SHiP inspired design for the ToF system of the ND280 upgrade

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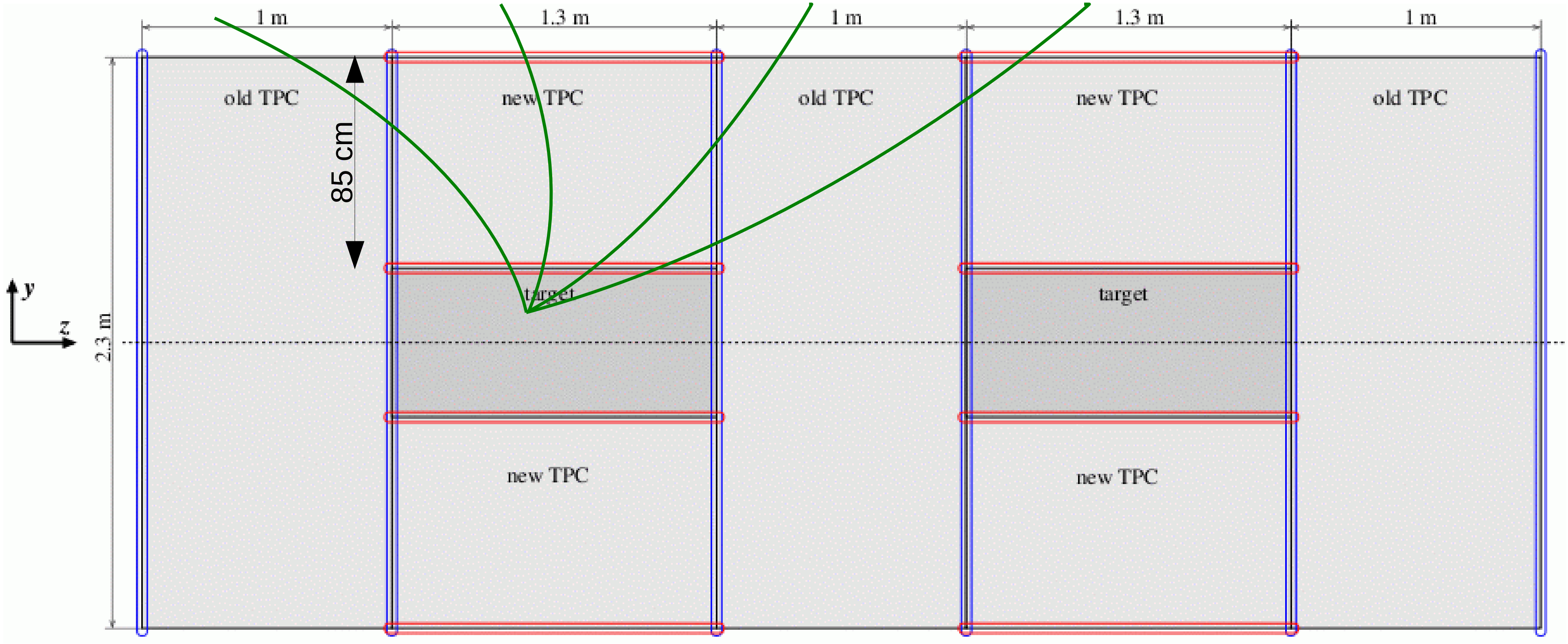
ND280 upgrade/ToF meeting
May 12, 2017

Upgrade of ND280 (T2K)



- Interaction of beam-neutrinos happen in the calorimeter => background
- Important to know the direction of particles: inside of outside the target
- Min time between the target and callorimeter t = 85 cm / 30 cm/ns = 2.8 ns
  - 5 sigmas: dt = 2.8 ns / 5 / $\sqrt{2}$ = 0.4 ns
- Resolution for PID: see plots of Davide
- ToF system: cast (SHiP-like) or extruded plastic (babyMIND-like)

ToF mass

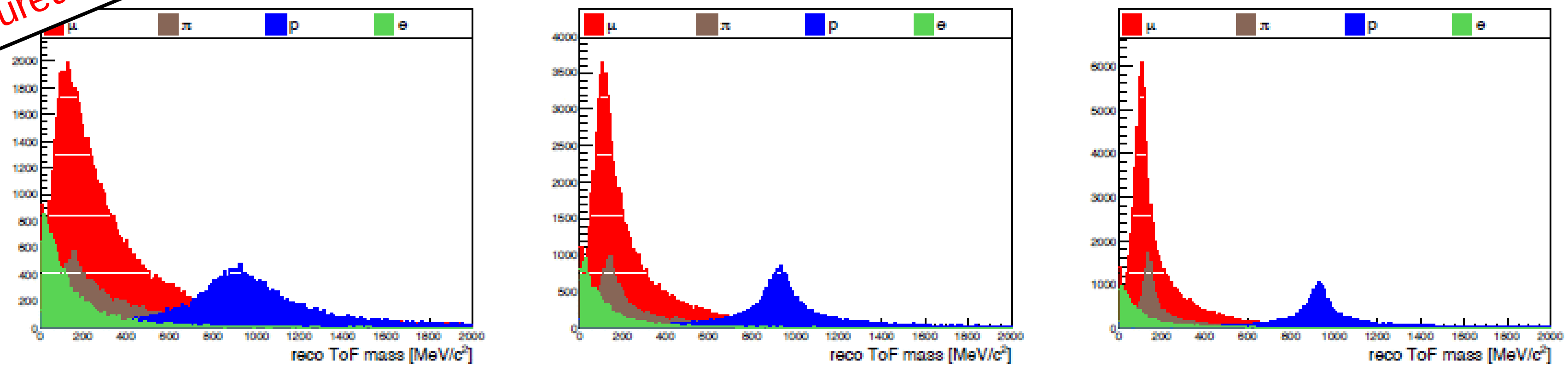
$$m_{ToF} = p \times \sqrt{\frac{c^2(\Delta t_{reco})^2}{L^2} - 1}$$

Sample of preselected ν_μ events

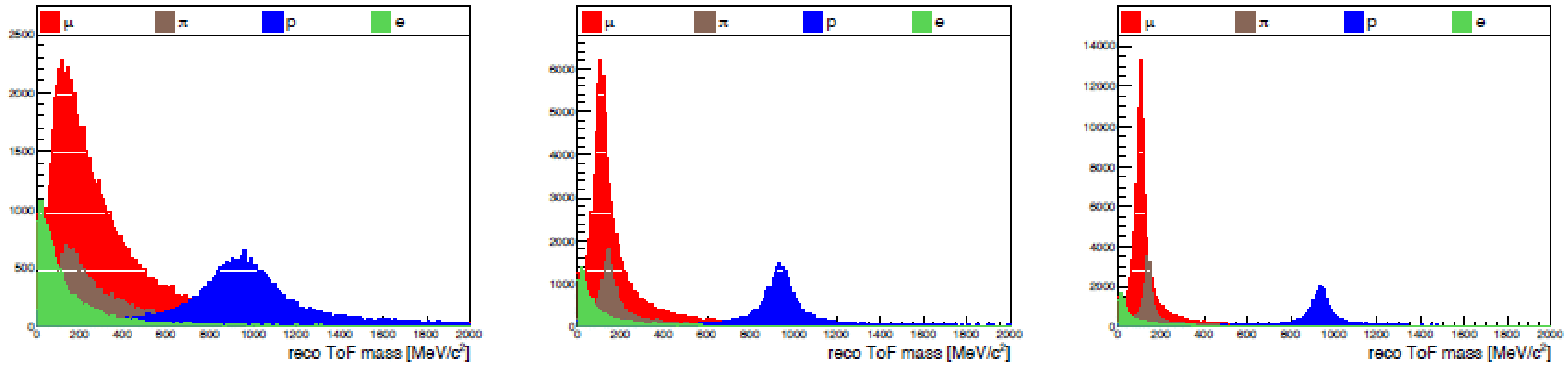
Look at all particles with ToF information (not only highest momentum)

For details see slides of M. Lamoureux on May 10

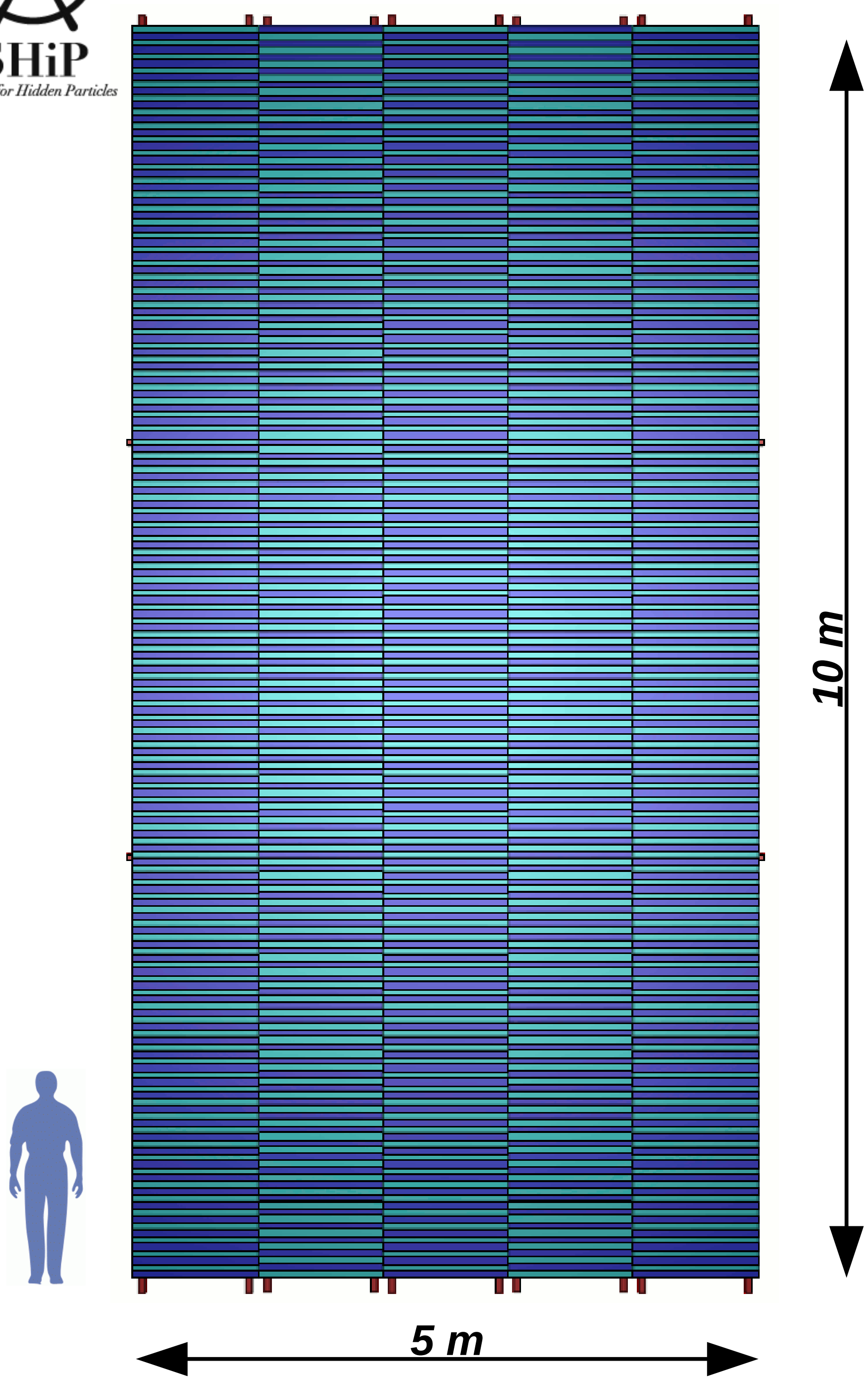
reference configuration



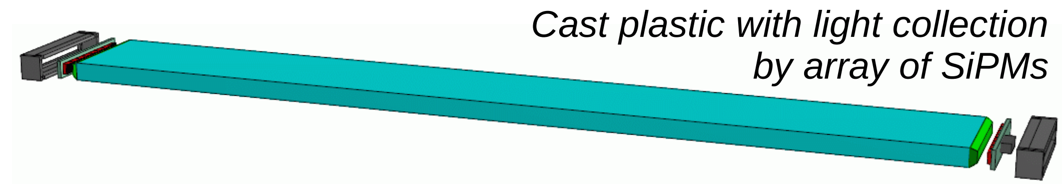
adding new ToF between Target and HTPC



$\sigma_{ToF} = 600$ ps $\uparrow$ $\sigma_{ToF} = 150$ ps $\uparrow$ $\sigma_{ToF} = 50$ ps $\uparrow$

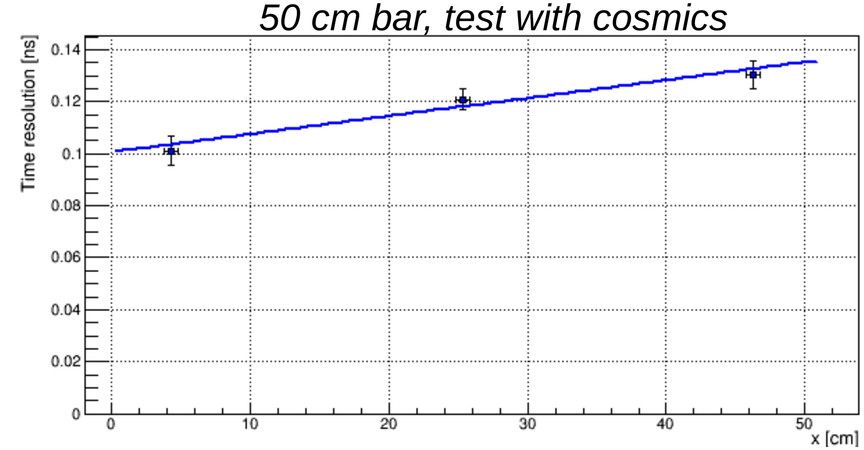


Timing Detector in SHiP

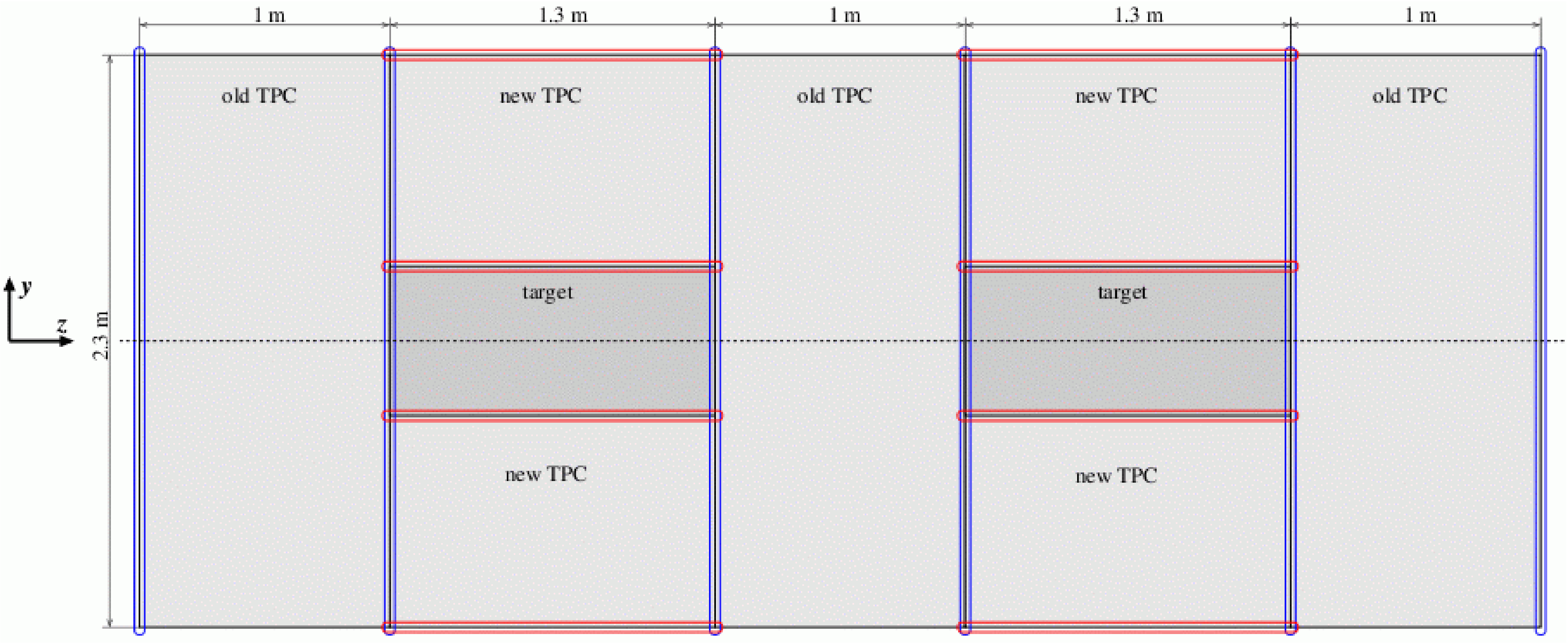


- For the TD of size 5 m x 10 m with a bar ***100 cm x 6 cm x 1 cm***
  - 5 col x 182 row = 910 bars   =>
  - 910 bars x 2 = 1820 ch =>
  - 1820 x 8 = 14560 SiPMs
- The resolution at 50 cm is ~140 ps => we can use with 1 m bar and 2-side readout to be within 100 ps.

50 cm bar, test with cosmics



Proposal for the use of ToF based on a cast plastic

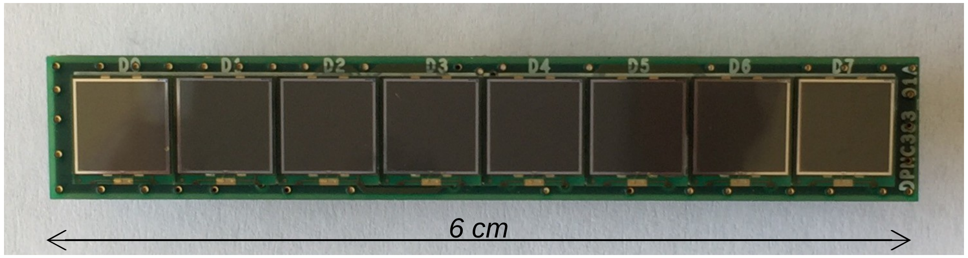


- 6 modules **XY** with dimensions 230 cm x 230 cm each
- 12 modules (**YZ+XZ**) with dimensions 130 cm x 230 cm each
- All modules can be assembled with bars of 230 cm long
- No space for plastic around old TPCs (?)

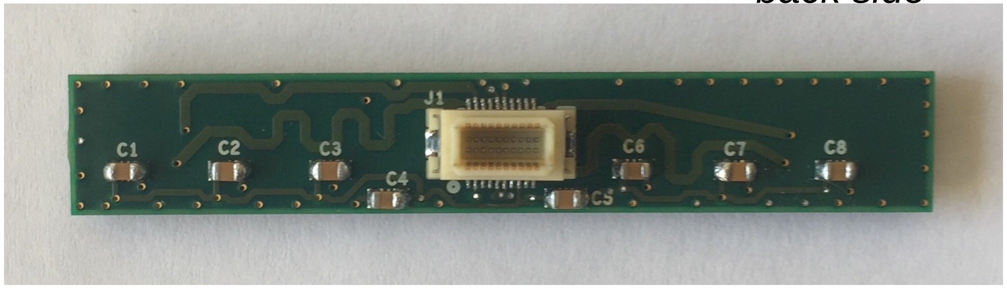
Bar and sensors

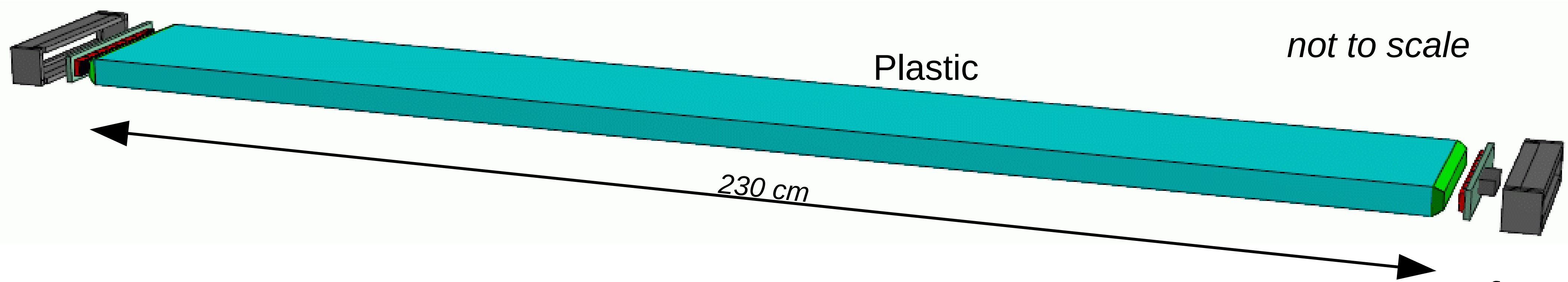
- Bar: 230 cm x 6 cm x 1 cm
- Plastic material:
  - EJ200 (BC408) or EJ208(BC412)
  - Attenuation length ~4 m
  - 1.42 kg/bar
- Readout from both ends
  - 8 sensors of 6 mm x 6 mm
  - Example: S13360-6050PE

front side

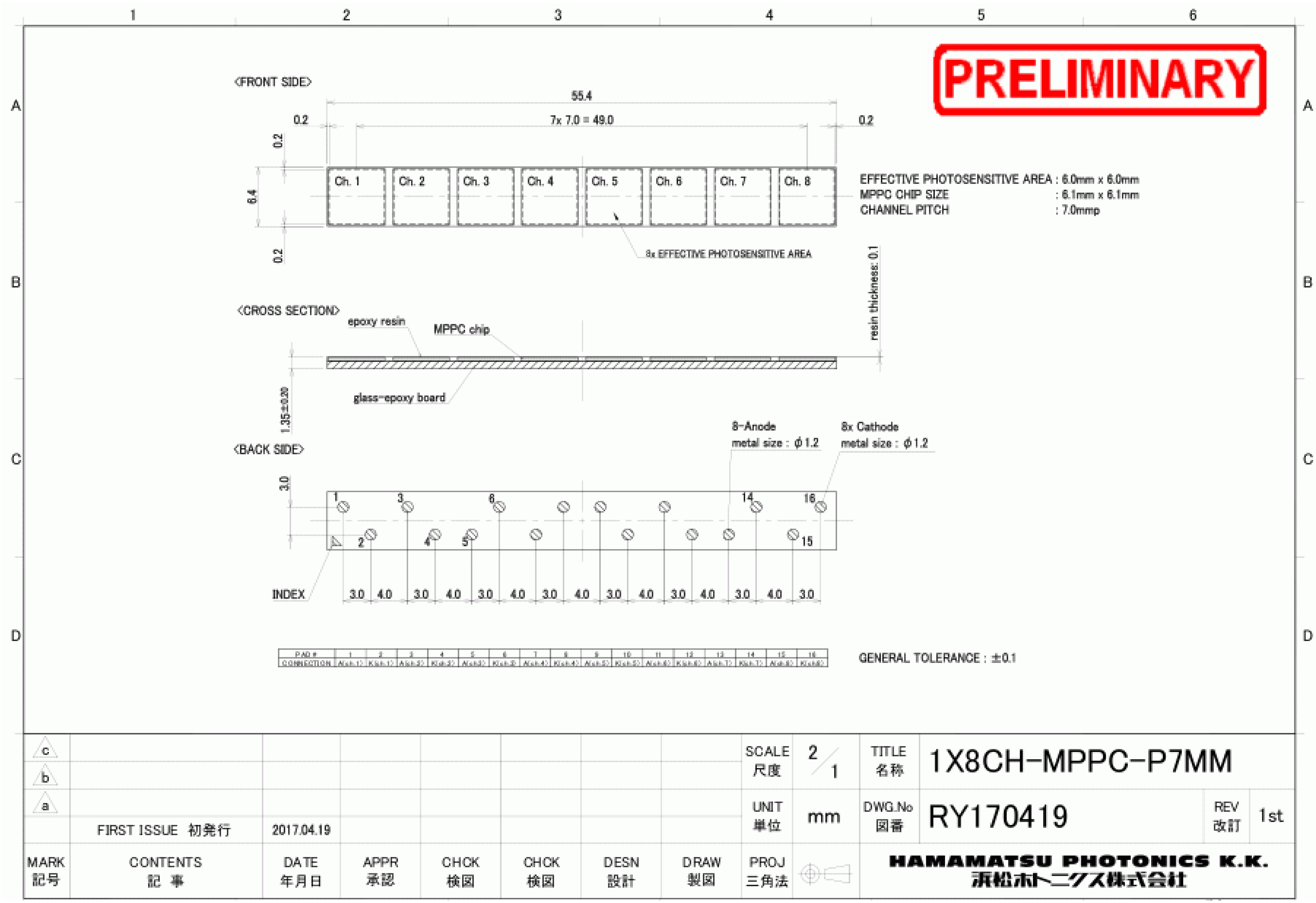


back side

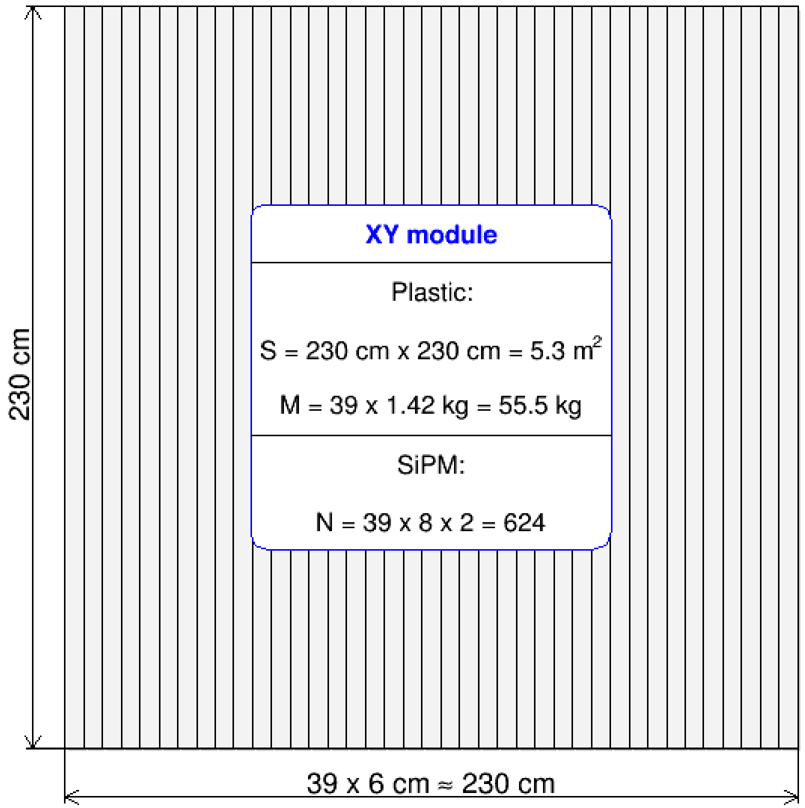


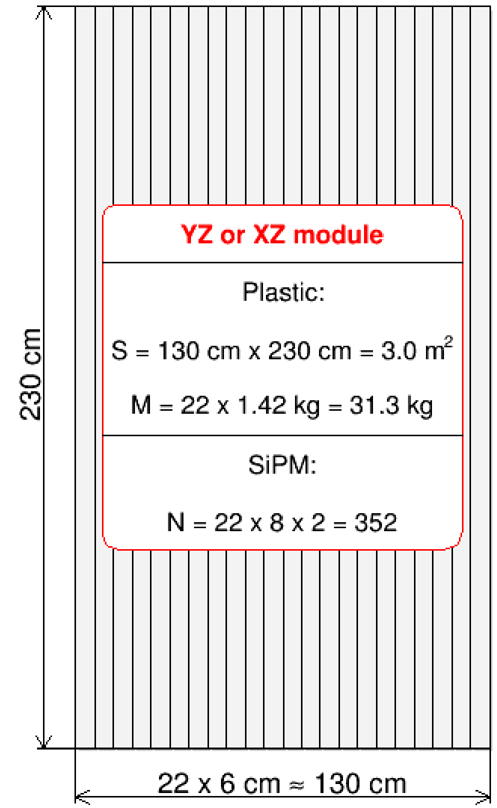


Array of SiPMs (11% cheaper)



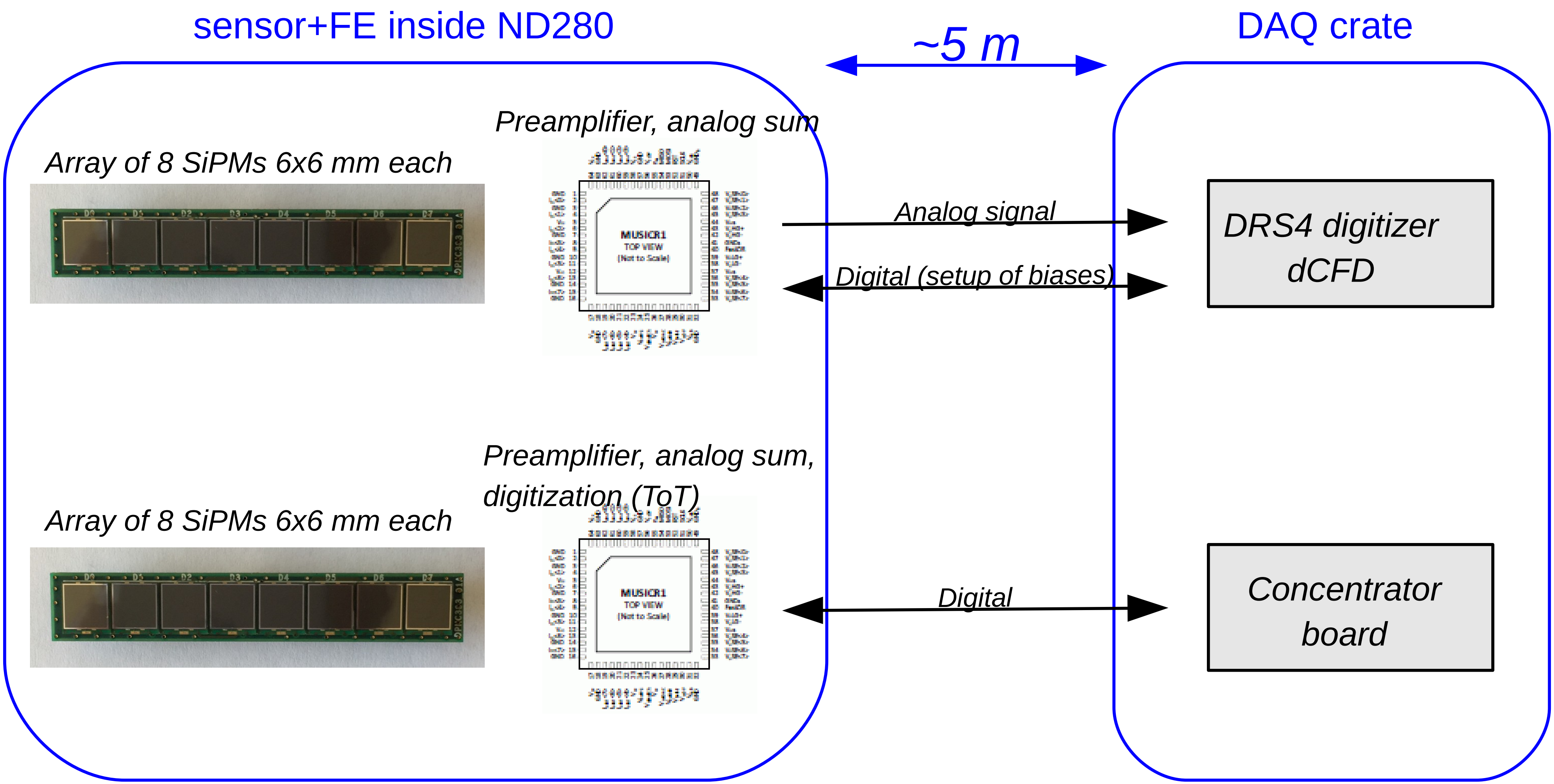
Modules





- 6 modules XY and 12 modules (YZ+XZ)
- Surface 6 x 5.3 m^2 + 12 x 3 m^2 = 67.6 m^2, weight 0.7 ton
- Number of bars (230 cm) = 498. Number of SiPMs = 498 x 2 x 8 = 7968
- In case of the 5 mm overlap between bars all estimates to be increased by 5/60=8.3%

Options for electronics

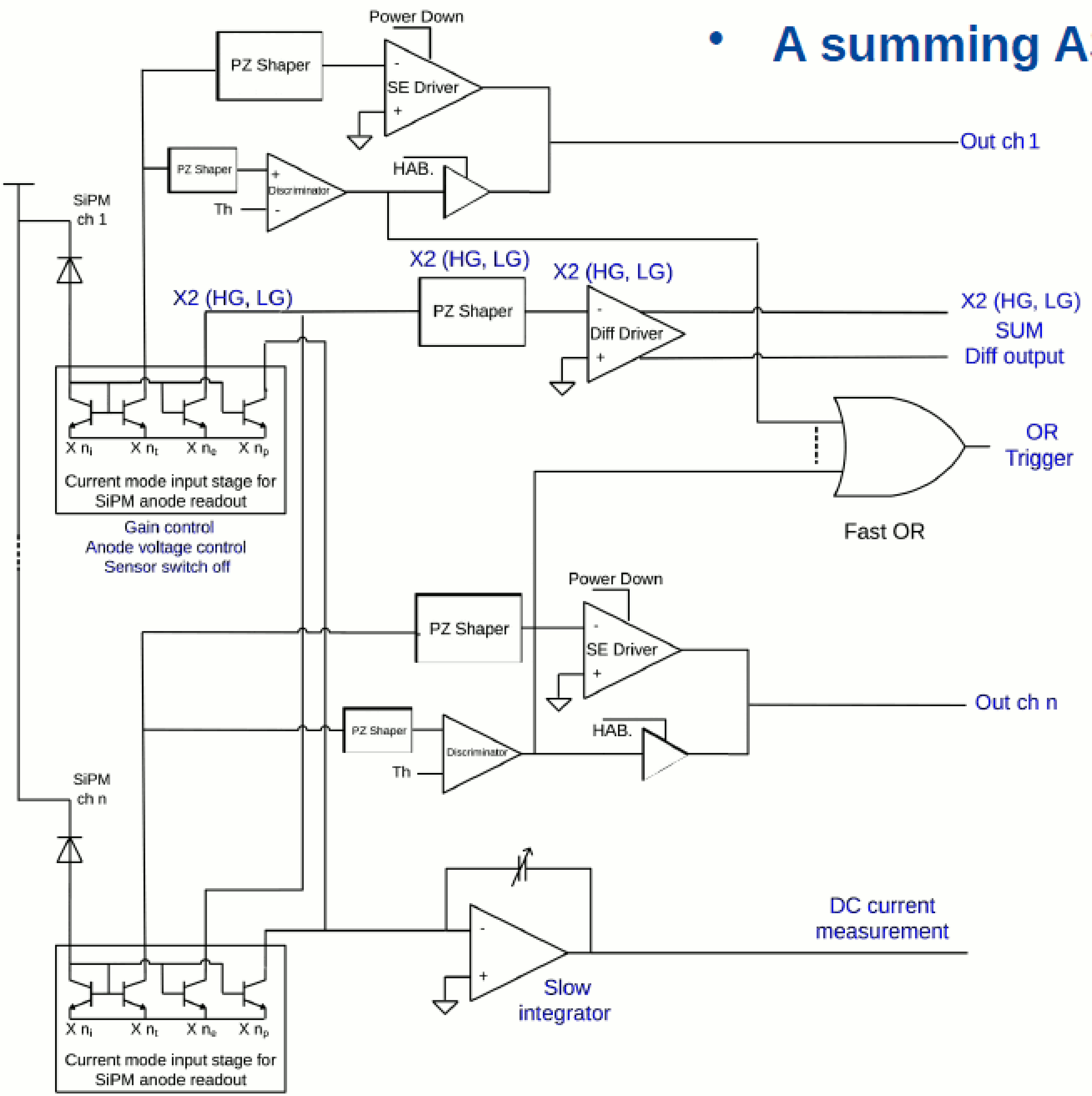


- Price per ASIC (MUSIC R1) is 80 EUR. Total: 1000 x 80 EUR = 80 kEUR
  - Including connectors, PCBs and so on 120 kEUR (estimate by Barcelona Uni)
- Can UniGe also contribute with electronics (Yannick)

Electronics: ASIC *vs* discrete circuit

- The idea of the readout is basically the same as applied in CTA (Yannick)
  - Capacitance increases with the surface of SiPM => rise time increases => time resolution degrades. Solution: readout sensors in parts, amplify and sum
- Advantage of ASIC (MUSIC R1) as compared to the discrete circuit
  - Amplification, summation and discrimination within a single chip
  - Occupied space is much smaller
  - Power consumption is an order of magnitude lower => lower heating => less constrains for the cooling system
  - 'current buffer' is used for the input stage of MUSIC => minimum input impedance which is the best for the readout of large capacitance

MUSIC (Multiple Use SiPM IC)



• A summing ASIC and more…

- Input
  - Up to 8 pixels (6x6 mm^2 SiPMs)
  - Possible to disable each input reducing overvoltage by 4V
- Outputs:
  - High Gain SUM
    - Diff, 100 Ω, 500 MHz
  - Low Gain SUM
    - Diff, 100 Ω, 500 MHz
  - OR trigger
  - Per channel, choose between:
    - Analog (S.E, 50 Ω,, 100 MHz)
    - Digital
  - "DC current"
    - Sum output
    - Per channel mux output
    - Integrator: 1 ms time constant
- Control
  - Every block and channel can be disabled (power down)
  - Many config parameters

Cost estimate: Plastic

- Bar with dimensions: 230 cm x 6 cm x 1 cm
  - Scintillator EJ-200 (BC-408, NE/Pilot F), attenuation length 380 cm.
    - 1 pcs: 990 EUR
    - 2 pcs: 665 EUR
    - 500 pcs: 290 EUR
    - Total: 500 x 290 EUR = **145 kEUR**
  - Scintillator EJ-208 (BC-412, NE-110), attenuation length 400 cm.
    - 1 pcs: 995 EUR
    - 2 pcs: 665 EUR
    - 500 pcs: 295 EUR
    - Total: 500 x 295 EUR = **147.5 kEUR**
- UVT PMMA Light-Guide
  - Dimensions: 60 mm x 10 mm by 4 mm thick tapered to 56 mm x 6 mm
  - 1000 pcs: 45 EUR
  - Total: 1000 x 45 EUR = **45 kEUR**
- Quotation by Scionix (NL) on Apr 11, 2017

Cost estimate: SiPMs

- based on **S13360-6050PE** : 6x6mm, 50 µm pixel, low xtalk & afterpulse, epoxy resin
- Individual SMT packages
  - 10 pcs: 11'610 JPY = 106.7 CHF/MPPC
  - 100 pcs: 6'290 JPY = 57.8 CHF/MPPC
  - 8000 pcs: 2'990 JPY = 27.5 CHF/MPPC, Total: 8000 x 27.5 CHF = **220.0 kCHF**
  - 10 kpcs: 2'420 JPY = 22.2 CHF/MPPC
  - Pricebreak: 10-49 / 100-299 / 5k-9'999 / 10k – 49'999 pcs
- Array 6X6MM-1X8CH-MPPC
  - NRE COST SSD: 625 kJPY = 5.8 kCHF
  - 10 pcs: 57'750 JPY = 530.6 CHF/array => 66.3 CHF/MPPC
  - 1000 pcs: 21'450 JPY = 197.1 CHF/array => 24.3 CHF/MPPC
    - Total: 1000 x 197.1 CHF = **197.1 kCHF**
  - 2000 pcs: 17'420 JPY = 160.1 CHF/array => 20.0 CHF/MPPC
  - Pricebreak: 10 (MOQ) – 49 / 1k – 1'999 / 2k -4'999 pcs
- Quotation by Hamamatsu on Apr 11, 2017
- Exchange rate assumed: 1 CHF = 108.8 JPY

Summary for the cost estimate

- Main contributes to the overall cost of the 'cast' version of ToF
  - Electronics: 120 kEUR
  - Plastic: 145 kEUR
  - SiPM arrays: 197.1 kCHF
  - Together: 1.1x(120+145)+197.1 = 489 kCHF
- If DRS is used one adds: 1000 ch x 50 CHF = 50 kCHF
- Reduction of the number of channels (Electronics+SiPMs) => square root reduction of the time resolution
- Time resolution with a long bar will be measured at the test-beam at the end of June.

backup

plastic

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SCIONIX — Dedicated Scintillation detectors

Physics Associate II at University of Geneva, DPNC
Address: 1-1-074, CERN, 1211 Geneve 23,
Att. R. Alexander Korzenev
korzenev@mail.cern.ch

Quotation Number QU1722026 **13-04-2017**

Item	Quantity	Description	Price/piece
1)		EJ-200 Plastic Scintillator Size: 230cm x 6cm x 1cm, edges diamond-milled, faces as-cast.	
	1 ea		€ 990,--
	2 ea		€ 665,--
	500 ea		€ 290,--
2)		EJ-208 Plastic Scintillator Size: 230cm x 6cm x 1cm, edges diamond-milled, faces as-cast.	
	1 ea		€ 995,--
	2 ea		€ 670,--
	500		€ 295,--
3)		UVT PMMA Light-Guide Size: 60mm x 10mm by 4mm thick tapered to 56mm x 6mm according to customers drawing.	
	1000 ea		€ 45,--

CONDITIONS:

Prices : NET Ex-Works Bunnik, The Netherlands
Please provide us your courier name and account number.

Delivery time: : Quantities 1 & 2: 5-6 weeks; Quantity 500: 8-10 weeks; Quantity 1000: 10-12 weeks. ARO"Lead times are based on our current workloads. A firm delivery date will be provided at the time of the order.

Payment term: : 30 days net

Warranty : One year after receipt of goods

Validity of quote : 60 days.

Sincerely yours,

R.Bosmans
Scionix Holland BV

SCIONIX HOLLAND B.V.
p.o. Box 143, 3980 CC BUNNIK
The Netherlands
Tel.: +31- 306570312
Fax: +31- 306567563
www.scionix.nl

Bank:	Deutsche Bank,	BIC code:	DEUTNL2N
Dollar account no:	44.76.14.843,	IBAN code:	NL97DEUT0447614843
EURO account no.	54.01.45.033,	IBAN code:	NL89DEUT0540145033
Chamber of Commerce Utrecht, Reg. No. 109468		VAT. No.:	NL 80 15 95 824 B01

sensors (array)

Quotation

HAMAMATSU
PHOTON IS OUR BUSINESS

Hamamatsu Photonics Swiss Office - Dornacherplatz 7 - 4500 Solothurn

Mr Alexander Korzenev
Département de physique nucléaire et corpusculaire DPNC, University of Geneva
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1211 Genève 4
SWITZERLAND

Quotation No: H16544
Quotation Date: 11.04.17
Revision No: 1

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Dear Mr Korzenev,

Please find hereafter your requested quotation:

Pos.	Part No. Description	Quantity [pcs]	Unit Price JPY	Net Amount JPY
1.1	NRE COST SSD Non-recurring engineering (SSD)	1	625'000.00	625'000.00
2.1	6X6MM-1X8CH-MPPC MPPC 1x8 channel (based on same chip as S13361-6050NE)	10	57'750.00	577'500.00
2.2	6X6MM-1X8CH-MPPC MPPC 1x8 channel (based on same chip as S13361-6050NE)	1000	21'450.00	21'450'000.00

Pricebreak: 10 (MOQ) -49 / 1K - 1999pcs
Design: 1x8ch array similar to SMD PKG type like S13361-6050NE

Quotation valid for: 30 days
Terms of Delivery: Free carrier Solothurn (CHF 20.-/ shipment)
Payment Terms: 30 days net

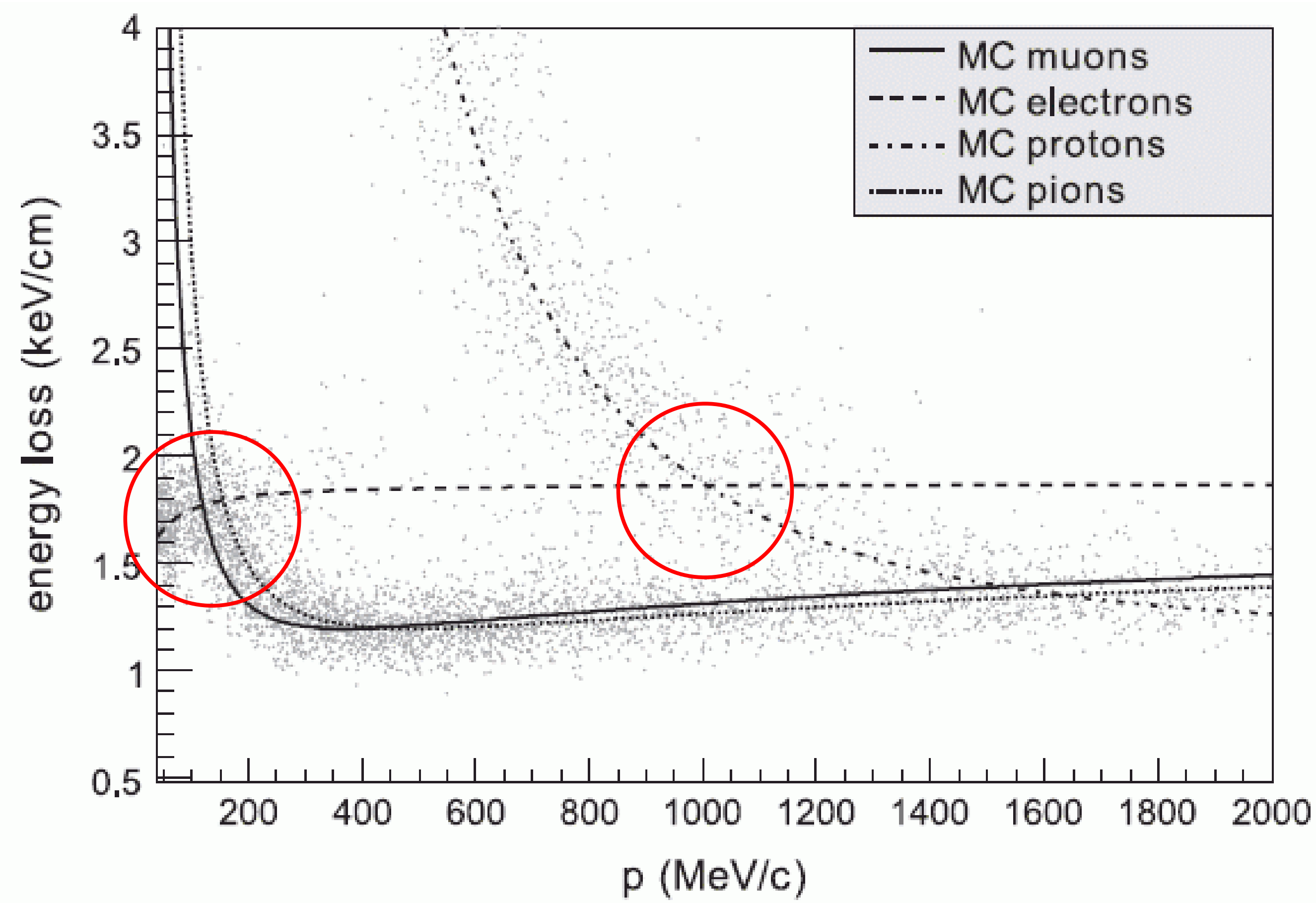

Fig. 21. Each point shows measurements by a single TPC of the energy loss and momentum of positively charged particles produced in neutrino interactions. The expected relationships for muons, positrons, protons, and pions are shown by the curves.

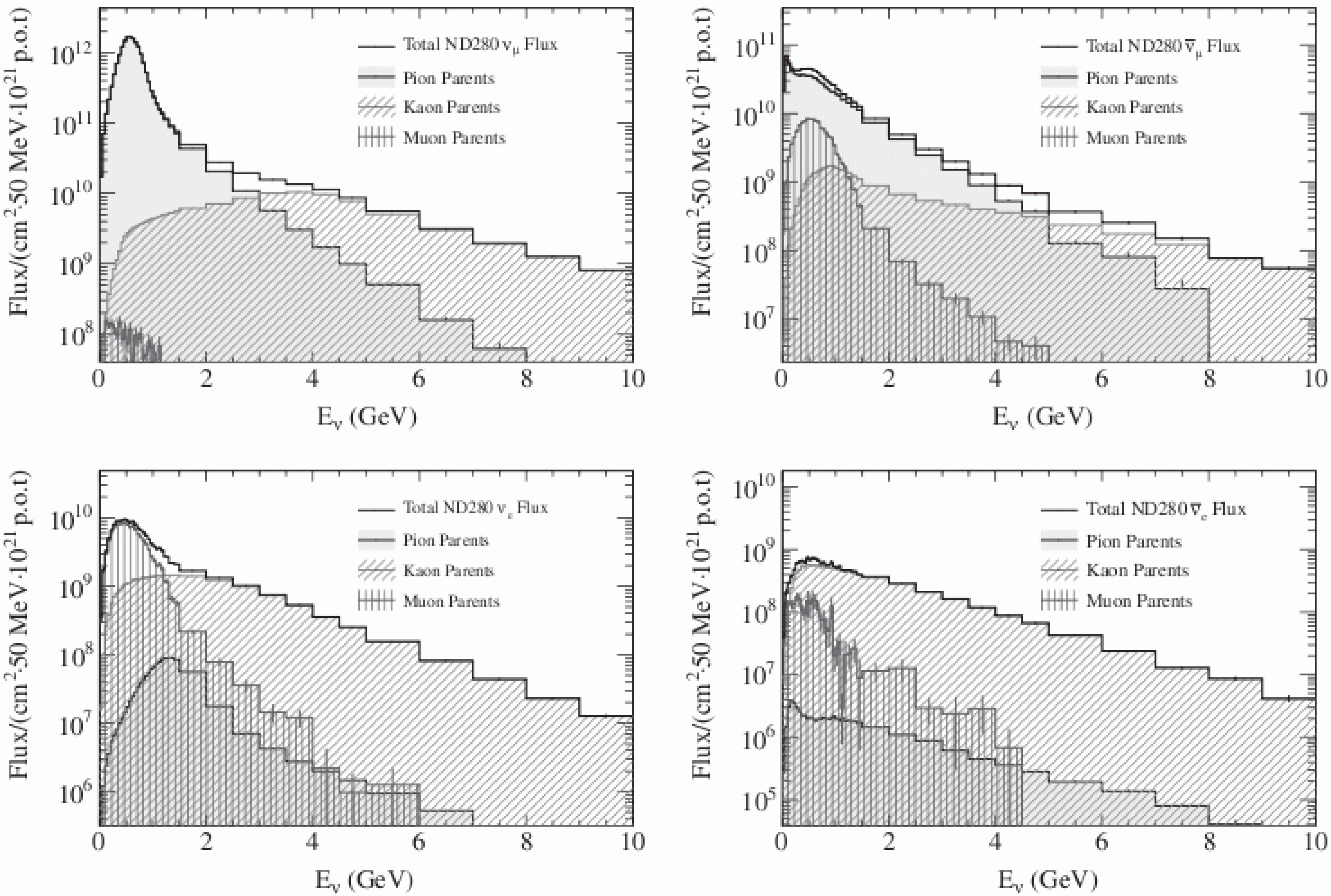

FIG. 25. The flux predictions for the SK far detector and ND280 near detector broken down by the neutrino parent particle type. The error bars, which are too small to be seen in most energy bins, are due to the MC statistical error.