Scintillating Tiles for the Muon Upgrade II Outer Regions

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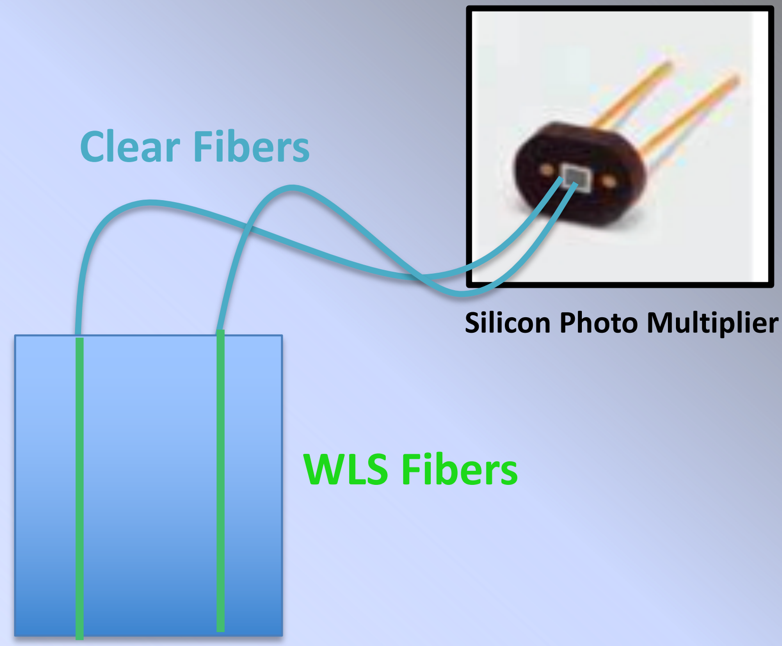
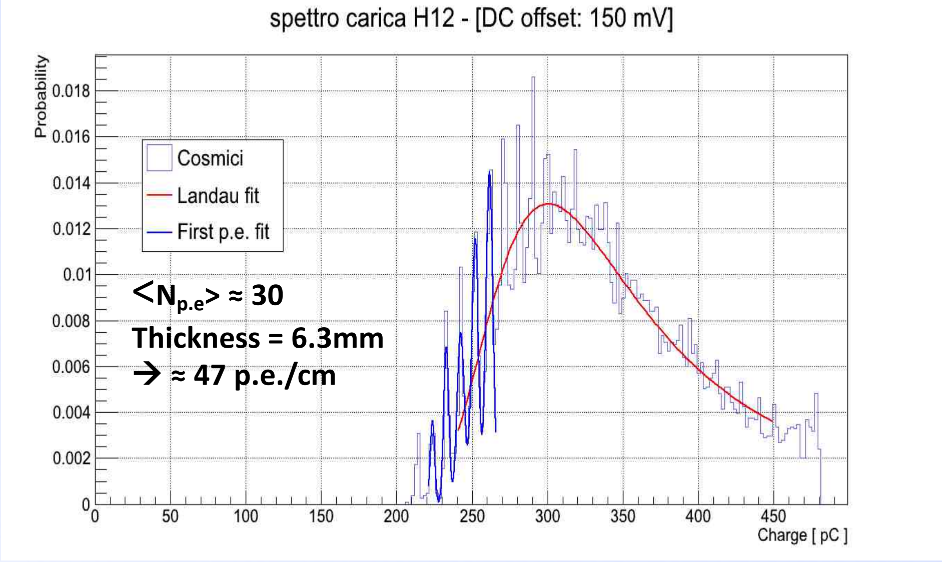
The Idea

- **Scintillating tiles** read out through WLS/Clear fibers and SiPMs
- each scintillator tile can be 1-2 cm thick, in order to have a high light yield → high detection efficiency
- scintillator+fiber+SiPM yield is usually **40-50 p.e./cm** → high thresholds → lower Dark Count Rate (DCR)
- Scint. light collected by short **WLS fibers** (~25cm) and guided to SiPMs via **clear fibers**
- $$I = I^0 e^{-l/\lambda}$$
  - l = lenght of fiber
  - λ = Attenuation length:
    - λ ~ 2-3m for WLS fibers
    - λ ~ 10m for clear fibers
- **Critical point is the SiPMs damage with radiation, especially Neutrons**

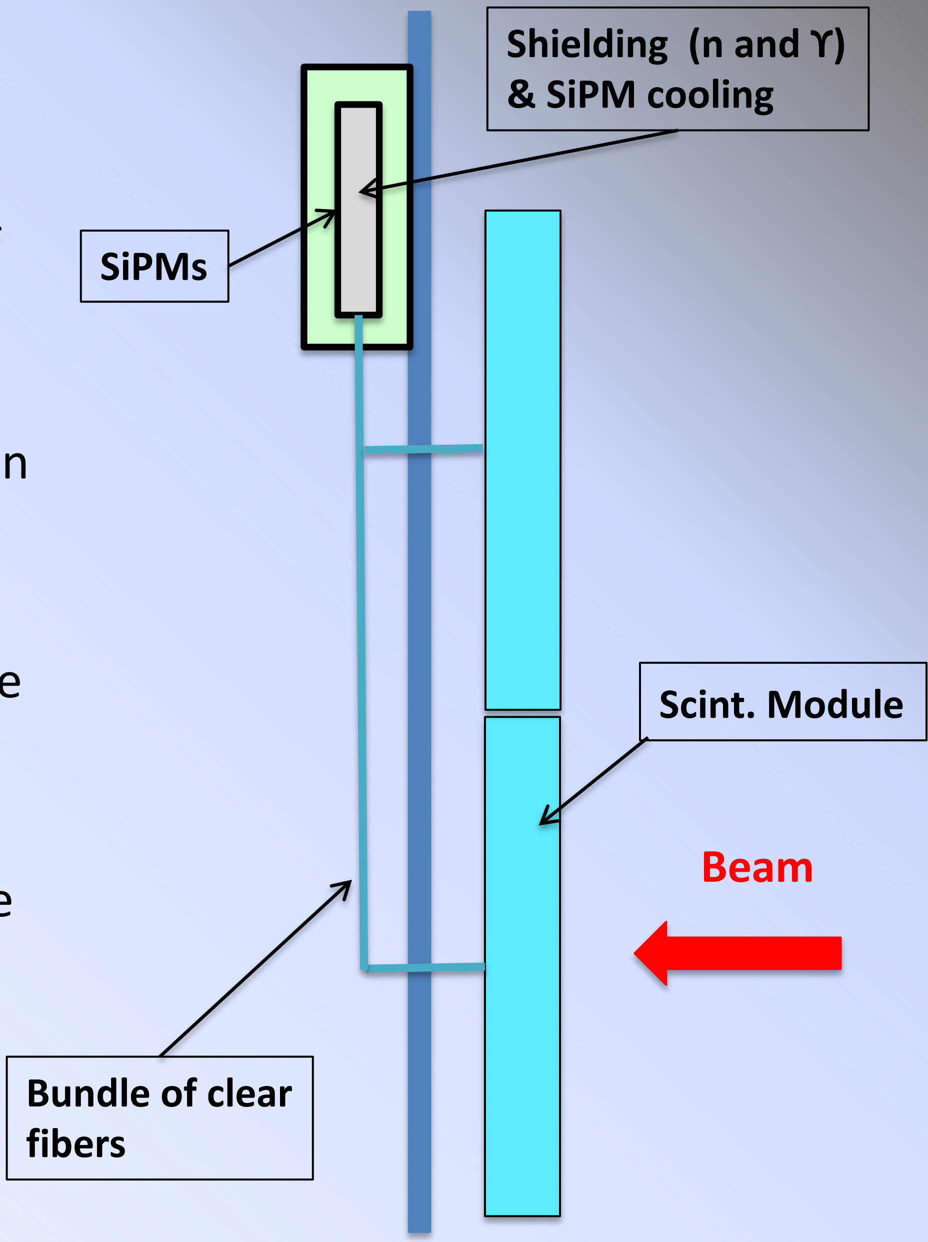


Surface grooves or embedded holes in extruded scintillators



The Idea

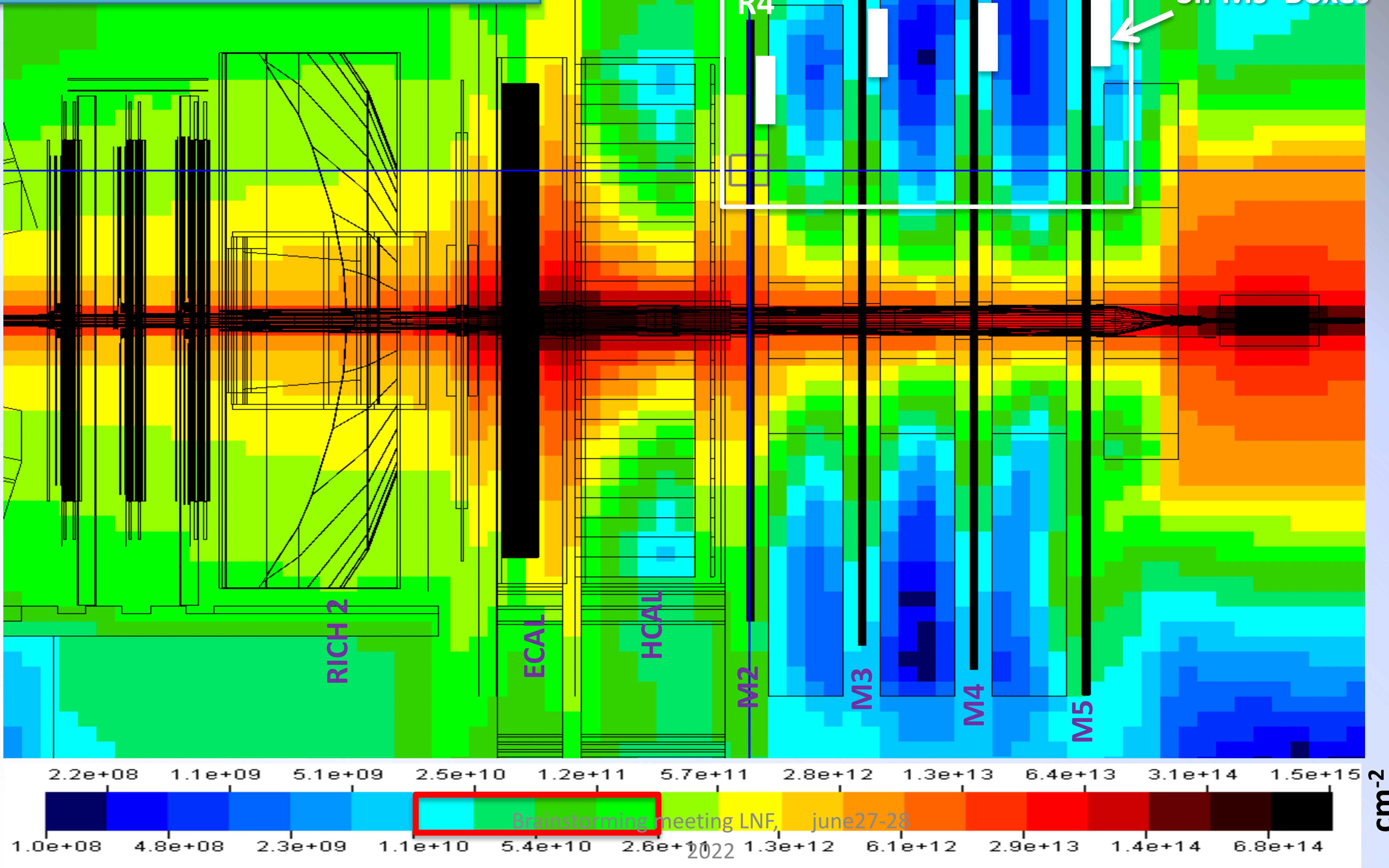
- The scintillator can be put on the front of the support wall
- SiPMs and FE electronics can be located on the back
- Location of SiPMs should be chosen where the integrated neutron flux is lower
- Keeping anyway fibers as short as possible to collect as much light as possible
- In this way we could keep SiPMs 4π shielded from radiation (polyethylene + boron for neutrons) and cooled



Expected Neutron Flux @ U2 Conditions (50 fb^{-1})

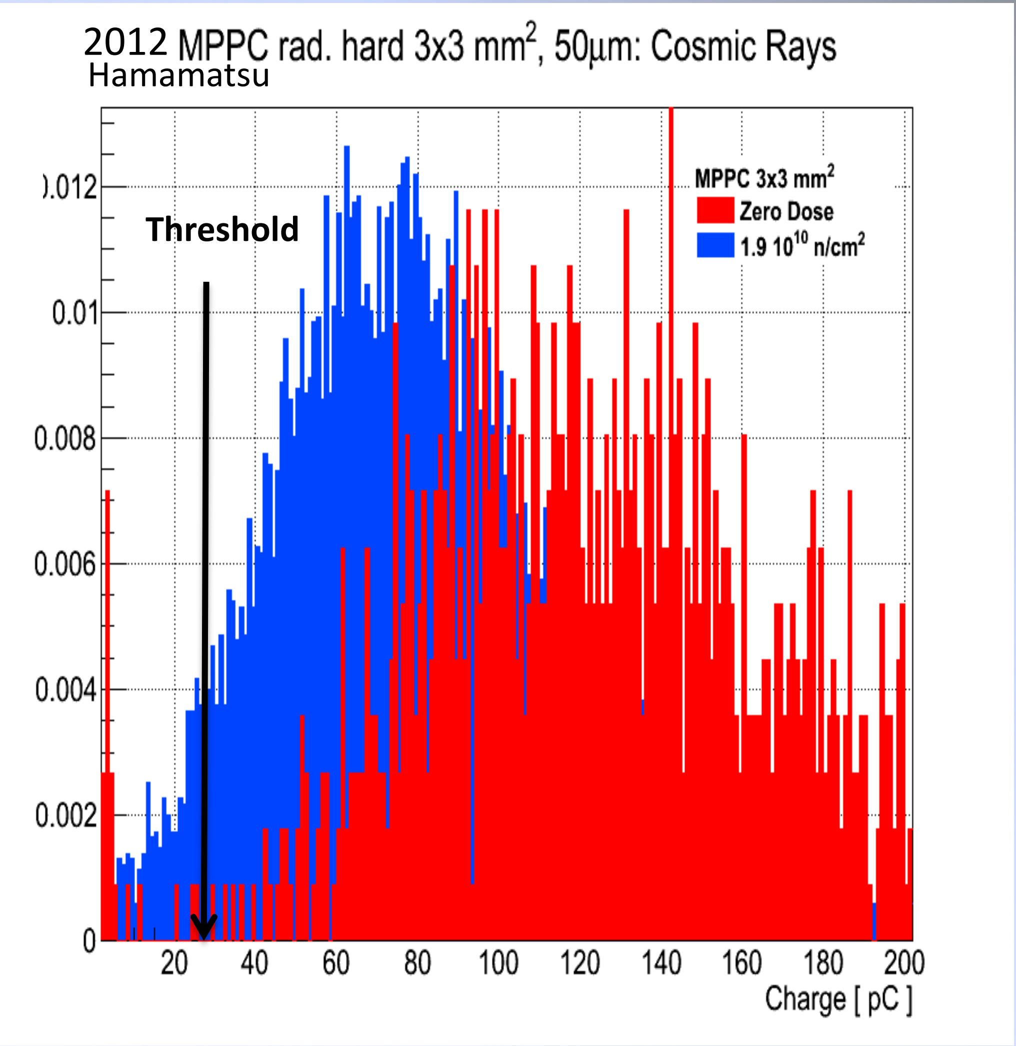
M. Karachson

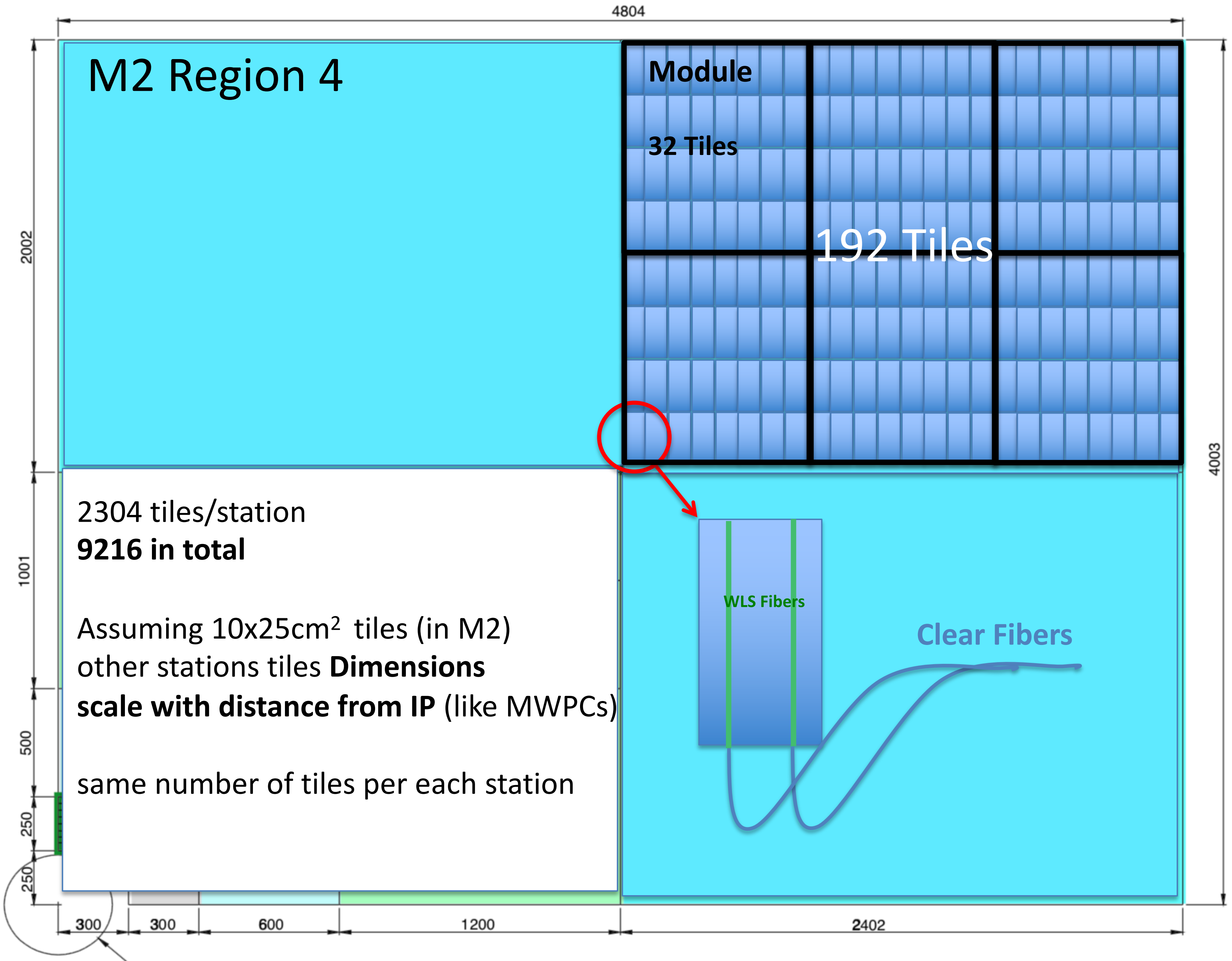
- 30cm neutron shielding in place of M1
- PS/SPD and lead removed
- Integrated Lumi: 50 fb^{-1}



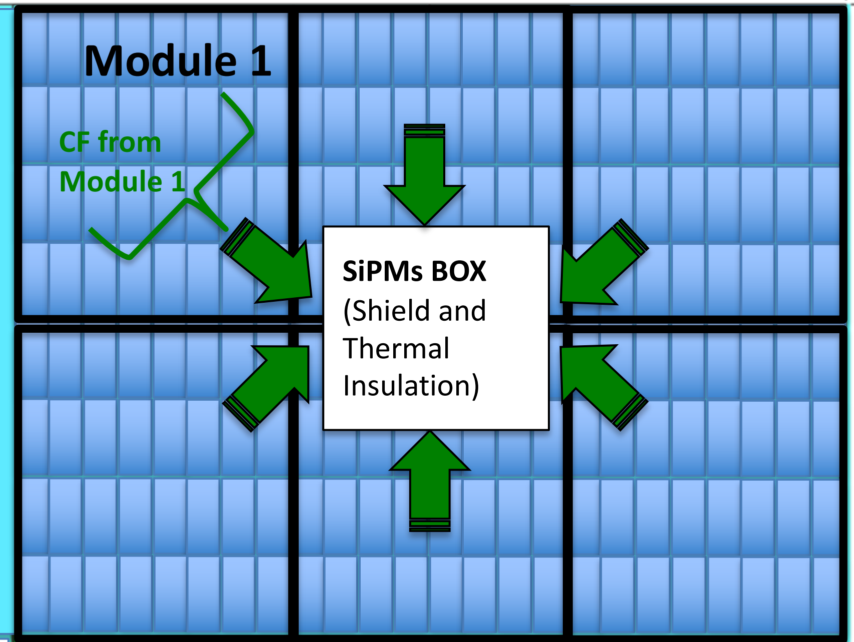
SiPMs Irradiation

- According to present simulations we can put SiPMs where the fluence is ~ 5 x 10^{10} n/cm^2 (for 50 fb^{-1})
- Assuming a safety factor 5 → **2.5 x 10^{11} n/cm^2**
  - → work properly up to ~ 10^{10} n/cm^2
  - → we have to gain a factor ~25 with shielding (factor ~10) and cooling
  - → cooling: as rule of thumb: gain a factor ~2 in noise rate every 10 degrees → cooling to ~ 0° C – 10° C
- In M2 is more critical
- Latest SiPMs to be studied → more radiation tolerant?




4804
M2 Region 4
Module
32 Tiles
192 Tiles
2002
1001
500
250
250
4003
2304 tiles/station
9216 in total
Assuming 10x25cm^2 tiles (in M2)
other stations tiles **Dimensions**
scale with distance from IP (like MWPCs)
same number of tiles per each station
WLS Fibers
Clear Fibers
300
300
600
1200
2402

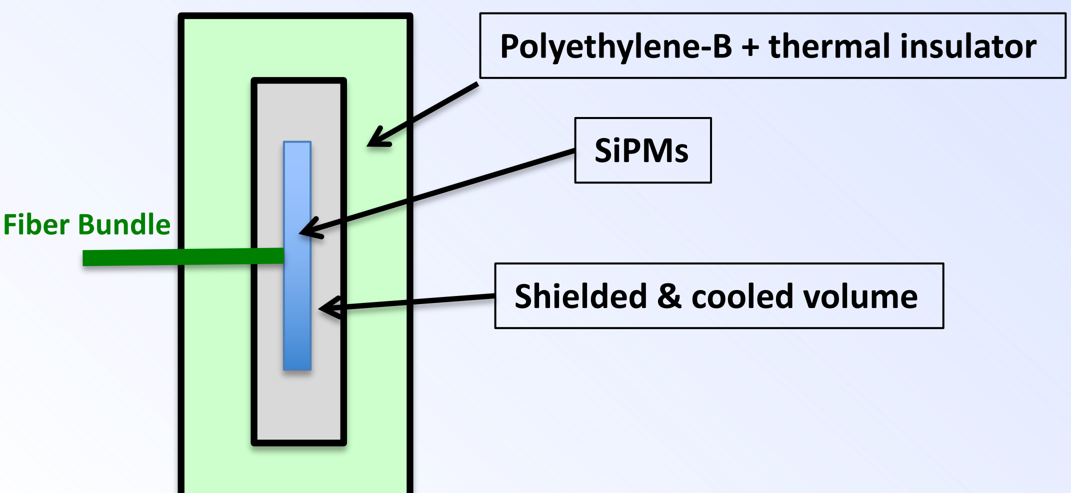
M2 Region 4

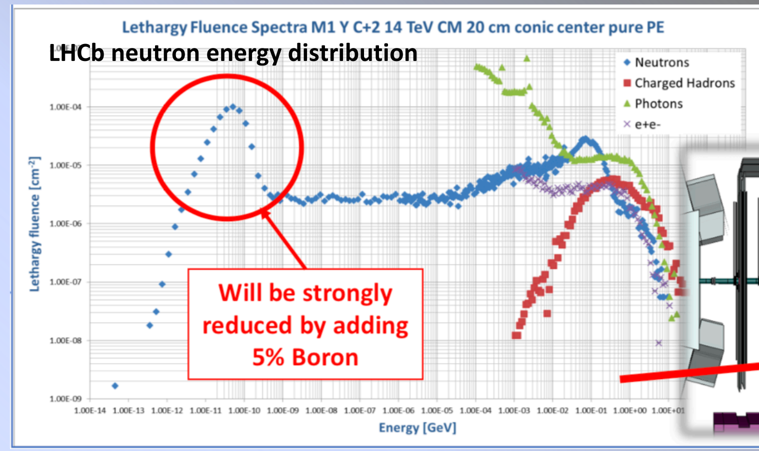


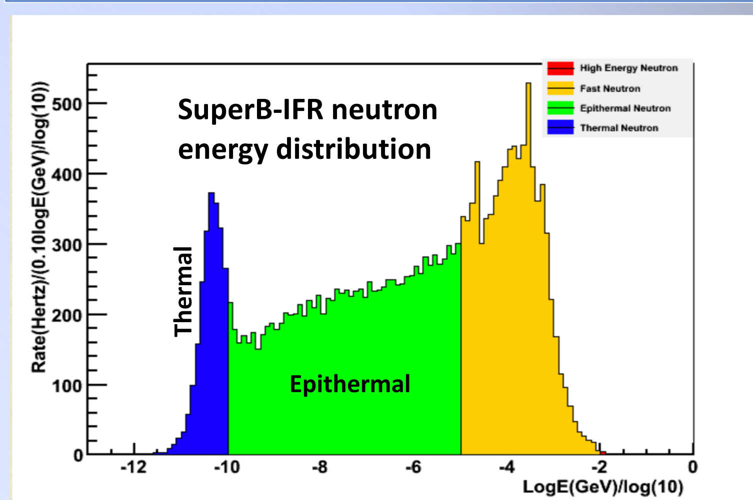
- → 2 Clear Fibers (CF) per SiPM (3x3 mm^2)
- → 384 CF on 192 SiPM in one BOX
  - → SiPMs matrices 4x4 (2 per module)
- → Maximum Clear Fiber Length: ~2 m
  - → $I/I_0 \sim 0.8$ → light loss ≤ 20%

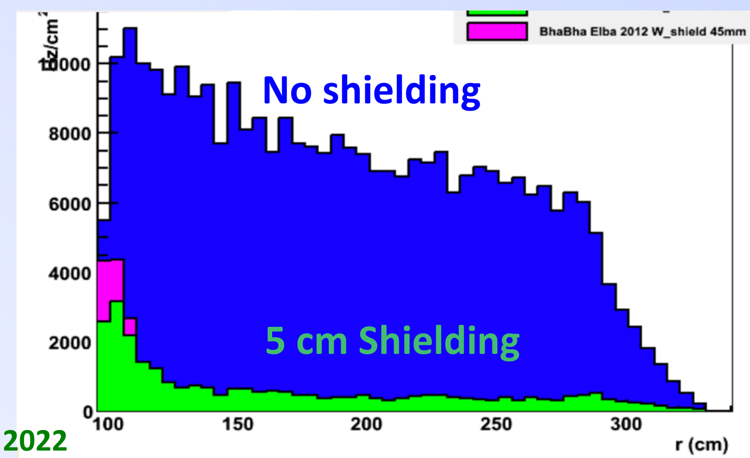
Neutrons Shielding

- Poliethylene + 5% Boron as a neutron shielding, to absorb slow/thermal neutrons
- As a very rough number:
  - → ≈ factor 10 reduction of the fluence for 5 cm layer
- Thermal neutrons generate lots of ϒ
  - → 1-2 cm Pb shielding
- More Studies needed!

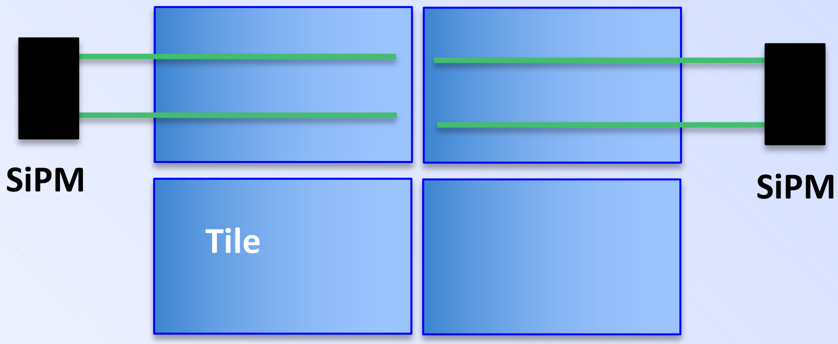








Detection Options: Single Tile Readout

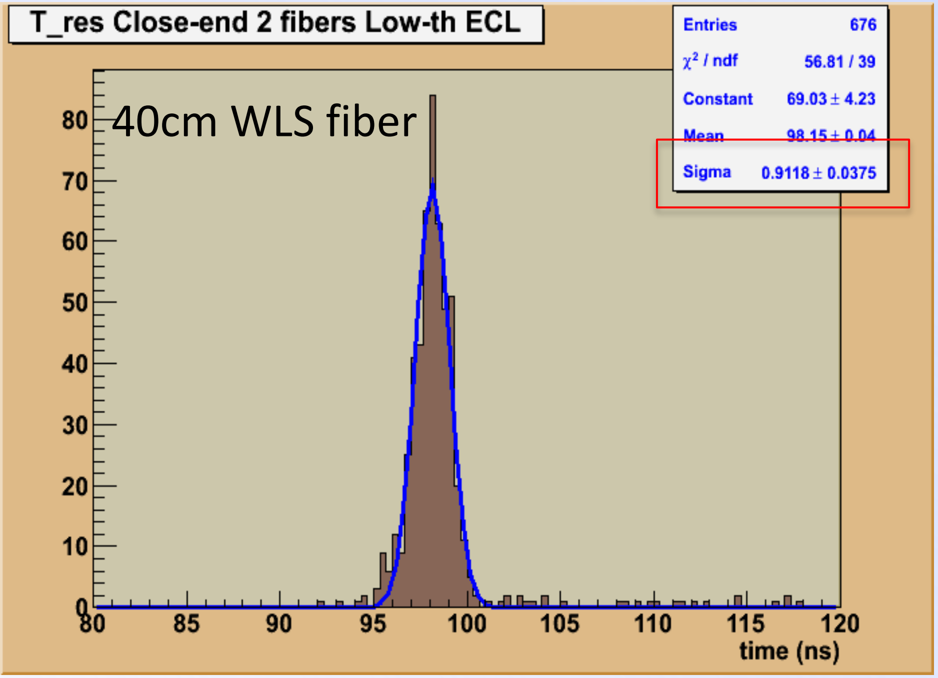


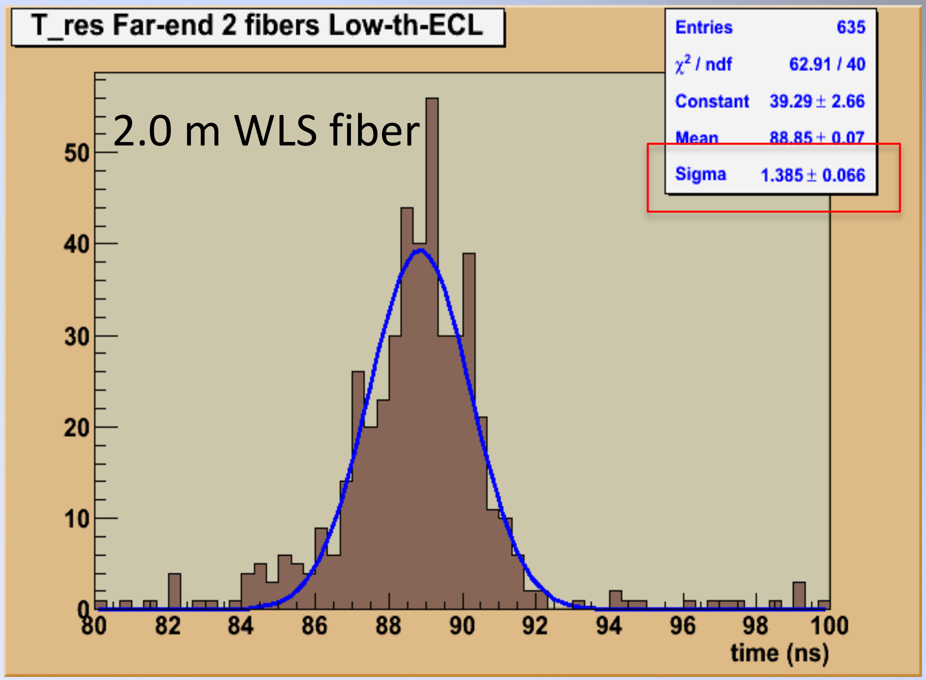
Assuming tiles 10 x 25cm^2 in M2
→ ~40 tiles/m^2 in M2
→ All R4 regions ~ 290 m^2
→ ~**9200 tiles** in total (M2-M5 only R4)
→ ~ 40 SiPMs/m^2 → **~ 9200 SiPMs**

PRO:
- More robust against performance degradation

CONS:
- construction more complex
- more fibers and SiPMs
- more electronic channels

Time Resolution





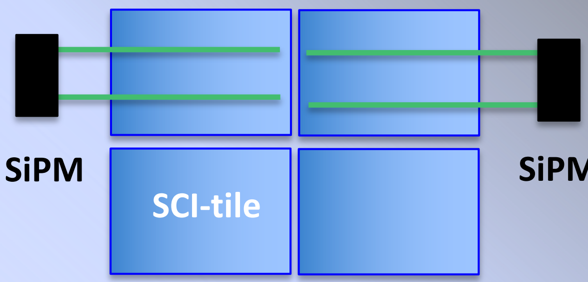
- Scintillator thickness: 1 cm → with 2cm better time resolution
- 2 Bicron WLS Fibers Φ=1.0 mm
- Close end: ~40cm
- Far end: ~2.4 m

→ expected time resolution 1.0 - 1.5 ns → ~ 20 - 25 cm in Y

Cost Estimate: Single Tile Readout

Assuming tiles 10 x 25cm^2

- **R4 region ~ 290 m^2**
- **9200 tiles** in total (M2-M5 only R4)
- 1 SiPM/tile → **9200 SiPMs**
- WLS Fibers: 0.5 m/tile (2 fibers/tile)
- Clear Fibers: 10m/tile (2 fibers/tile)



tentative cost estimate:

- Scintillator: ~ 2k€/m^2 → ~ 580k€
- SiPMs: ~ 20€/each → ~180k€
- Fibers:
  - WLS: 10€/m, 0.5m/tile → 46K€
  - Clear: 5€/m, 10m/tile → 460k€

  } 500k€
- Various material (wrapping, light tightening, glue etc...) : 300k€
- R/O electronics:
  - 9200 R/O channels
  - 50€/ch → 460k€

SiPMs to be replaced over the years (every 2 years?) → ~100k€/year

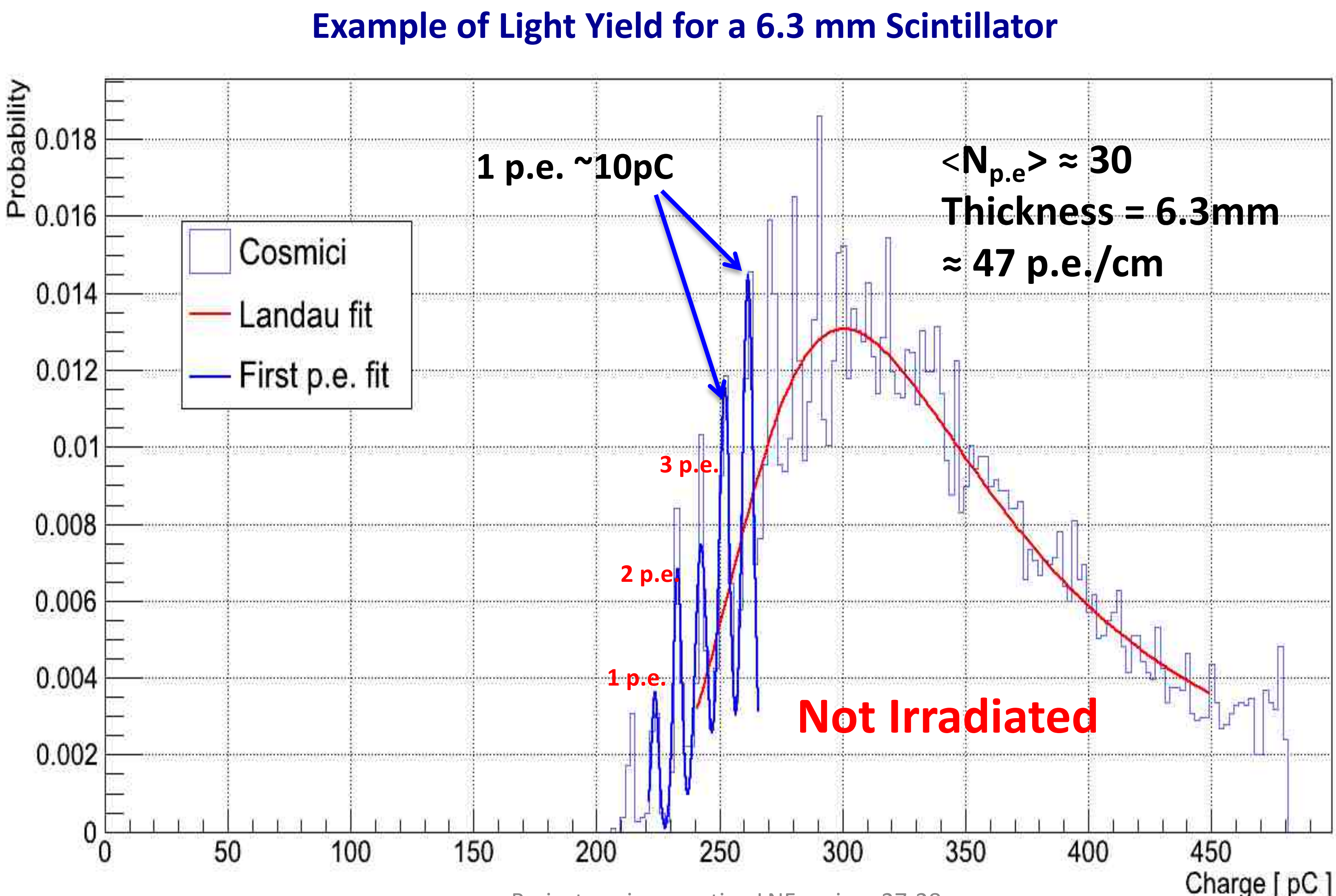
Total: ≈ 2.0 M€

Conclusions

- SCI-Tiles + fibers + SiPMs option for the Muon outer regions in Upgrade II
- compact and relatively easy to build
- radiation damage is a critical item, but lots of studies already performed → rather well understood
- need to shield/cool down the SiPMs and probably to replace them when damaged
- Important to further investigate possible synergies with other sub-detectors using a similar technique (Magnet Stations, SCI-FI-II)

SPARE SLIDES

Light Yield



Example of Light Yield for a 6.3 mm Scintillator
Probability
Cosmici
Landau fit
First p.e. fit
1 p.e. ~10pC
<Np.e> ≈ 30
Thickness = 6.3mm
≈ 47 p.e./cm
3 p.e.
2 p.e.
1 p.e.
Not Irradiated
Charge [pC]
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0
50
100
150
200
250
300
350
400
450

Dark Noise Spectra vs Dose

- Hamamatsu 1x1 mm2, 50 um pixel

N.Tosi