The Mu3e Scintillating Fiber Detector
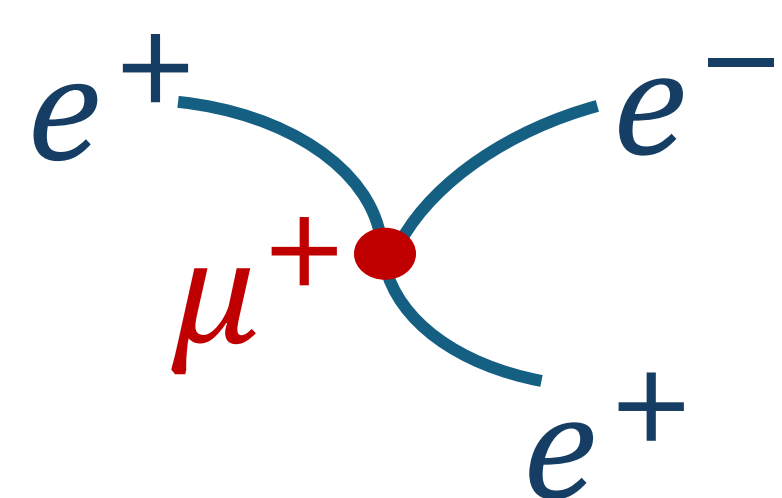
Gentian Shatri (University of Geneva)
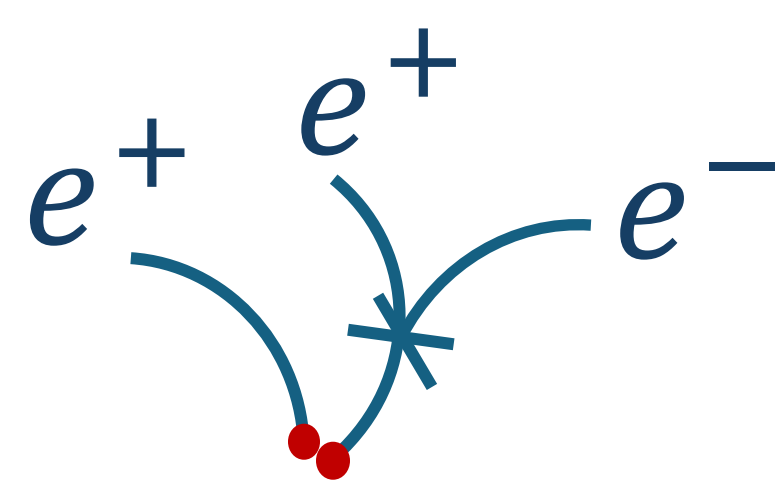
Why scintillating fibers (SciFi) ?

Signal

e^+ e^-
μ^+
e^+

Triple time coincidence
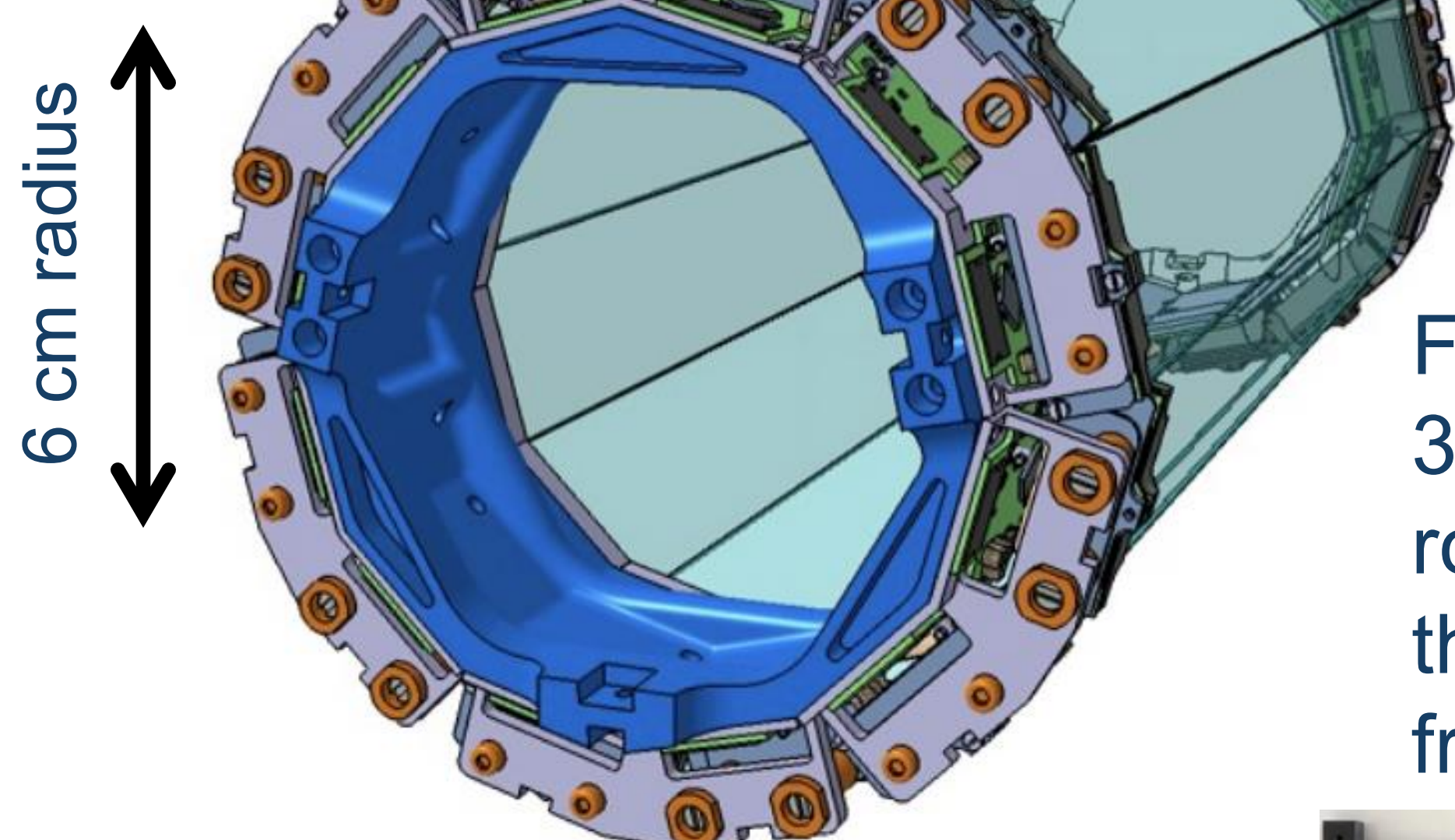
Combinatorial background

e^+ e^+
  e^-

2 muons pile-up (no coincidence)

→ Well suppressed using SciFi with a time resolution of 250 ps, and in association with tiles

+ SciFi can be used to resolve the direction of rotation of the tracks (e^+ or e^-)

Design and Performance

6 cm radius

Spring loaded to prevent thermal sagging of the ribbon

Fiber ribbon of 32.5 mm x 300 mm
3 longitudinally staggered layers of 250 μm round fibers, each layer having 128 fibers
thin ribbons (< 800 μm, 0.2% X_0) from Kuraray, type SCSF-78MJ

12 SciFi ribbons (3072 channels)
+ Support Structure with 2 Cooling Rings (in blue)
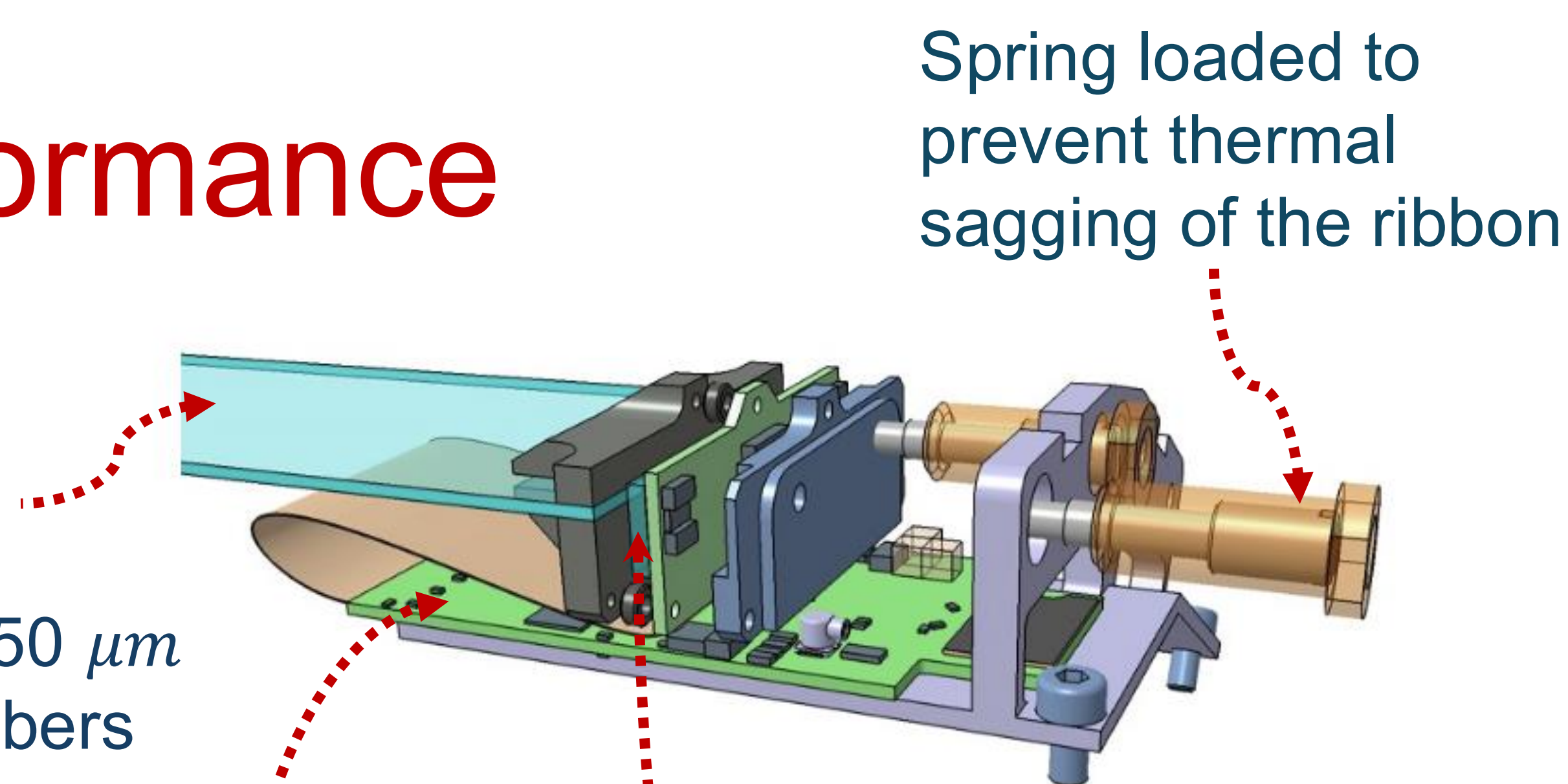
Each ribbon coupled at both ends to Hamamatsu S13552-HRQ SiPM arrays (128 ch, 250μm pitch, $R_q = 500\ k\Omega$)
→ $V_{op} \sim V_{breakdown}(52.5V) + 3.5V$
→ Cooled below -10°C to reduce the Dark Count Rate
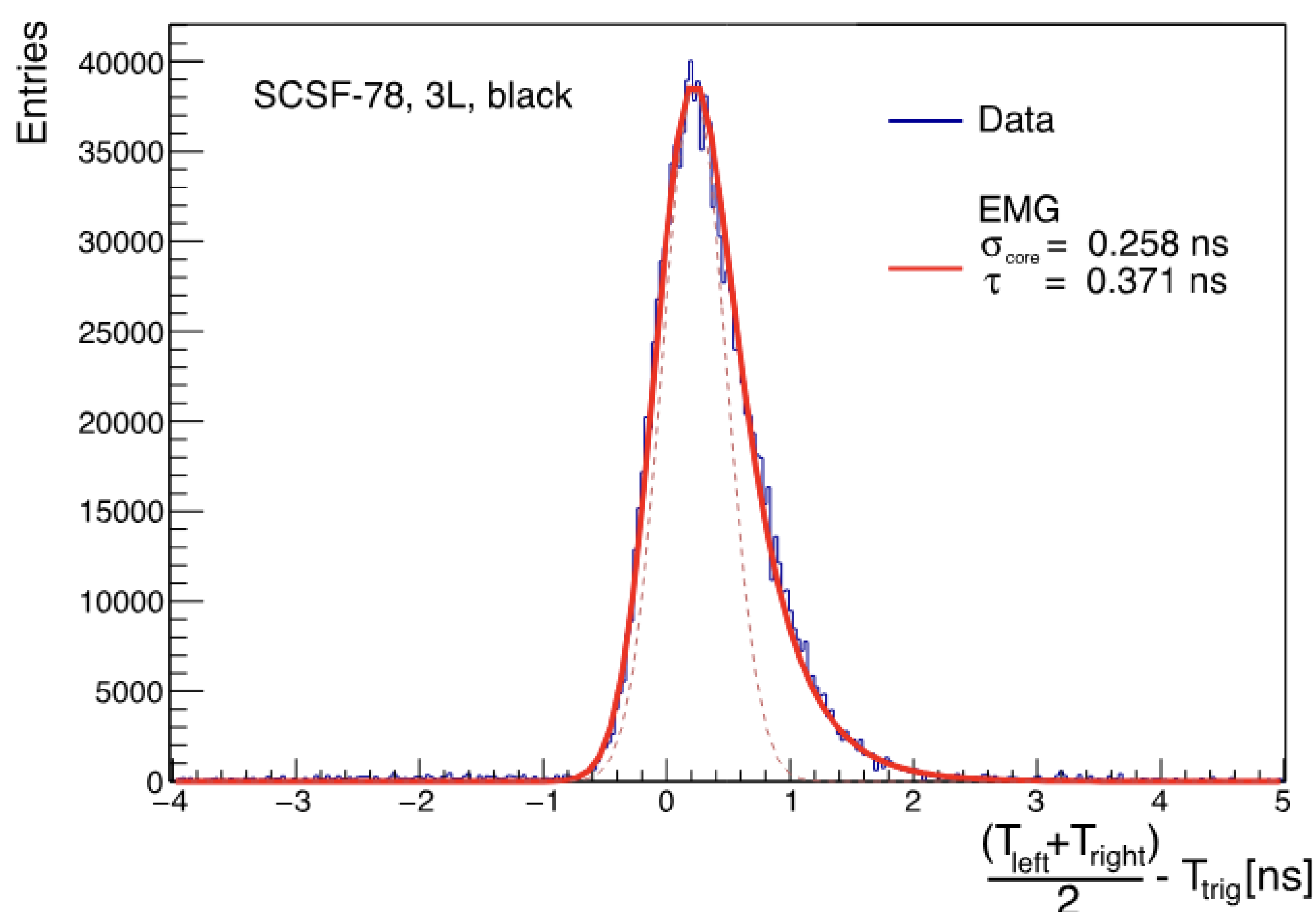
32.5 mm
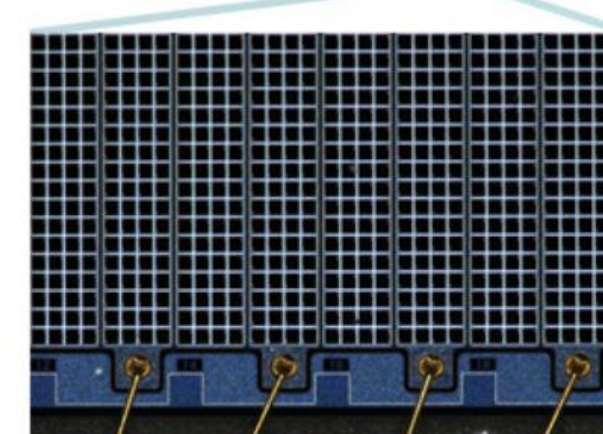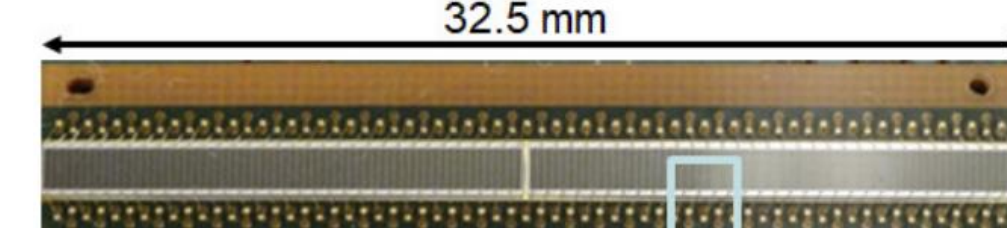
SiPM analog signals transmitted via flexprint to a SciFi Module Board (SMB)
→ Each SiPM array is read out with 4 MuTRiG ASICs (32 channel, 50 ps TDC) wire bonded to the SMB.
The MuTRiG can process rates up to 1 MHz/ch, expected in Mu3e Phase-1 (10^8 muon decays /s)

+ 3.5V
SiPM bias connector
LDO
Interposer
Clock buffer
Temp. sensor
4 MuTRiG3
SMB-3-1-001
UNIVERSITÉ DE GENÈVE
Temp. sensor
SiPM array (on the back)
GND
LDO
+ 2.5V

Installation of two SciFi ribbons for the June 2025 Mu3e commissioning beam time : SciFi was operated, along the inner Vertex and Tiles, at full beam rate

→ Matching clusters at both ends to reduce noise and form the mean time $\frac{1}{2}(T_L + T_R)$ with $\sigma \sim 250\ ps$, which is independent of the hit position along the SciFi ribbon, as opposed to $T_L - T_R$

SCSF-78, 3L, black

— Data

EMG
σ_{core} = 0.258 ns
τ = 0.371 ns

Entries

$\frac{(T_{left} + T_{right})}{2} - T_{trig}$ [ns]

1 hit   2 hits

Efficiency [%]

Efficiency per cluster size

SCSF-78, 3L, black
○ No ΔT cut
△ |ΔT| < 5$\sigma_{\Delta T}$
◇ |ΔT| < 3$\sigma_{\Delta T}$

0.5   1.0   1.5   2.0   2.5 ph.e.   0.5   1.0   1.5   2.0   2.5 ph.e.

Data taken with DRS4 electronics → analysis of recent beam tests with MuTRiG electronics is ongoing