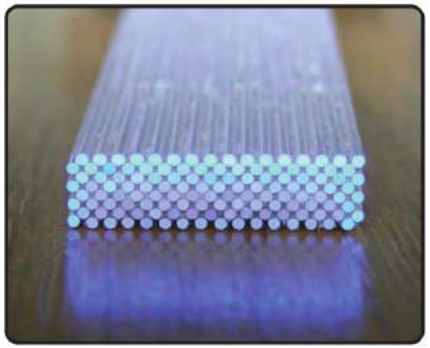
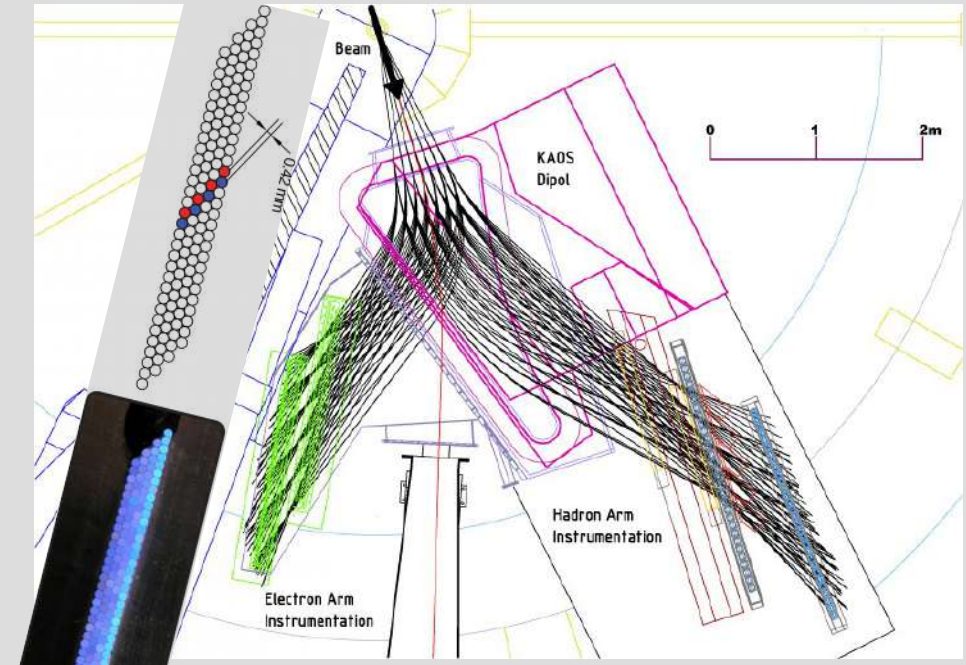



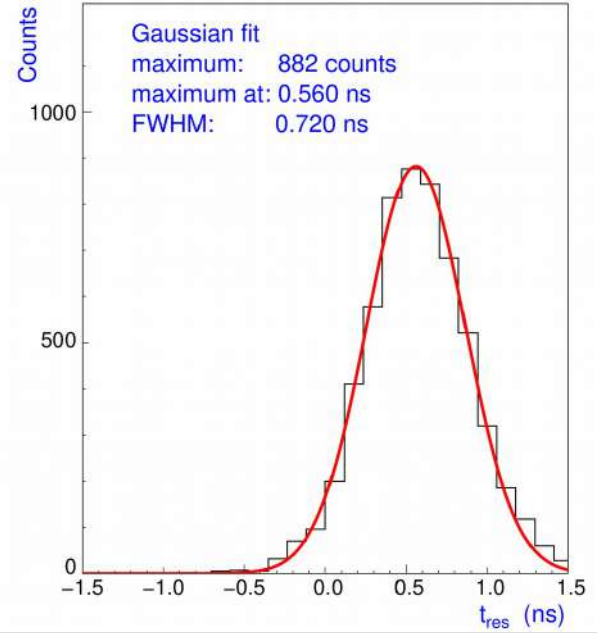
**Figure 3.21:** Left. Scheme of the fiber arrangement of 0°. Columns of the same color represent a single readout channel. The pitch between between each column is of 0.6 mm. Right. Photograph of the bundle arrangement.

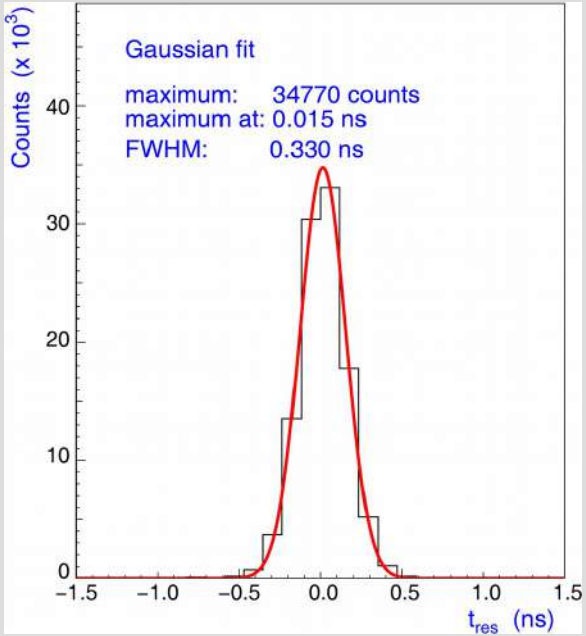


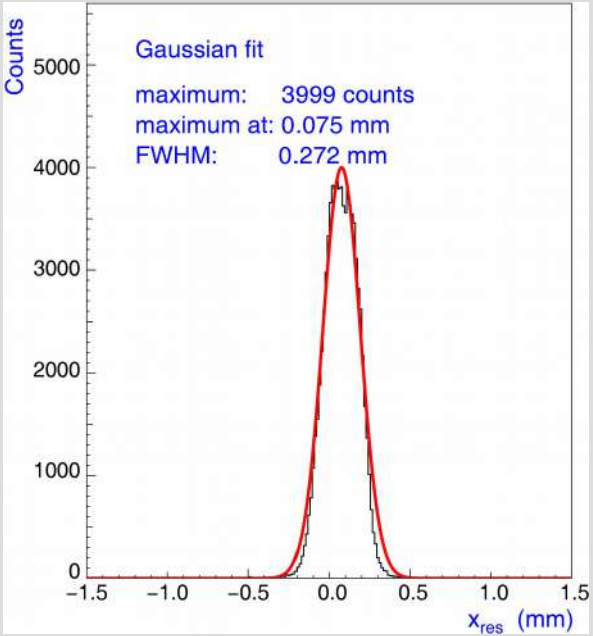

KaoS detector layout

CA – PhD thesis 2012
Johannes Gutenberg – Mainz Universitaet

# Test beam at GSI

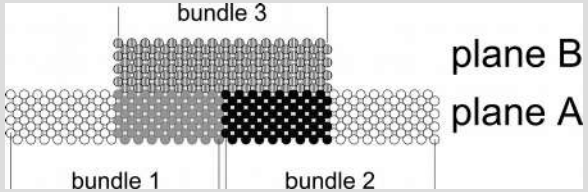



Some numbers from 2007 GSI beam test (cocktail beam $\pi^+$/p/d at 1GeV/c) and C beam of 2 AGeV energy:

- Residual of $t_A$-$t_B$ FWHM = 720ps (cocktail) → 510ps single plane,
  330ps (carbon) → 220ps single plane

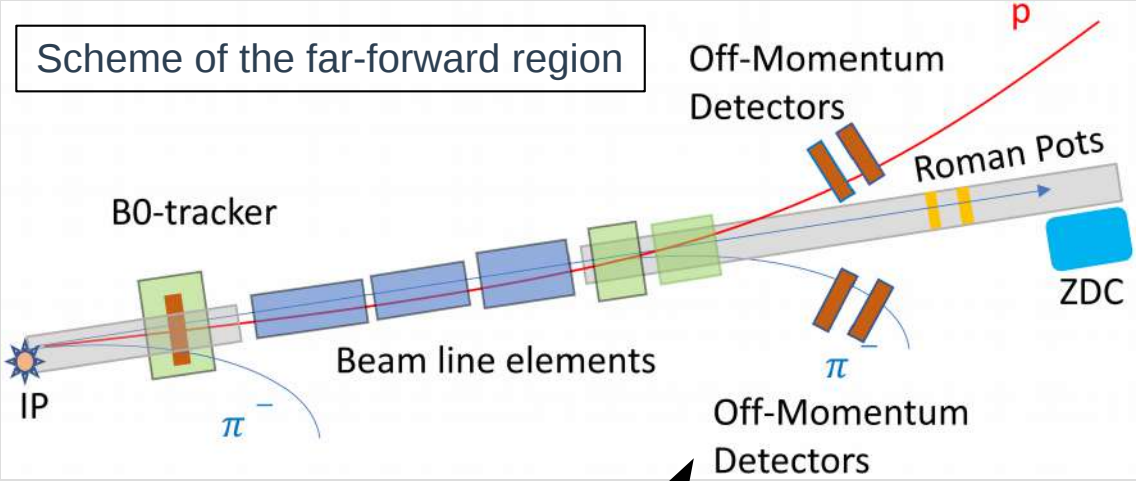



- Residual track position $X_A$-$X_B$ FWHM ~0.27mm (carbon)

P. Achenbach, C. Ayerbe Gayoso, J. Bernauer, R. Bohm, M. Distler, et al., “In-beam tests of scintillating fibre detectors at MAMI and at GSI,” Nucl.Instrum.Meth.,vol. A593, pp. 353–360, 2008.

# Far-Forward detectors at EIC

The Zero Degree Calorimeter (ZDC) is part of the far forward instrumentation of EIC and play a critical role for different physics topics, in particular the meson structure.




From the EIC YR-Meson WG

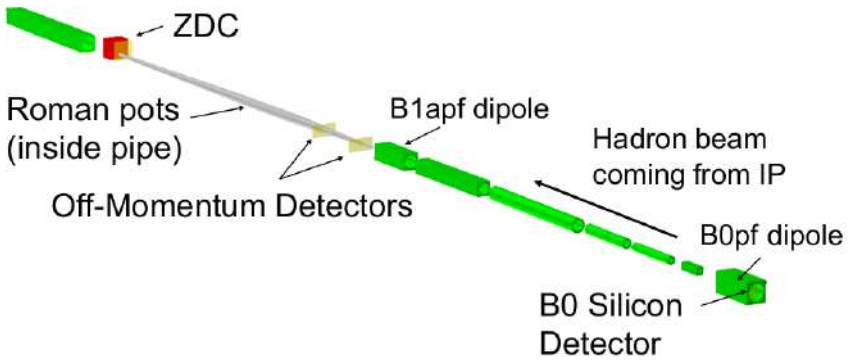
Detection of the decay channel $\Lambda \rightarrow n + \pi^0$ is feasible (...).
Detection of the other decay channel, $\Lambda \rightarrow p + \pi^-$, poses a more challenging measurement owing to its requirement of additional **charged-particle trackers or a veto trigger** on the path to ZDC.

Here was the first scintillator fiber idea

Bill Li question at EIC Early Career Workshop:
“can be used too as Off-momentum Detectors?”

ANSWER: OF COURSE!!

# Far-Forward Region



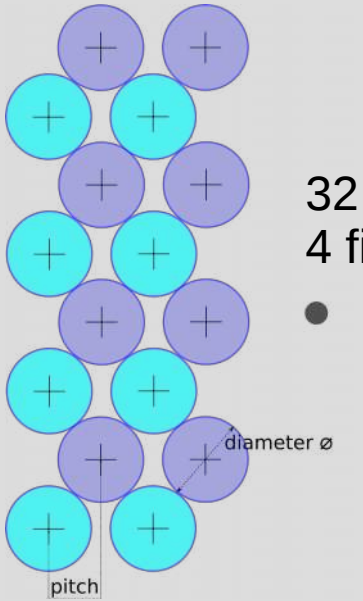

EIC Yellow Report 2021, pag. 548

| Detector | (x,z) Position [m] | Dimensions | $\theta$ [mrad] | Notes |
|---|---|---|---|---|
| ZDC | (0.96, 37.5) | (60cm, 60cm, 2m) | $\theta < 5.5$ | $\sim$4.0 mrad at $\phi = \pi$ |
| Roman Pots (2 stations) | (0.85, 26.0) (0.94, 28.0) | (25cm, 10cm, n/a) | $0.0 < \theta < 5.5$ | $10\,\sigma$ cut. |
| Off-Momentum Detector | (0.8, 22.5), (0.85, 24.5) | (30cm, 30cm, n/a) | $0.0 < \theta < 5.0$ | $0.4 < x_L < 0.6$ |
| B0 Spectrometer | (x = 0.19, 5.4 < z < 6.4) | (26cm, 27cm, n/a) | $5.5 < \theta < 13.0$ | $\sim$20 mrad at $\phi$=0 |

The planes have a "hole" for the passage of the hadron beam pipe that has a radius of 3.2cm.

I am not addressing this 'issue' right now

# Proposed Layout




Kuraray SCSF78M ⌀ = 1mm

32 channels.
4 fibers per channel

● ● ●

Pitch ($p$) = { 0.6 mm ; 0.7 mm }

$$\sigma \propto \frac{p}{\sqrt{12}}$$

σ = { 173 μm ; 200 μm }

**Theoretical spatial resolution**

Width of the bundle

$$L = \varnothing + p \times (ch - 1)$$

→ L = { 19.6 mm ; 22.7 mm }

p=0.6mm → 300mm / 19.6mm/module = 15.3 → 16 modules →
16 modules x 32 channels/module = 512 channels $L_{real}$ = 313.6mm

p=0.7mm → 300mm / 22.7mm/module = 13.2 → 14 modules →
14 modules x 32 channels/module = 448 channels $L_{real}$ = 317.8mm

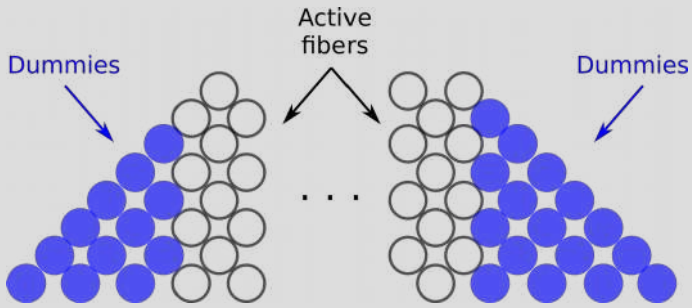
2 Stations x 2 planes (X-Y)/station = 4 planes $\#_{channels}$ = { 2048 ; 1792 }

# Cost (fibers)

- Assuming the larger number of channels → 512ch /plane

512 ch/plane x 4 fibers/ch x (30cm +20cm)/fib = 102,400cm/plane ≡ 1024m/plane

28 dummies/bundle x 16/bundle/plane x 40cm/dummies = 179200 cm ≡ 179.2 m/plane




Fibers + dummies → 1203.2m/plane

x4 planes = 4812.8m + 1 extra plane (contingency)
= 6016m → 6100m

SCSF-78M-1mm-D-6100m-B J

I've been waiting for a quote from Kuraray since last week.
An estimation from an old quote in 2009.
7km (0.83mm) → ¥1.6M = $17,080 (2009) → inflation accumulated (USA) $21,700
I would assume **~$30k**

# Cost (PMTs)

Photomultiplier tube with active divider circuit
Linear multianode PMT assembly, ~~8-channel (H9530 series)~~/
~~16-channel (H10515B series)~~/ 32-channel (H7260 series)

**FEATURES**

- High cathode sensitivity
  Luminous 500 μA/lm Typ. (-20 type)
- Effective area per channel
  ~~H9530 / H11451 / H11932 series ... 2.0 mm × 2.5 mm × 8 channels~~
  ~~H10515B / H11459 series ... 0.8 mm × 16 mm × 16 channels~~
  H7260 / H11460 series ..... 0.8 mm × 7 mm × 32 channels
- High speed response
  ~~H9530 series rise time ..... 0.7 ns Typ.~~
  ~~H10515B series~~, H7260 series rise time ... 0.6 ns Typ.
- Good anode uniformity (H9530 series)
  1:1.1 Max. (at -1000 V and peak wavelength)
- Low cross-talk (H9530 series)
  0.1 % Typ. (each channel)
  Black slit faceplate used
- Built in preamplifier and high voltage power supply circuit (Module types)

Assembly types: H9530 series, H10515B series, H7260 series

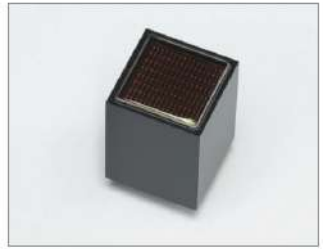
32 lineal → 64 units
**$3507/unit**

MULTIANODE
PHOTOMULTIPLIER TUBE ASSEMBLY
**H12428 SERIES**

8 × 8 Multianode, High Speed Response, High Collection Efficiency
30 mm Square, Super Bialkali and Ultra Bialkali Photocathode
12-stage, Head-on Type

**FEATURES**

- High Quantum Efficiency
- Compact
- 8 × 8 Multianode
- Effective Area: 23 mm × 23 mm
- High Speed Response
- High Cathode Sensitivity
  Luminous 105 μA/lm Typ. (-100/-103 Type)
  Luminous 135 μA/lm Typ. (-200/-203 Type)
- Weight: Approx. 62 g



8x8=64 ch →32 units
**$2053/unit**

FLAT PANEL TYPE
MULTIANODE PMT ASSEMBLY
**H12700 SERIES / H14220 SERIES**

**FEATURES**

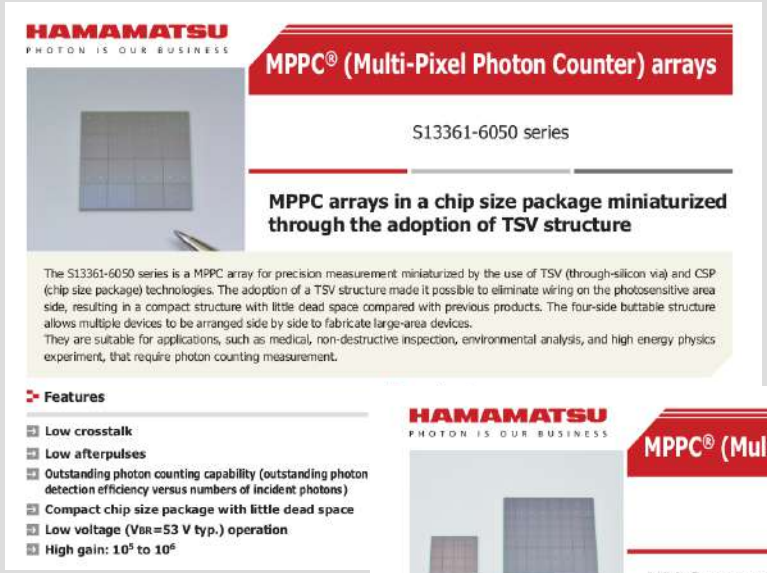
- Large effective area: 48.5 mm × 48.5 mm
- Packing density: 87 %
- 8 × 8 multianode,
  Pixel size: 6 mm × 6 mm / anode
- High quantum efficiency: 33 % Typ.
- Small dead space
- Fast time response
- Two types for HV input
  H12700A series / H14220A: Cable input type
  H12700B series / H14220B: Connector input type
- With tapered divider (-10 type)
- High sensitivity in green region: H14220 series

Left: HV cable input type, Right: HV connector input type

8x8=64 ch →32 units
**$4971/unit**

The PMTs have spectral response and peak sensitive close to the emission spectra of the fibers

# Cost (SiPMTs)



HAMAMATSU
PHOTON IS OUR BUSINESS

**MPPC® (Multi-Pixel Photon Counter) arrays**

S13361-6050 series

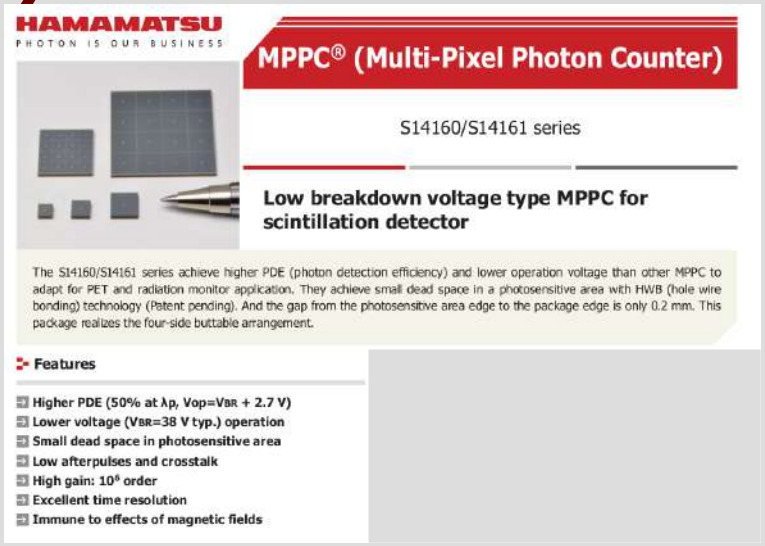
**MPPC arrays in a chip size package miniaturized through the adoption of TSV structure**

The S13361-6050 series is a MPPC array for precision measurement miniaturized by the use of TSV (through-silicon via) and CSP (chip size package) technologies. The adoption of a TSV structure made it possible to eliminate wiring on the photosensitive area side, resulting in a compact structure with little dead space compared with previous products. The four-side buttable structure allows multiple devices to be arranged side by side to fabricate large-area devices.
They are suitable for applications, such as medical, non-destructive inspection, environmental analysis, and high energy physics experiment, that require photon counting measurement.

**Features**

- Low crosstalk
- Low afterpulses
- Outstanding photon counting capability (outstanding photon detection efficiency versus numbers of incident photons)
- Compact chip size package with little dead space
- Low voltage ($V_{BR}$=53 V typ.) operation
- High gain: $10^5$ to $10^6$

4x4 = 16ch → 128 units
**$453.75/unit**



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**MPPC® (Multi-Pixel Photon Counter)**

S14160/S14161 series

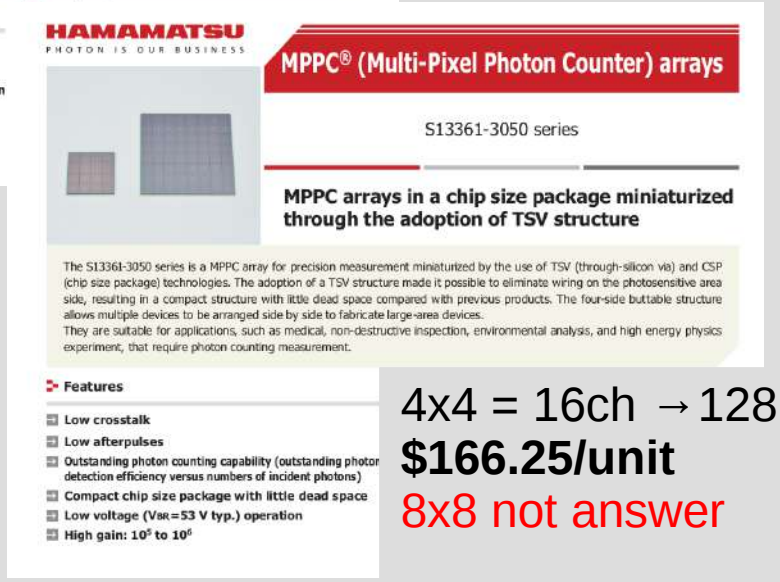
**Low breakdown voltage type MPPC for scintillation detector**

The S14160/S14161 series achieve higher PDE (photon detection efficiency) and lower operation voltage than other MPPC to adapt for PET and radiation monitor application. They achieve small dead space in a photosensitive area with HWB (hole wire bonding) technology (Patent pending). And the gap from the photosensitive area edge to the package edge is only 0.2 mm. This package realizes the four-side buttable arrangement.

**Features**

- Higher PDE (50% at λp, Vop=$V_{BR}$ + 2.7 V)
- Lower voltage ($V_{BR}$=38 V typ.) operation
- Small dead space in photosensitive area
- Low afterpulses and crosstalk
- High gain: $10^6$ order
- Excellent time resolution
- Immune to effects of magnetic fields

4x4 = 16ch →128 units
**$144.00/unit**



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**MPPC® (Multi-Pixel Photon Counter) arrays**

S13361-3050 series

**MPPC arrays in a chip size package miniaturized through the adoption of TSV structure**

The S13361-3050 series is a MPPC array for precision measurement miniaturized by the use of TSV (through-silicon via) and CSP (chip size package) technologies. The adoption of a TSV structure made it possible to eliminate wiring on the photosensitive area side, resulting in a compact structure with little dead space compared with previous products. The four-side buttable structure allows multiple devices to be arranged side by side to fabricate large-area devices.
They are suitable for applications, such as medical, non-destructive inspection, environmental analysis, and high energy physics experiment, that require photon counting measurement.

**Features**

- Low crosstalk
- Low afterpulses
- Outstanding photon counting capability (outstanding photon detection efficiency versus numbers of incident photons)
- Compact chip size package with little dead space
- Low voltage ($V_{BR}$=53 V typ.) operation
- High gain: $10^5$ to $10^6$

4x4 = 16ch →128 units
**$166.25/unit**
8x8 not answer

8x8 = 64ch → 32 units
**$628.75/unit**

4x4 = 16ch →128 units
**$340.00/unit**
Larger area/channel

The SiPMTs have spectral response and peak sensitive close to the emission spectra of the fibers

# Summary

| | PMT | SiPMT | TOTAL $ (with est. Fibers) | Cost per channel $ (2048) |
|---|---|---|---|---|
| Max cost | $224,448 (H7260) | $58,080 (S13361-6050NE-04) | 254,448 / 88,080 | 124.24 / 43 |
| Min cost | $65,692 (H12428-100) | $18,432 (S14161-3050HS-04) | 95,692 / 48,432 | 46.75 / 23.65 |
| Fav cost (larger pixel area) | $159,072 (H14220B) | $43,520 (S14161-6050HS-04) | 189,072 / 73,520 | 92.32 / 35.9 |

Naturally, it needs to be included FE electronics, power and R&D specially for the SiPMT