Fiber Detector Status

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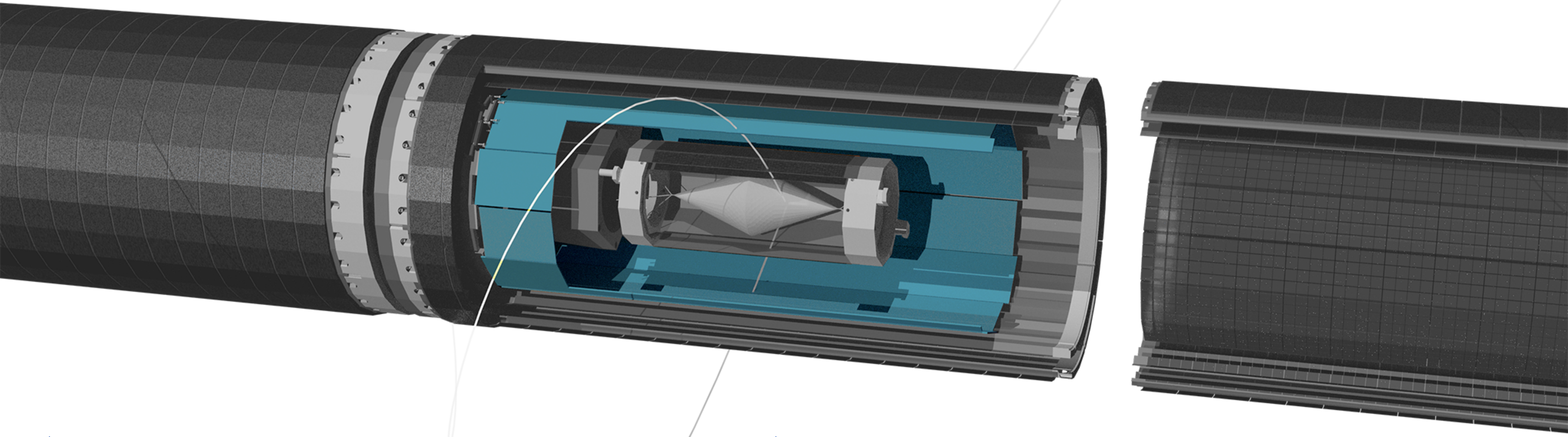
Baseline Design & Requirements



❖ **Design Parameters**

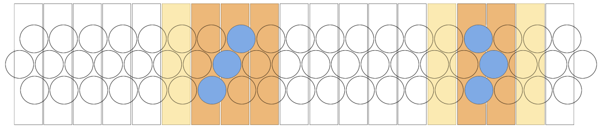
- 12 ribbons, 3-4 layers of 250 µm scintillating fibers
- 28-30 cm long, R ≈ 6 cm
- SiPM array for optical readout
- MuTRiG ASIC

❖ **Requirements**

- Thickness $X/X_0 \leq 0.5$ % ($\lesssim$1 mm)
- Efficiency $\gtrsim$ 95 %
- Time resolution better than 1ns -> 500 ps
- Limited space
- Handle high occupancy: up to 250 kHz/fiber

Ribbon: Addressed Challenges

- **Light Yield and Time Resolution** (BVR 48)
  Time resolution improves with light yield
- **Efficiency and Thickness** (BVR 48)
  Efficiency and and light yield increase with the number of layers of the ribbon, as does the multiple scattering, which deteriorates momentum resolution
- **Occupancy**
  400 -:- 1000 kHz / SiPM channel depending on cluster size



- **Fiber Material Effect on Timing/Light**
  - Kuraray SCSF 78 MJ
  - Kuraray SCSF 81 MJ
  - Kuraray NOL 11
  - Saint Gobain BCF12
- **Thickness Influence on Efficiency and Light Yield**
  - 2 Layers
  - 3 Layers
  - 4 Layers
- **Fiber Coating Effect on Cluster Size**
  - Clear epoxy
  - Epoxy mixed with 20% TiO_2 by weight
  - 100 nm of Al deposited on each fiber

Ribbon: Construction Challenges

Clear epoxy and Epoxy with TiO_2 mixture

Round
- Wind fibers from delivery spool directly onto a stand matching the desired length and width
- Coarse cut and mount in end piece
- Fine cut with a diamond blade
- Production time: **2h/layer** (2 x 128 fibers) + epoxy hardening

Square
- Align precut fibers in a pocket matching the desired length, width and layer thickness
- Combine finished layers and mount in end piece
- Fine cut with a diamond blade
- Production time: **4h/layer** (1 x 128 fibers) + epoxy hardening

➤ Fastest production

➤ Procedure suitable only for square fibers

× Limited in cluster size reduction

Aluminum Coating

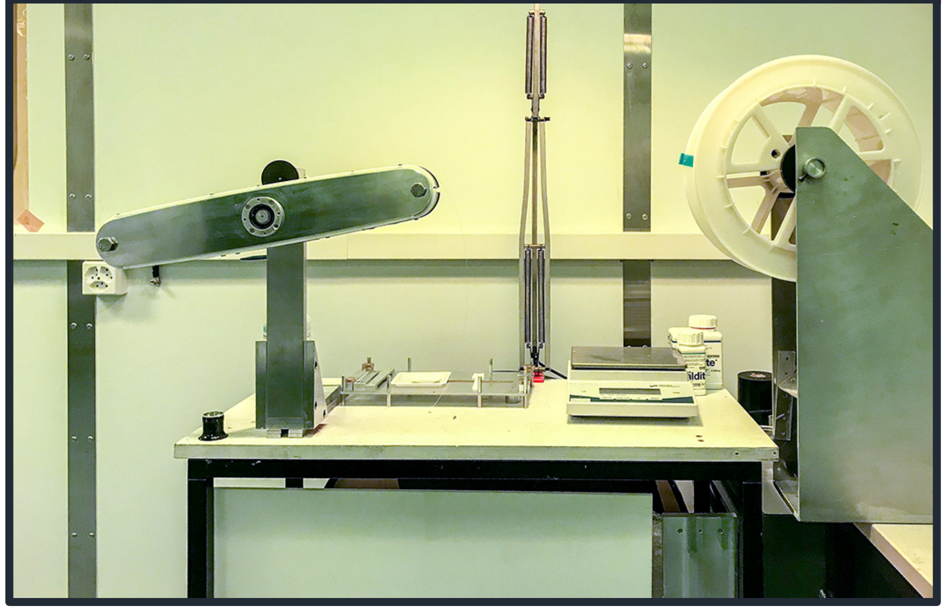
Round or Square
- Precut and clean the fibers
- Align in a grid for coating
- Remove from the grid and align in a pocket matching the desired length and layer thickness
- Combine finished layers and mount in end piece
- Fine cut with diamond blade
- Production time: **8h/layer** + aluminizing + epoxy hardening

➤ Best fiber cross talk reduction (< 1%)

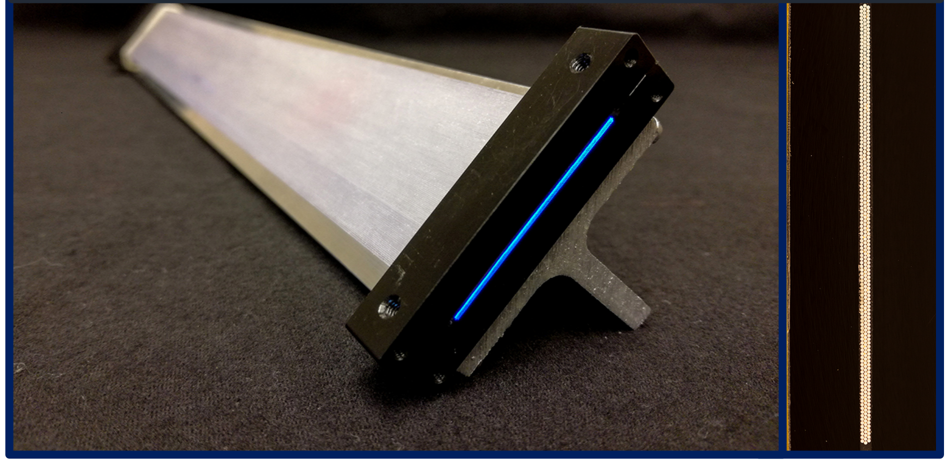
× Time consuming and expensive production

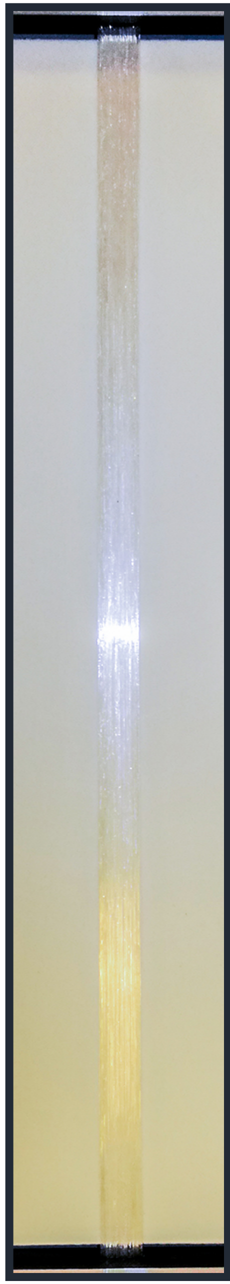
Ribbon: Prototype Photos

Winding Setup

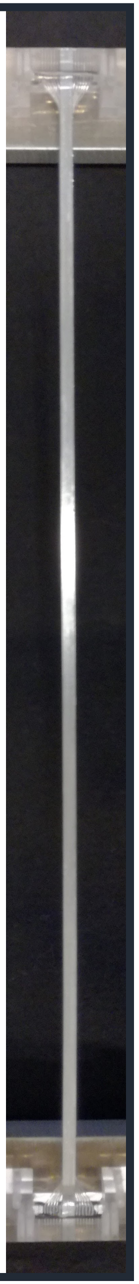


Full size ribbon, mechanical tests

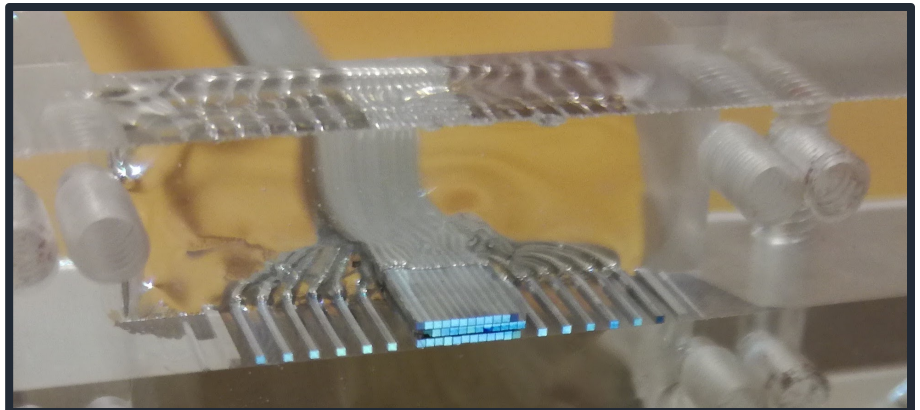




Full length ribbon prototypes, tested in 2017



Fibers arranged for Aluminizing

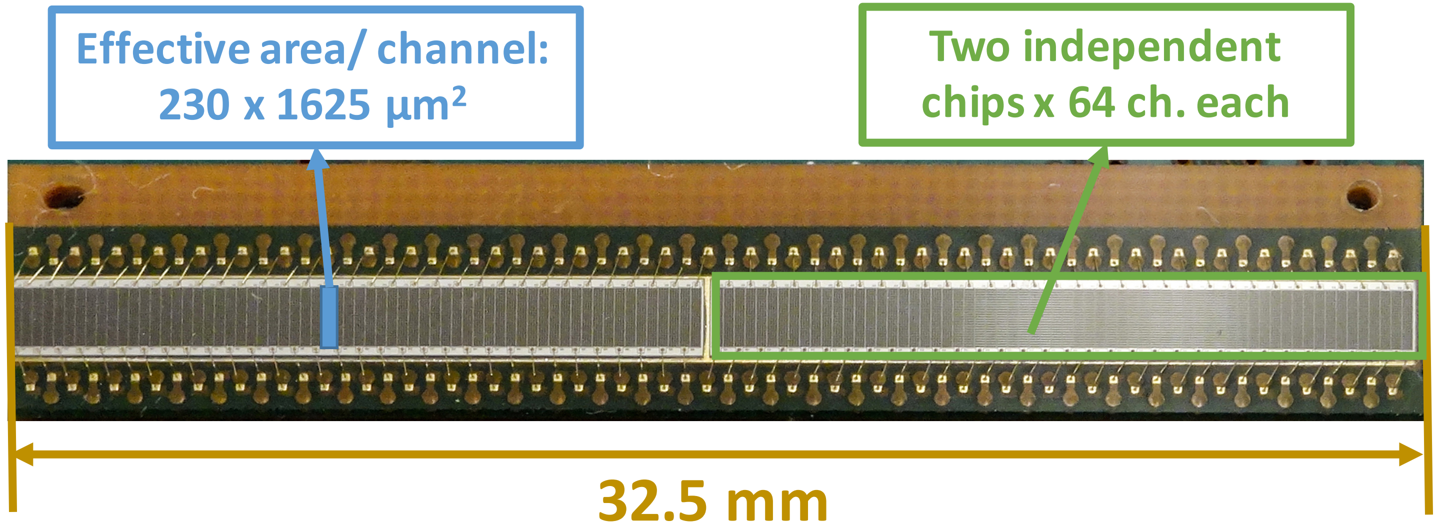


Cross-section of BCF 12 ribbon with 3 + 1 Layers

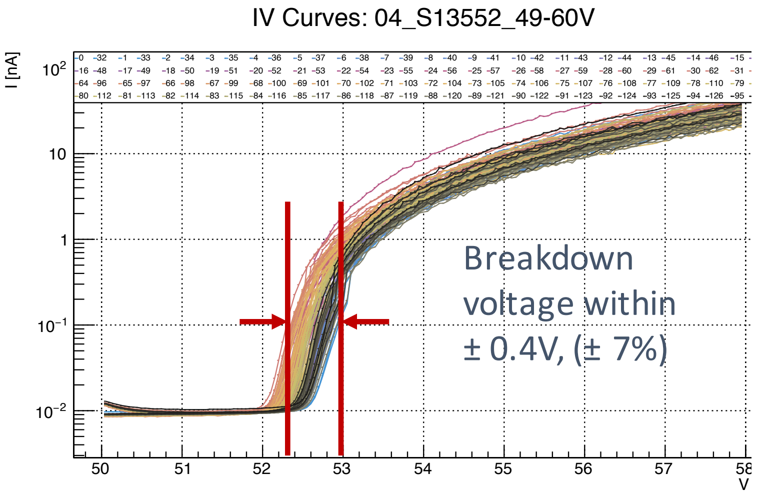
SiPM Detector

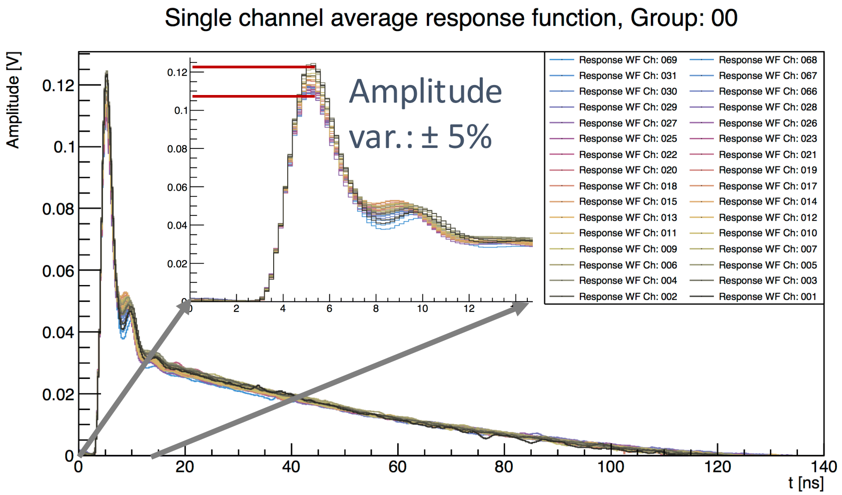
Hamamatsu S13552-HQR

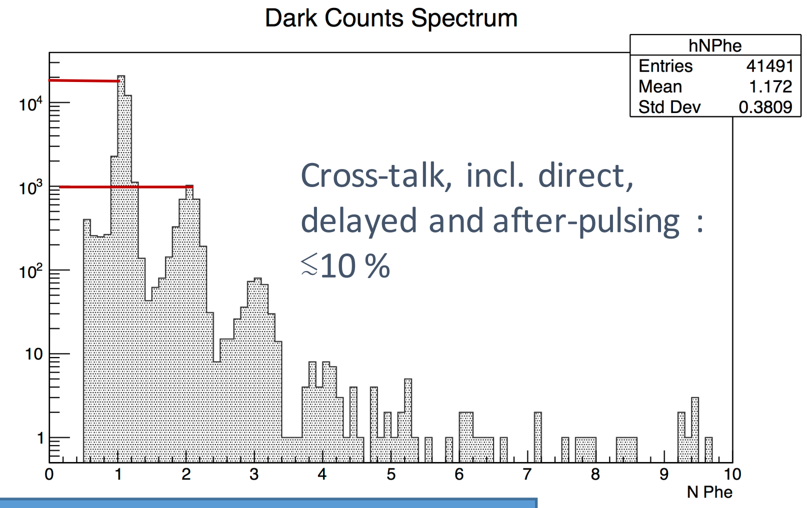
- ➢ LHCb design suitable for our needs



- ➢ Uniform Channel Behavior
- ➢ Low pixel cross talk

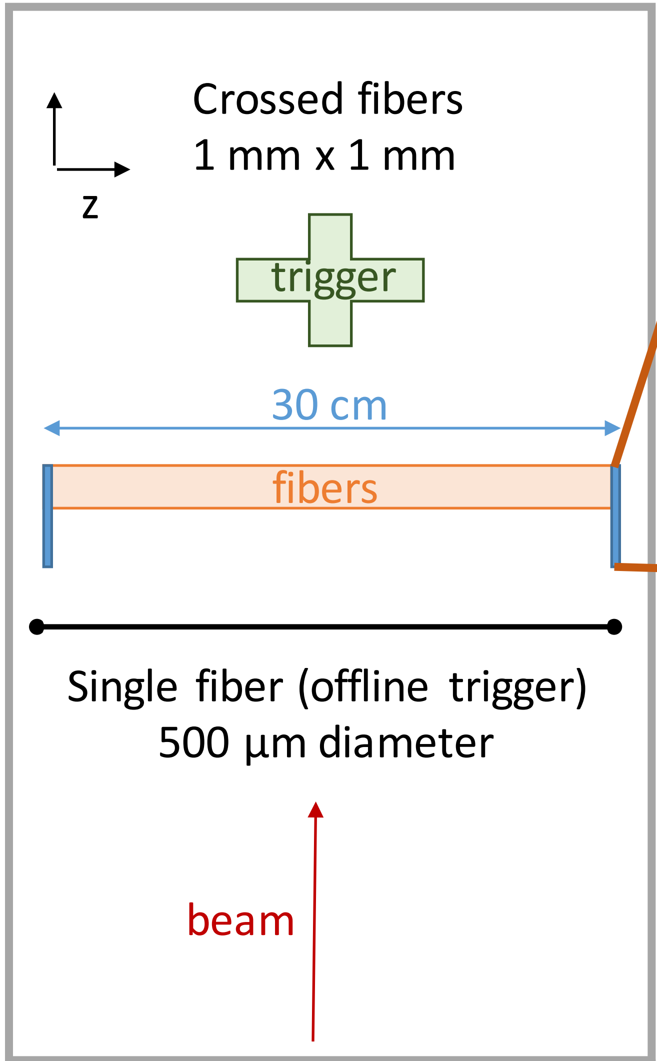




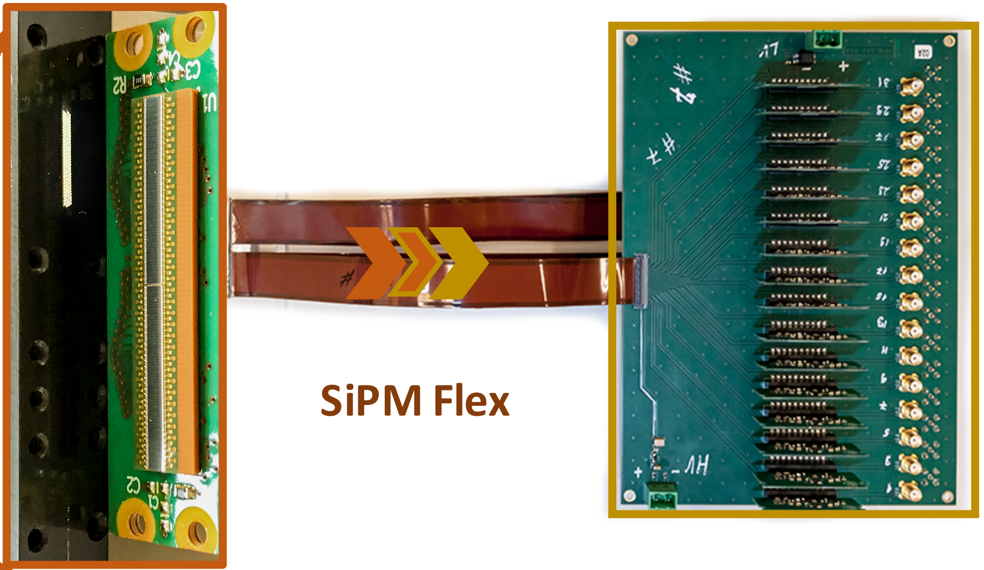


- ➢ **50 pieces** of Hamamatsu S13552-HQR ordered and **received**
- ➢ Automated **test procedures under development**

Ribbon Characterization: Setup



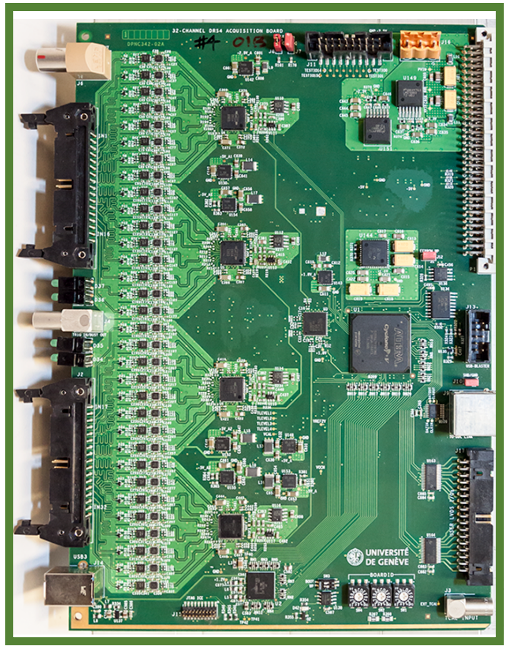
Measurement scheme



SiPM Flex

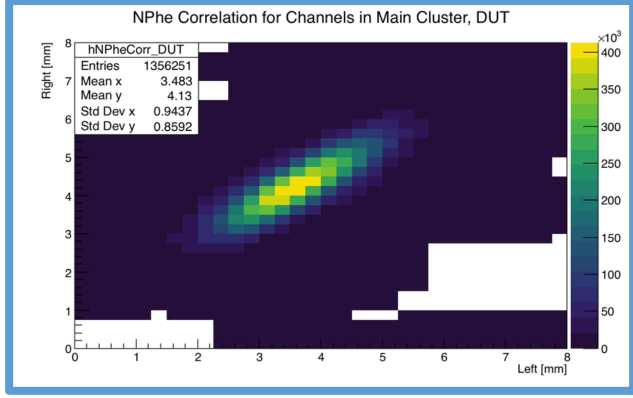
Ribbon/SiPM Coupling

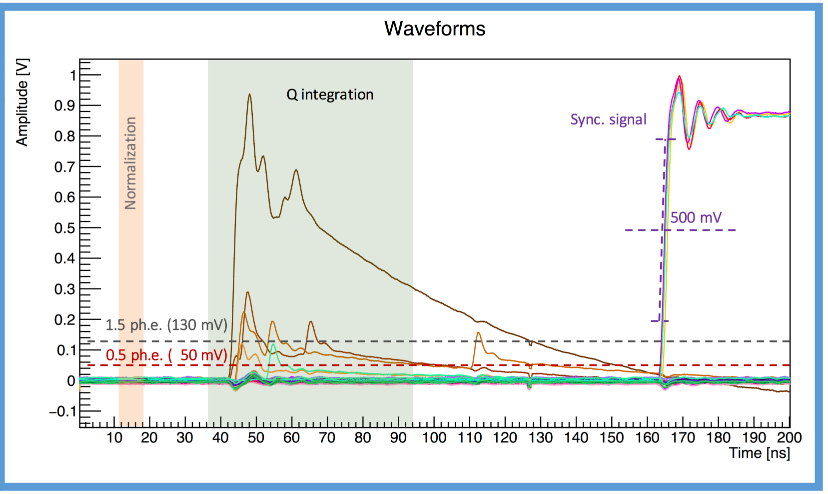
Fast Amplifier, 32 Ch.



Waveform digitizer, 4 x DRS4 chips, 32 Ch.

Run Data





➢ **Autonomous** system with discrete electronics allowing detailed studies

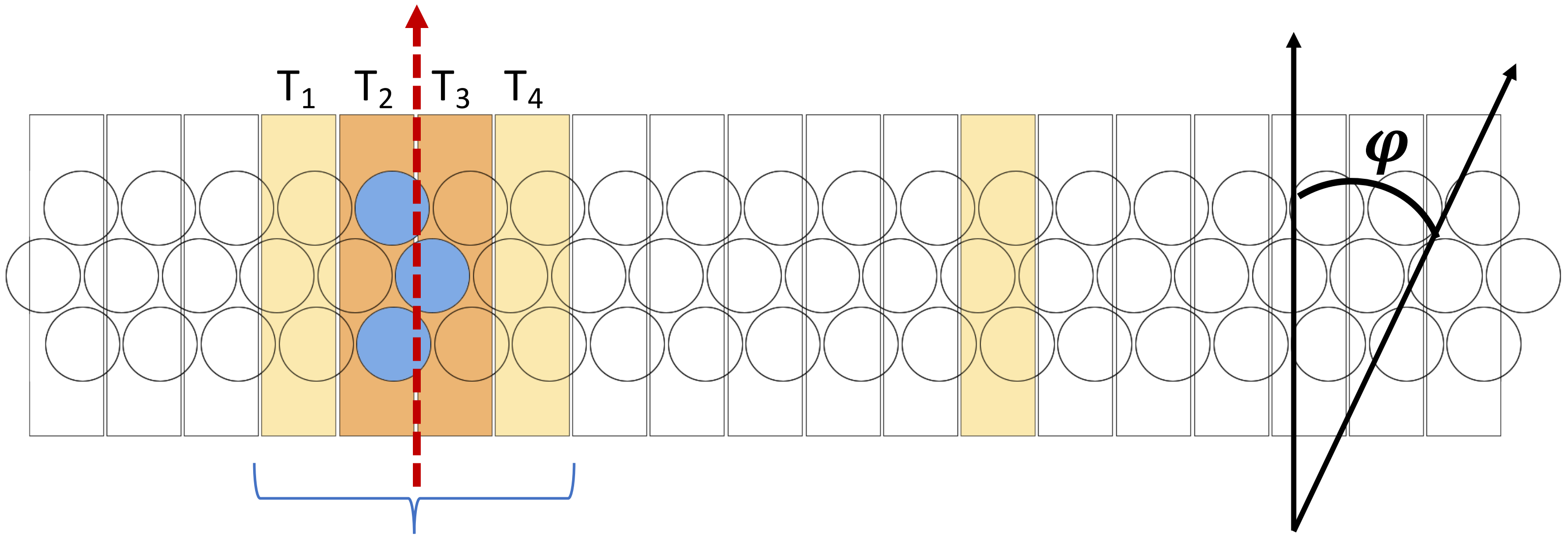
Ribbon Characterization: Analysis Algorithms

Time from Waveform

- Leading edge crossing at a fixed threshold of **0.5 ph.e.**

Clustering

- Minimum charge per channel: **0.5 ph.e.**
- Coincidence window: **20 ns**
- Minimum number of neighboring channels: **2**



Time Resolution

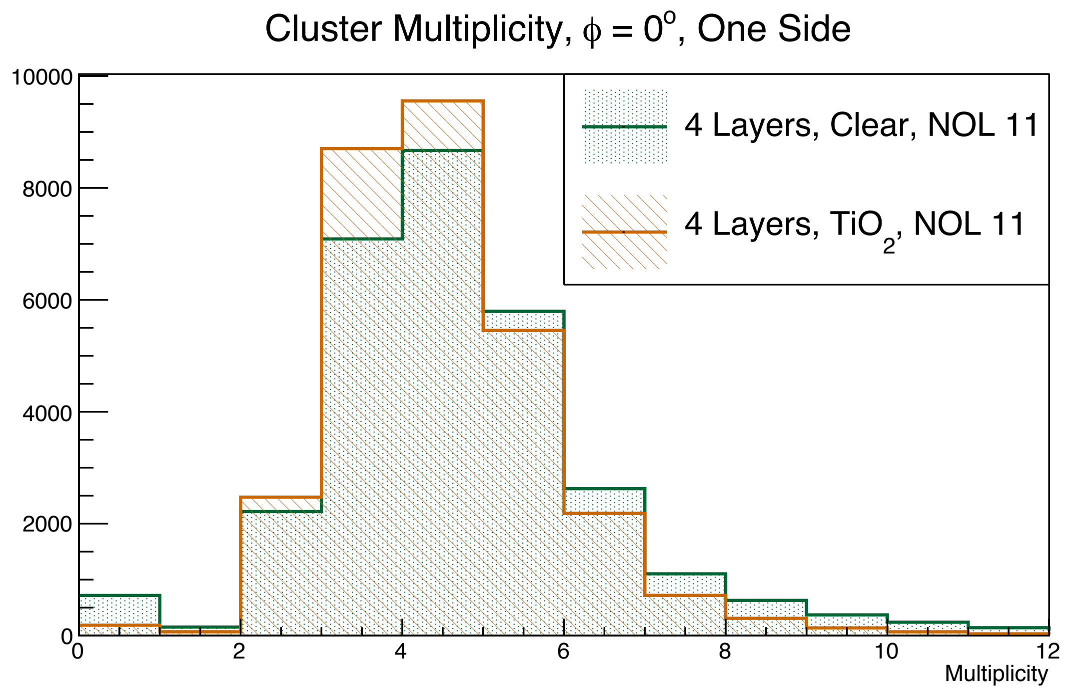
- Sort cluster T_i and pick the smallest T for each side
- Determine $\sigma(T^L_{min} - T^R_{min})$ from Gaussian fit. The required resolution is $\sigma = \sigma_{\Delta T}/\sqrt{2}$

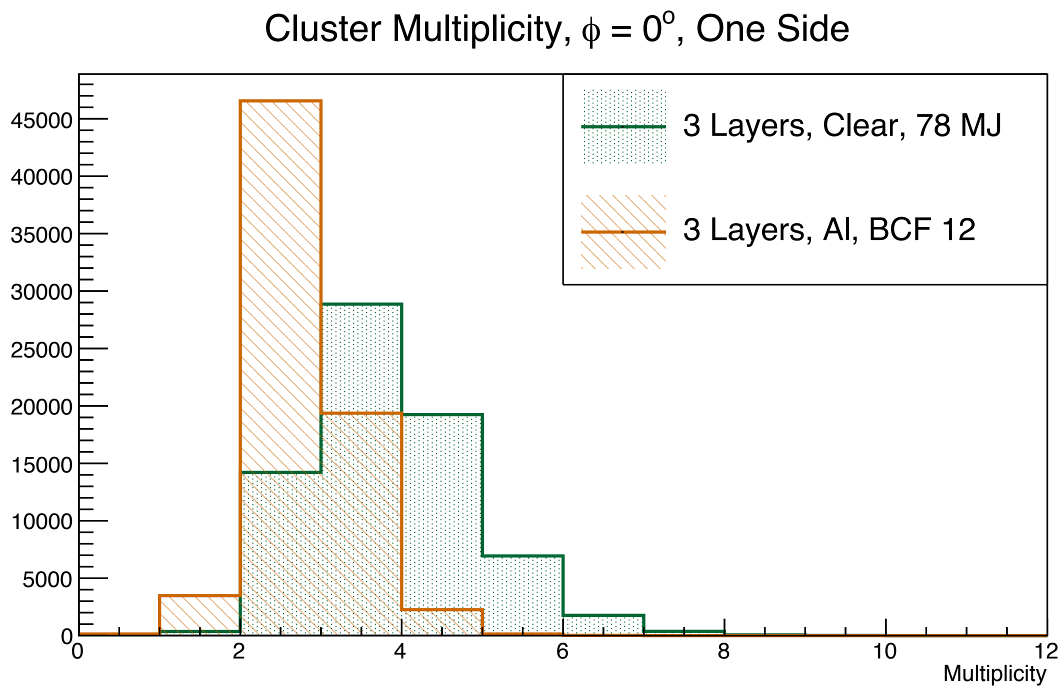
Ribbon Characterization: Coating

➢ **Fiber Coating Effect on Cluster Size**

- Clear epoxy
- Epoxy with 20% TiO_2

- 100 nm of Al on fiber





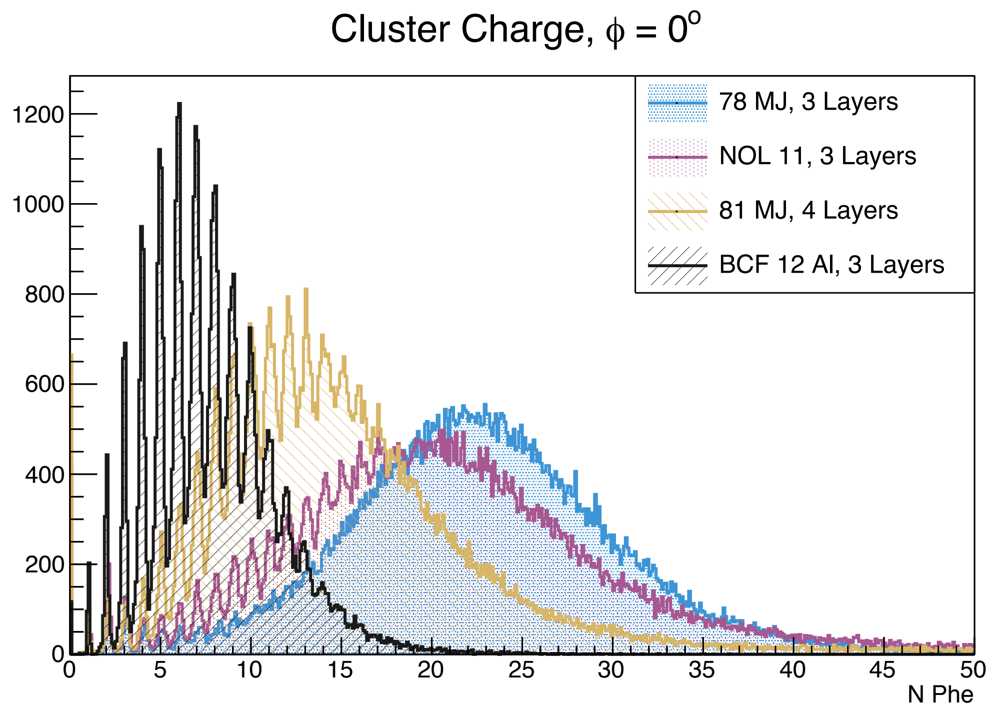
- TiO_2 mixture (as prepared) **does not** significantly **affect cluster size**
- **TiO_2 increases multiple scattering**

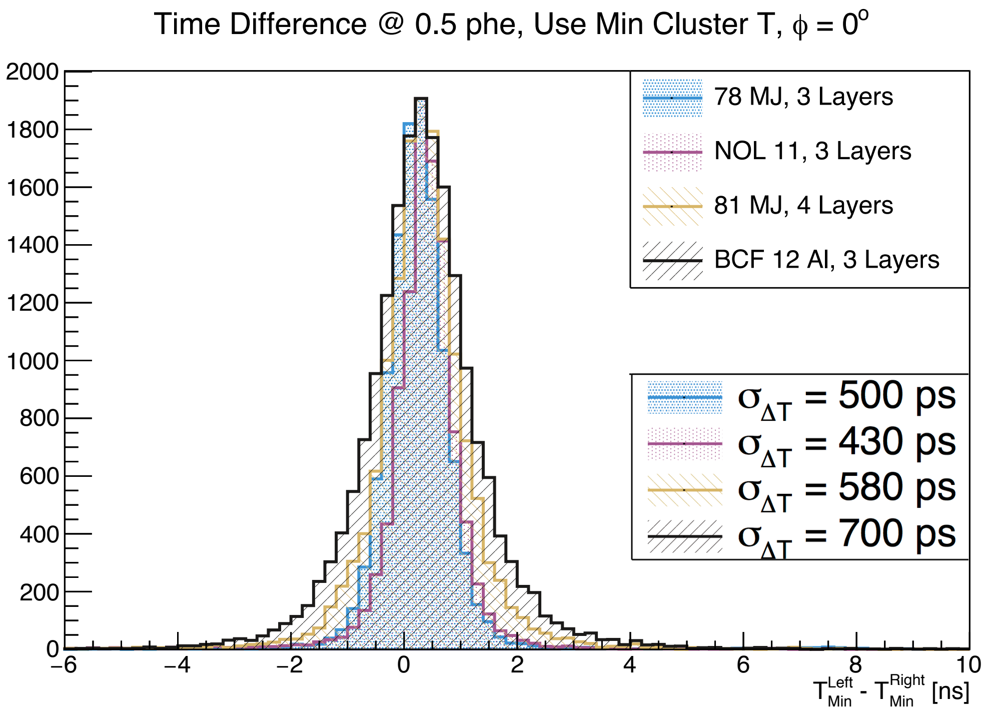
- **Al** coating results in **low cluster multiplicities**
- Difficult to distinguish from **darks**

Ribbon Characterization: Light Yield & Time Resolution

➢ **Fiber Material Effect on Light Yield**

- Kuraray SCSF 78 MJ
- Kuraray SCSF 81 MJ
- Kuraray NOL 11
- Saint Gobain BCF12

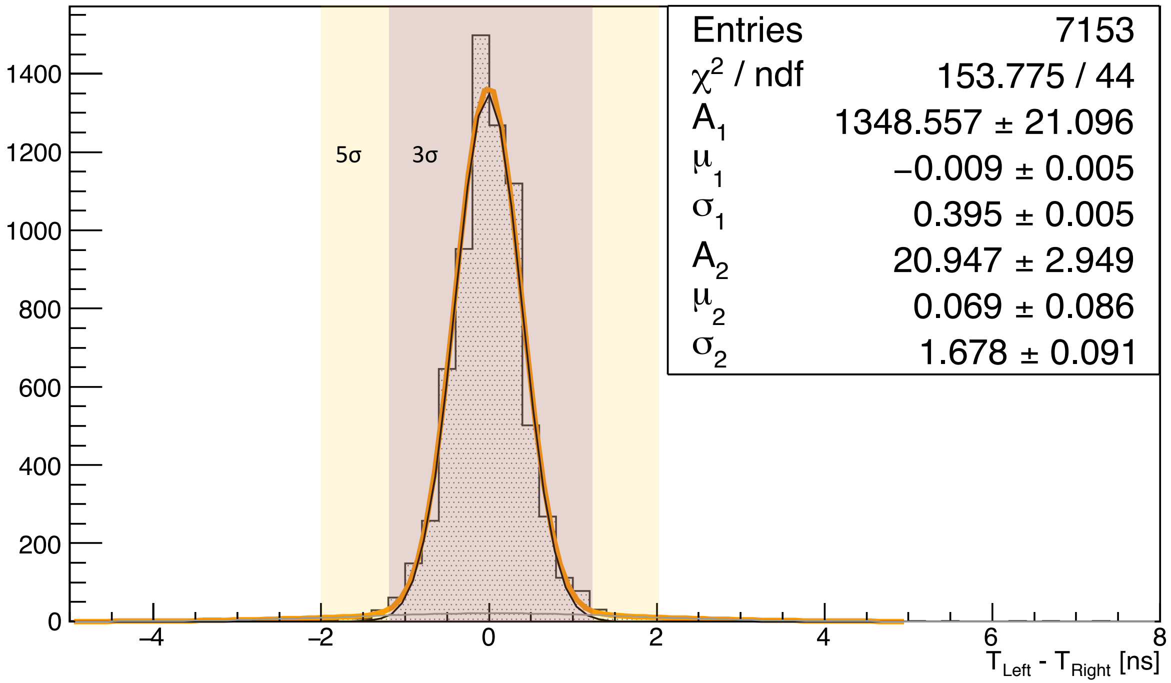




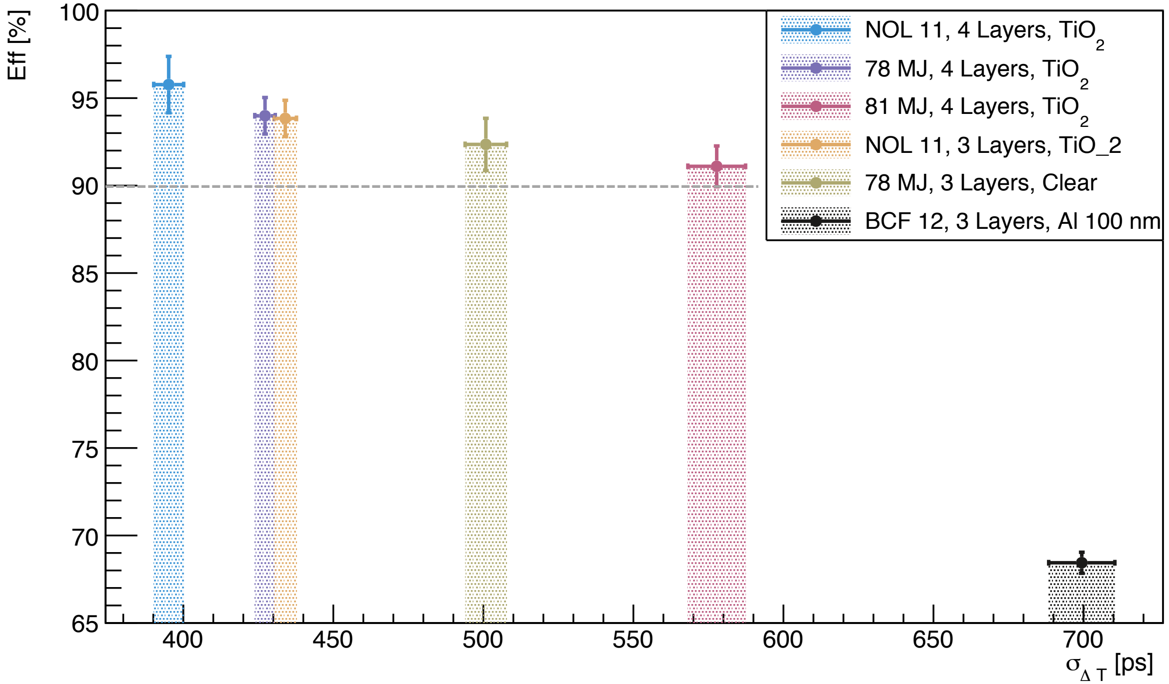
- **NOL 11** and **SCSF 78 MJ** have **comparable light yield,** but NOL 11 has **shorter decay time** (from literature) => **better time resolution**
- **All fibers** fulfil the baseline requirement in terms of time resolution, $\boldsymbol{\sigma_{\Delta T}} \lesssim$ **710 ps** (500 ps * √2)

Ribbon Characterization: Efficiency

Time Difference, NOL 11, 4 Layers, TiO_2



Core Time Difference Resolution vs Efficiency within 3σ



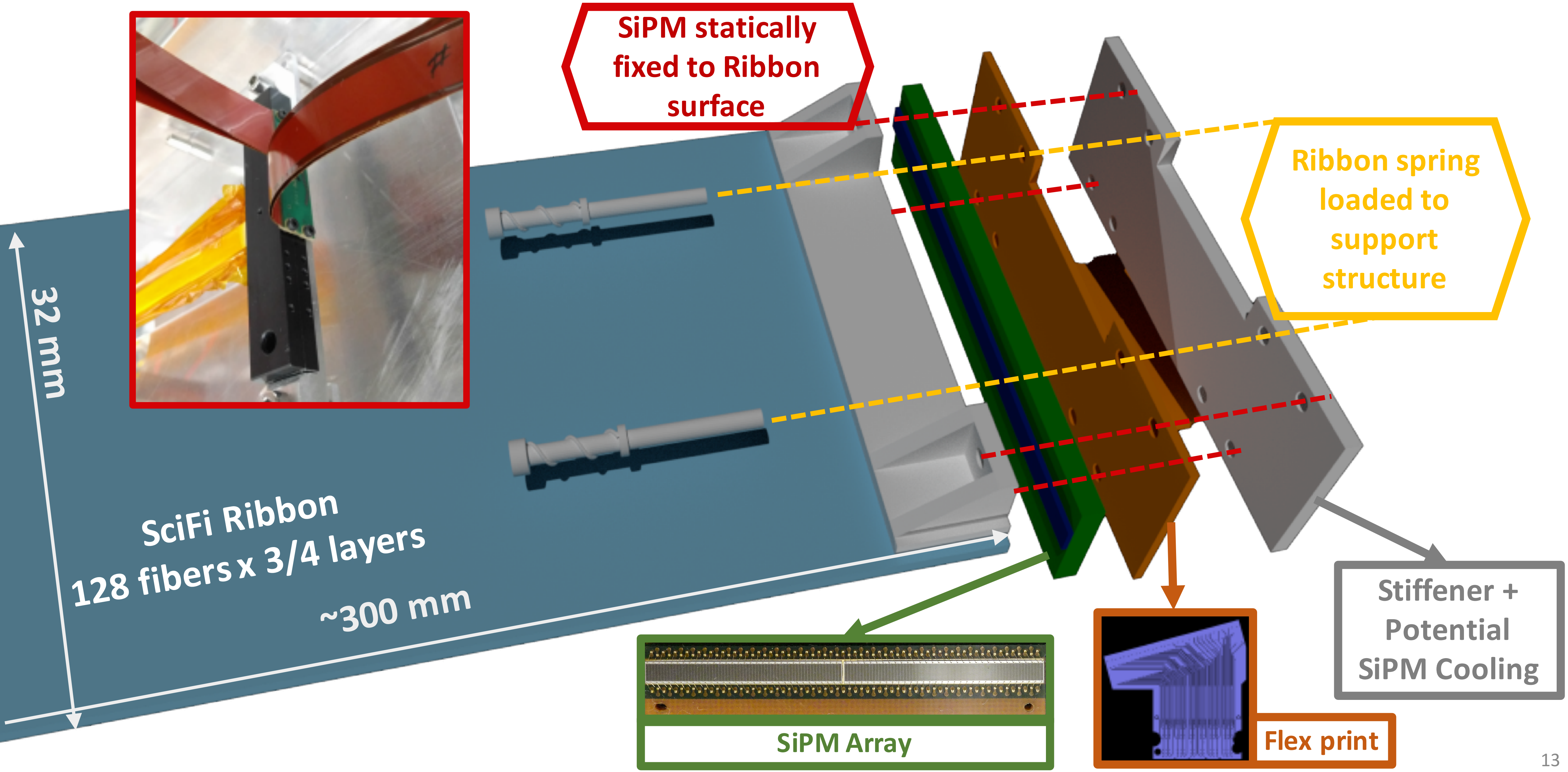
- The efficiency is estimated with the available setup and is slightly dependent upon the time fit
- Efficiency estimate **above 90% (**within 3σ of **Δ**t centroid) is achieved by the **78 MJ** and **NOL 11** ribbons with **3 and 4 layers**
- The estimated **lower** efficiency of **BCF 12** is due to the small cluster size and the applied **clustering** algorithm

Ribbon Characterization: Summary

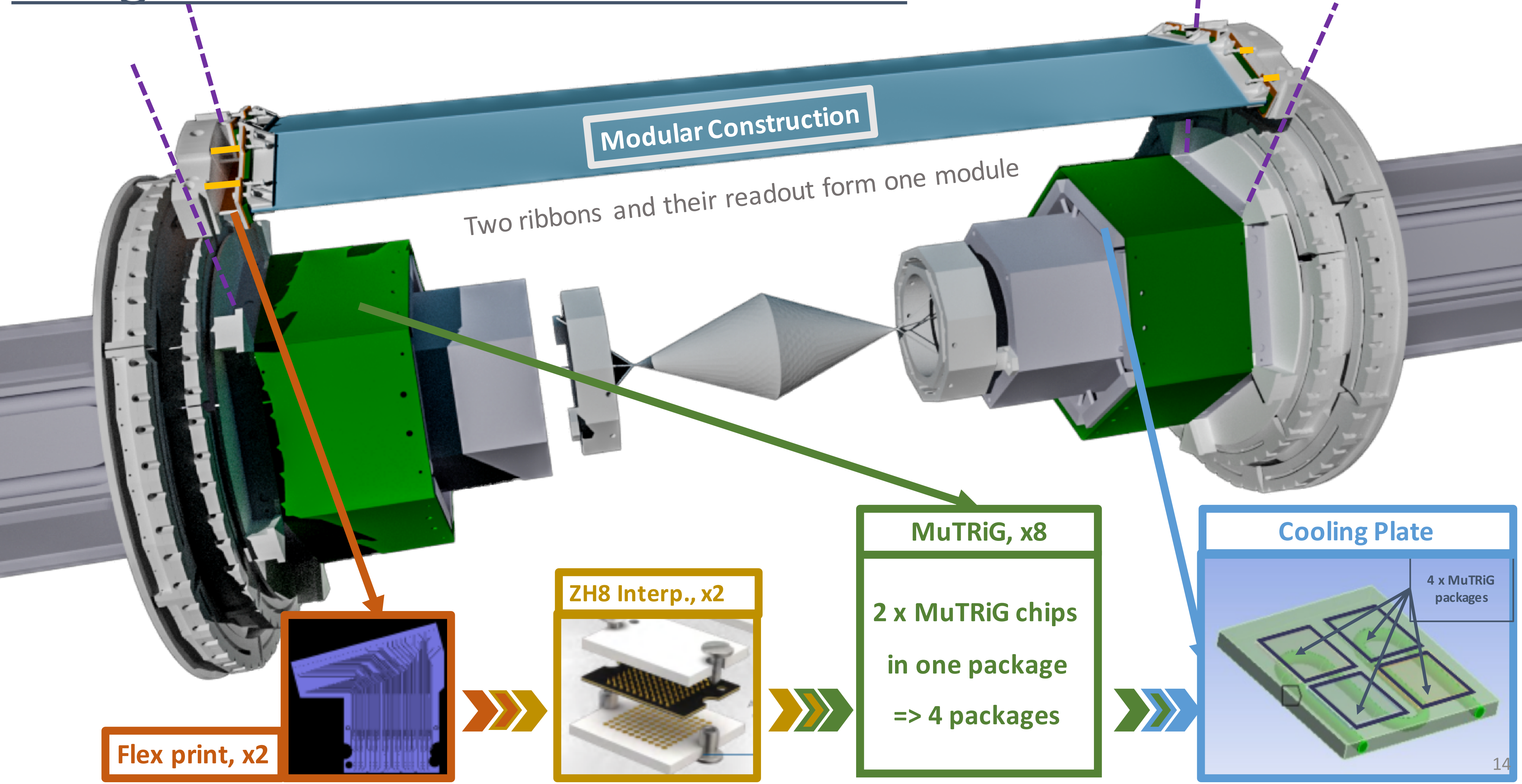
Fiber	Layers	Coating	$\sigma_{\Delta T}$ [ps]	Efficiency within ± 3σ [%]
SCSF 78 MJ	3	Clear	500	92.3
SCSF 78 MJ	4	Clear	450	97.3
SCSF 78 MJ	4	TiO2 20%	430	94.0
NOL 11	2	TiO2 Outside	510	88.7
NOL 11	3	TiO2 Outside	430	93.8
NOL 11	4	TiO2 20%	395	95.8
NOL 11	4	Clear	380	94.3
SCSF 81 MJ	4	TiO2 20%	580	91.1
BCF 12, square	3	Al 100 nm	700	68.5
Design requirement			**710**	**95.0**

➢ Ribbons will be produced with Kuraray **SCSF 78 MJ** using **Clear epoxy**

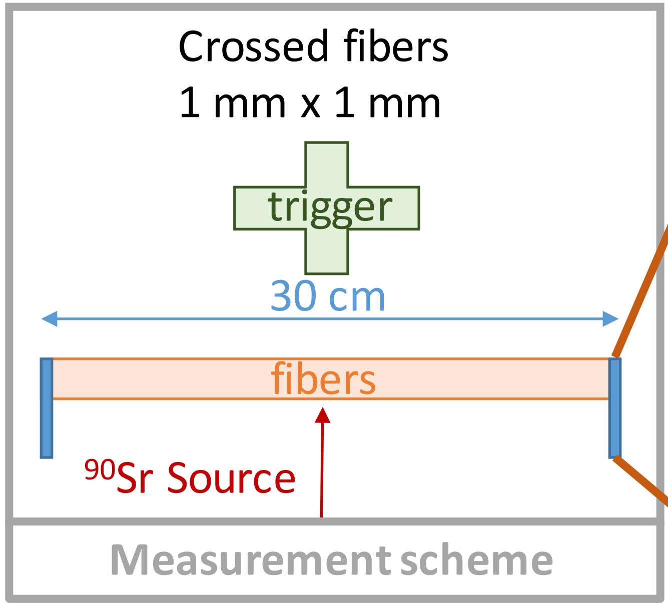
Integration Studies: Ribbon + SiPM

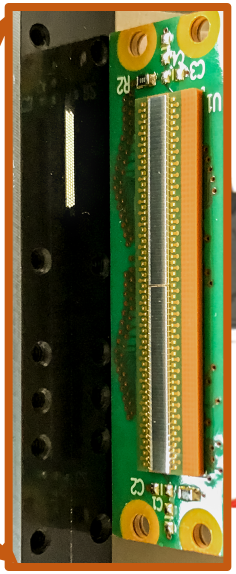


Integration Studies: SciFi Module



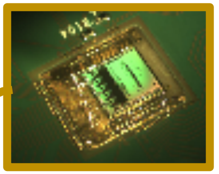
Readout Electronics: MuTRiG

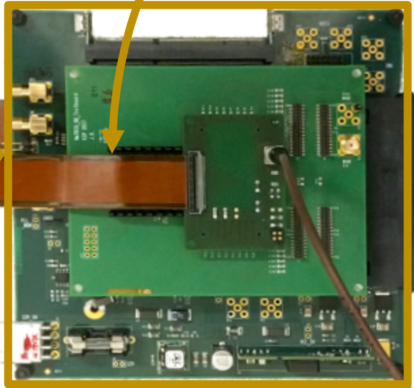




Ribbon/SiPM Coupling

SiPM Flex





(KIP) 1 x MuTRiG test board, 32 ch., Leading edge T stamps (50 ps)

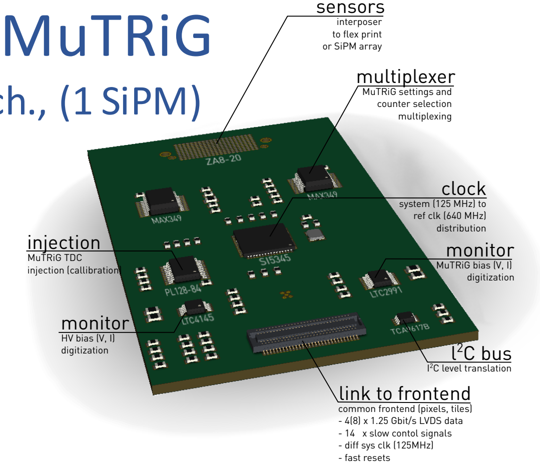
LVDS 1.25 Gbit/s

MIDAS Integrated DAQ

Next Step: Proto-board

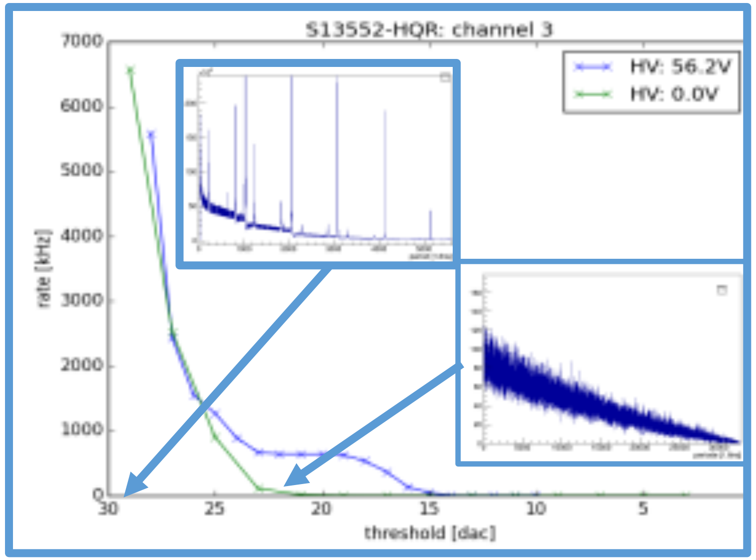
4 x MuTRiG

128 ch., (1 SiPM)



On going

Reproduce time resolution measurement



Summary

Accomplishments

- Completed a **systematic study** of various fiber materials and reached a **final decision** for the ribbons: **SCSF 78 MJ** will be used with **clear epoxy**
- **SiPM** detector has been selected and procured: **50 x Hamamatsu S13552-HQR**
- **Integration** work has **started** for sub components
- **MuTRiG DAQ integrated** with MIDAS
- Ribbon **measurements started** with **MuTRiG** readout

Near Future Plans

- **Proto-readout** board with **4 x MuTRiG** chips
- Build a **demonstrator** with **MuTRiG** readout of **2 x 128 ch**
- Continue **integration** work
- Develop **manufacturing** and **QA** procedure for fiber modules, characterize all SiPMs

Outlook

Milestone	BVR 48	BVR 49
Decision on fiber type	Q2/17	✓
Decision on SiPM array	Q2/17	✓
SiPM radiation hardness studies	Q4/17	Q2/18
Manufacturing and quality assurance strategy for fiber module production	Q3/17	Q3/18
MuTRiG readout demonstrator 2 x 128 ch, without final cooling and flex prints	Q3/17	Q3/18
Alignment and calibration scheme	Q3/17	Q3/18
Use demonstrator in V-slice tests		Q1/19
Full prototype (integration ready)	Q1/18	Q2/19
Full detector		Q4/19

Backup

Clusters and Efficiency