Megatiles for the AHCAL: hardware improvements and measurements with cosmic ray and testbeam data

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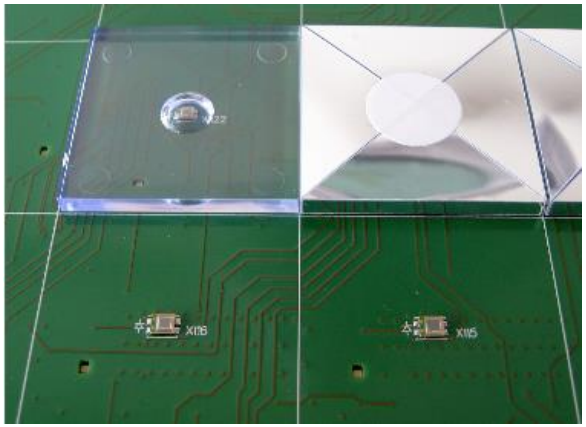
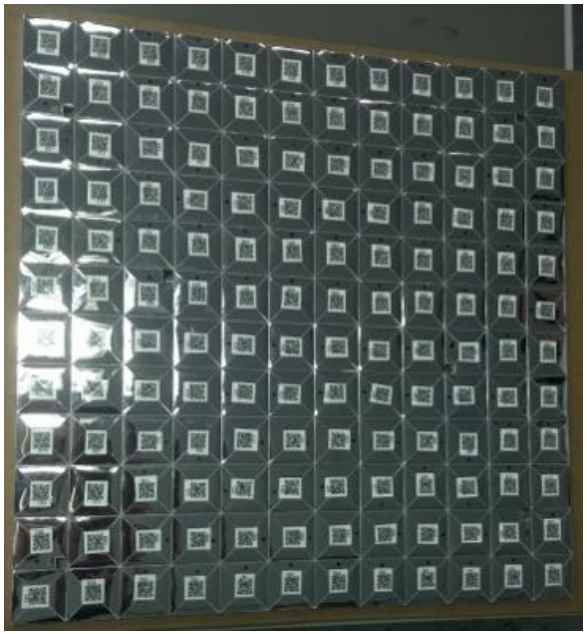
CALICE Collaboration Meeting - 25.03.2021

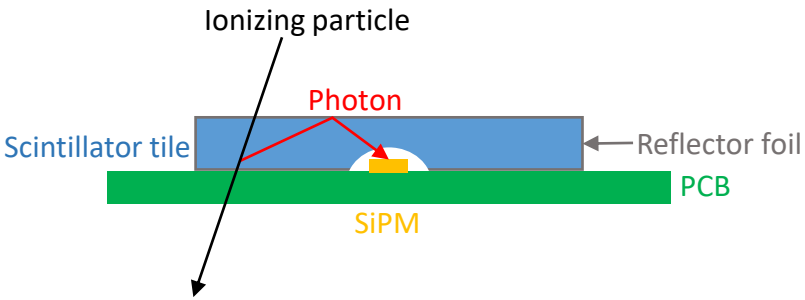
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

AHCAL Technological Prototype Design

- Individually wrapped 3 x 3 cm^2 scintillator tiles
- Tile thickness: 3 mm
- Read out with SiPMs
- 144 channels per board

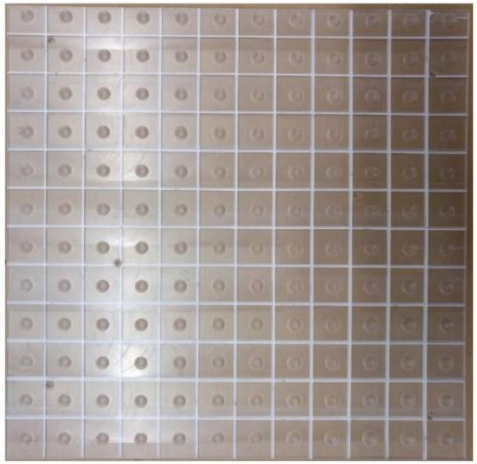


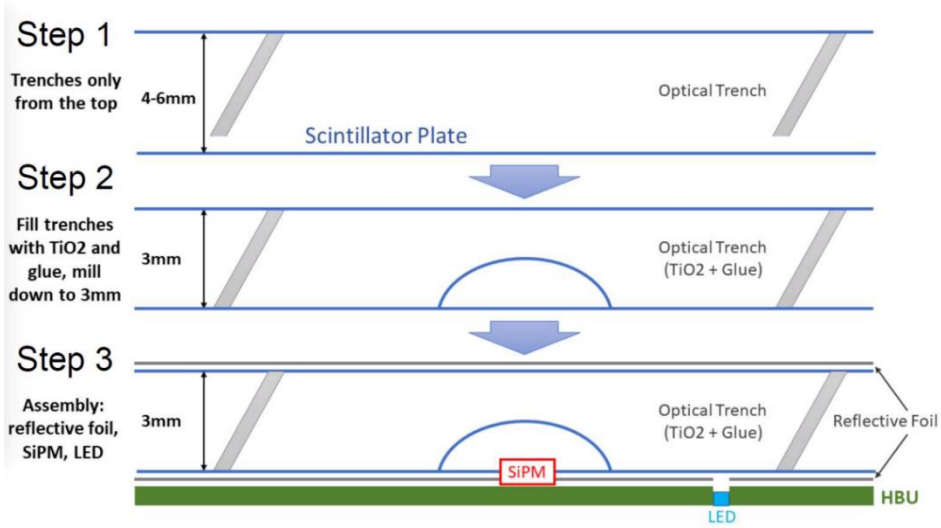




Megatile Concept

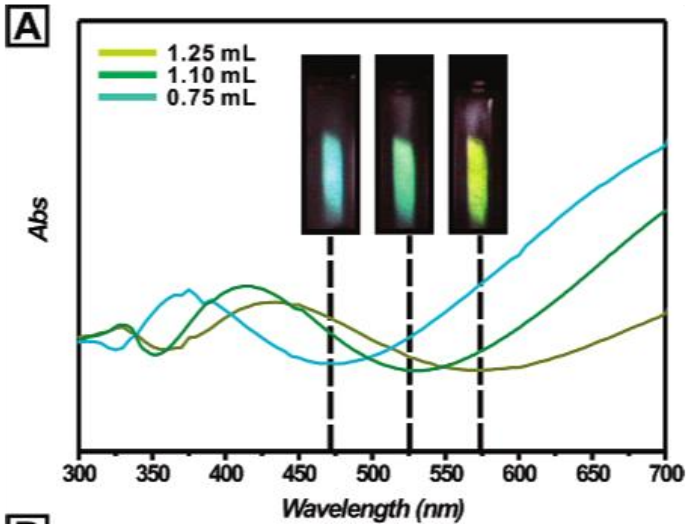
- Simplification of assembly process
- 36x36 cm^2 scintillator plate
  - Trenches filled with glue + TiO_2
  - Scintillator wrapped in reflective foil
    - ⇨Air gap
- Trench angle optimised for LY
  - Angle = 30°: minimal dead area
- 7 versions produced since 2017





Glue + TiO_2 Mixture

- LY depends on glue + TiO_2 mixture
  - Absorption/reflection vs λ depends on concentration, size and shape of TiO_2 granulate
- Trade-off:
  - Liquid enough to fill trenches
  - Adequate granularity
- Tested various mixtures
- Improved in latest prototypes



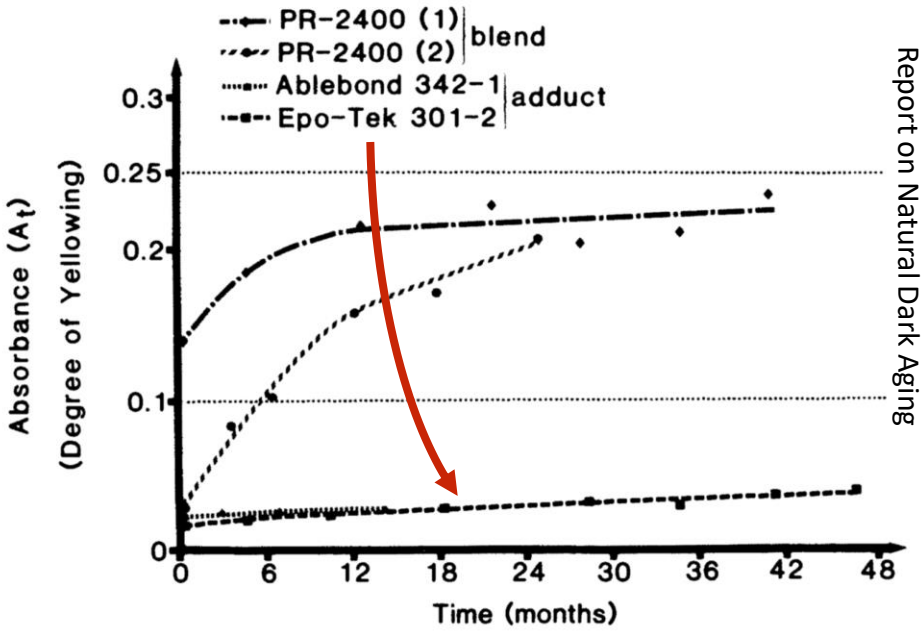
Tailor Made Mie Scattering Color Filters Made by Size-Tunable Titanium Dioxide Particles

Min Chiao Tsai et al., J. Phys. Chem. C, Vol. 112, No. 7, 2008

Glue + TiO_2 Mixture

- Glues known to yellow with time
  - Amplified with UV light and additives (like TiO_2)
  - Current choice: lowest ageing effect (10% yellowing threshold after > 15 years)

⇨Epotek 301-2-FL



The Yellowing of Epoxy Resin Adhesives: Report on Natural Dark Aging

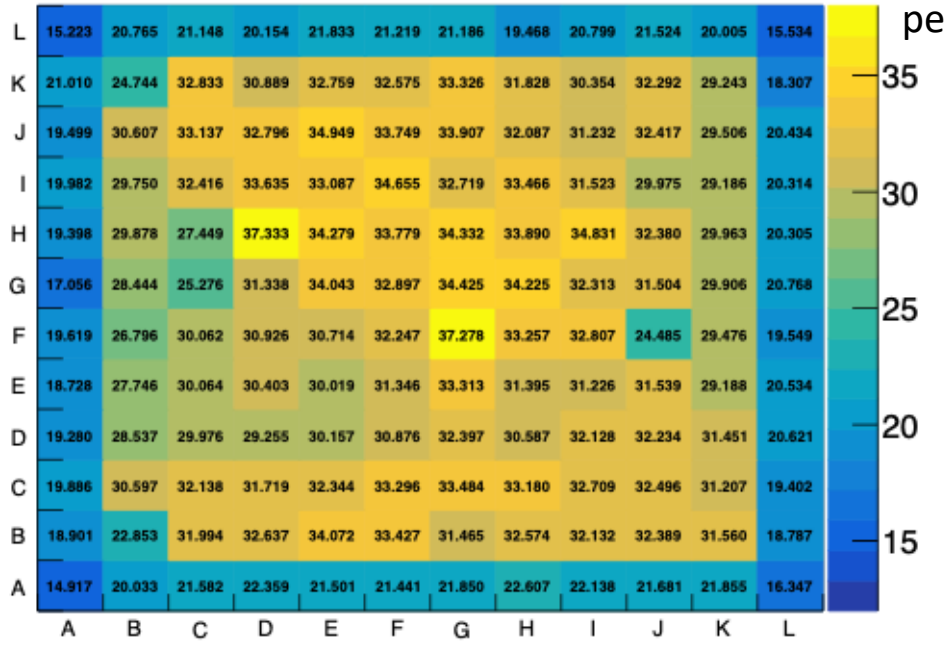
Jane L. Down, Studies in Conservation Vol. 29 No. 2 (1984)

Development of Megatile

- Continuously tested in cosmic test stand in Mainz
- Megatile lying flat with pressure on top
- Scintillators on top and bottom as triggers

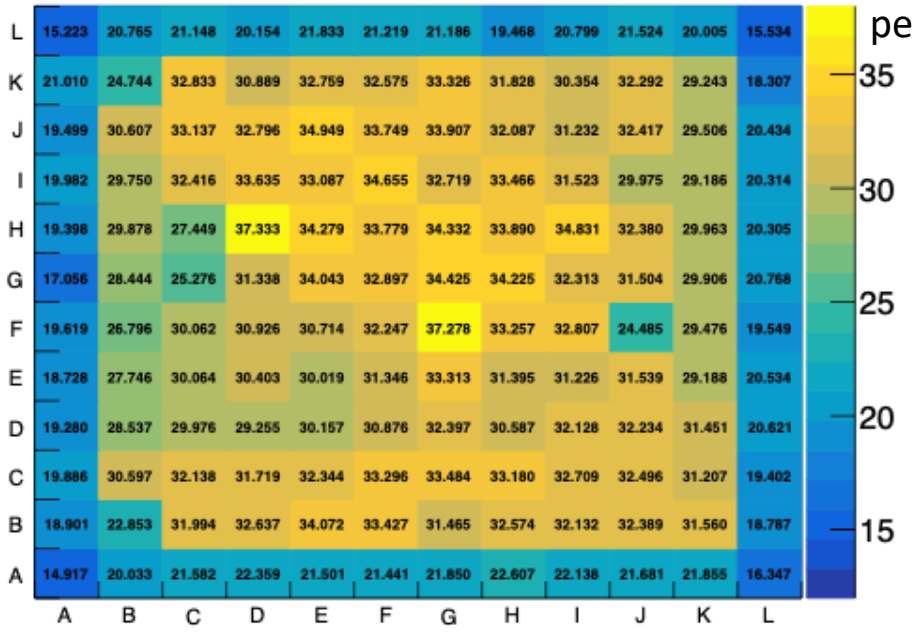
Megatile: A Promising Concept

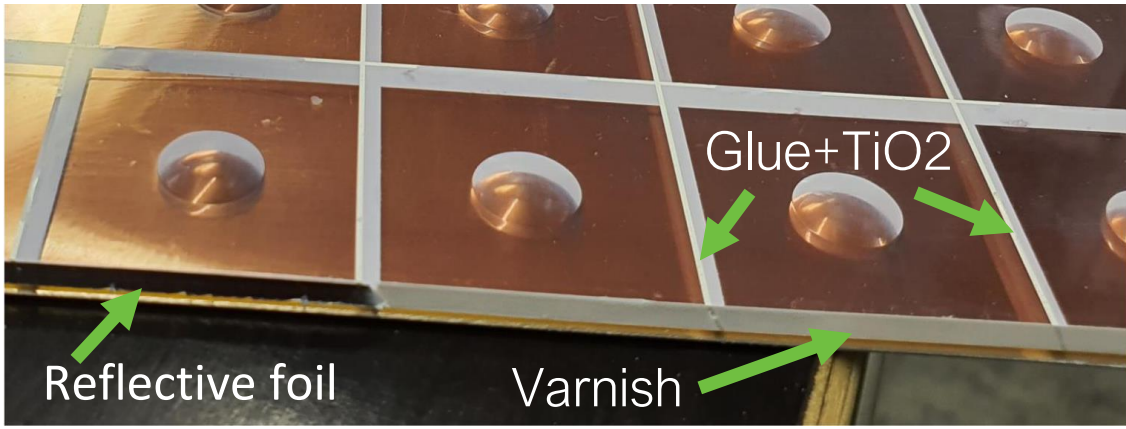
- High LY ≈ 32 pe/MIP (in MT6)
  ≈ as single wrapped tile



Edge Channels

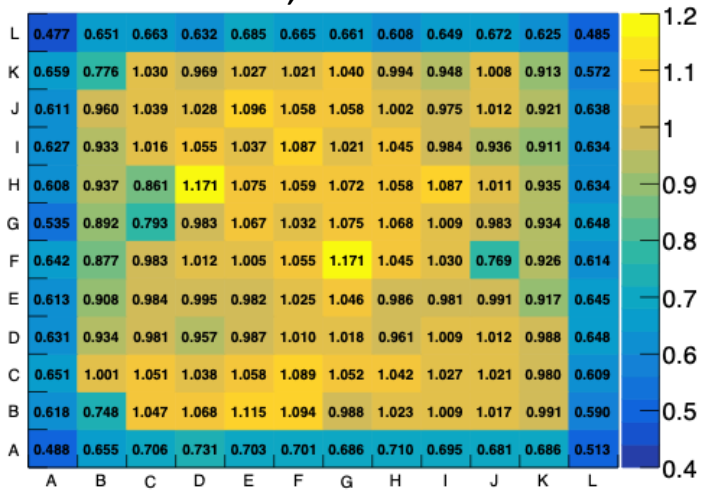
- High LY ≈ 32 pe/MIP
  ≈ as single wrapped tile
- But: Edges ≈ 20 pe/MIP
- Reason: Coating of edges technically difficult
- Simple workaround:
  - Adhesive reflective foil on edges
  - Limited improvement (included above)
- New solution:
  spray white varnish



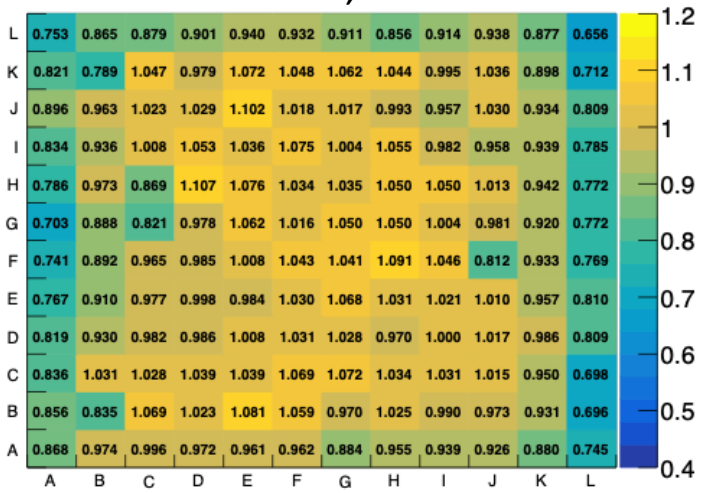


Edge Channels

Relative LY; Reflective foil



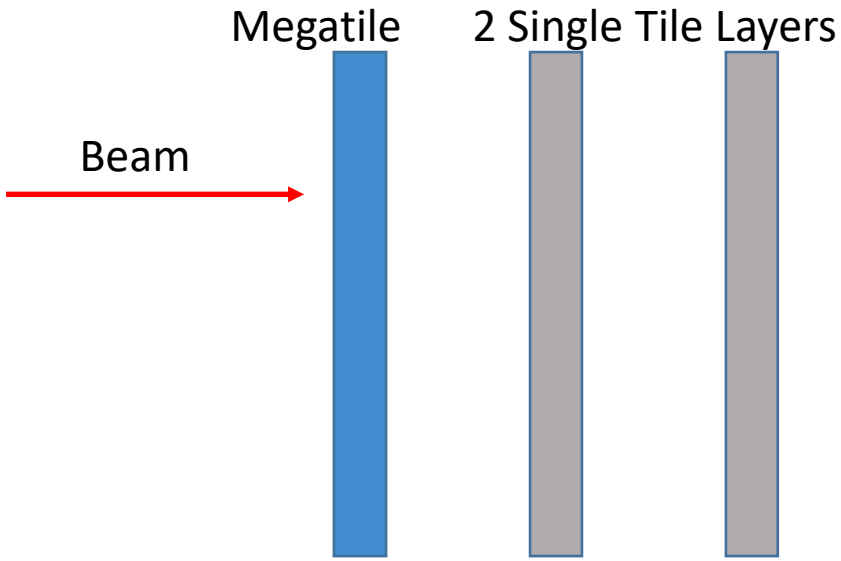
Relative LY; Varnish



- Uniformity map: For each quadrant, plot LY/<LY in central channels>
- Average ratio of 44 edge channels: 0.67->0.84
- Not yet perfect, but already >15% improvements
  - More studies ongoing

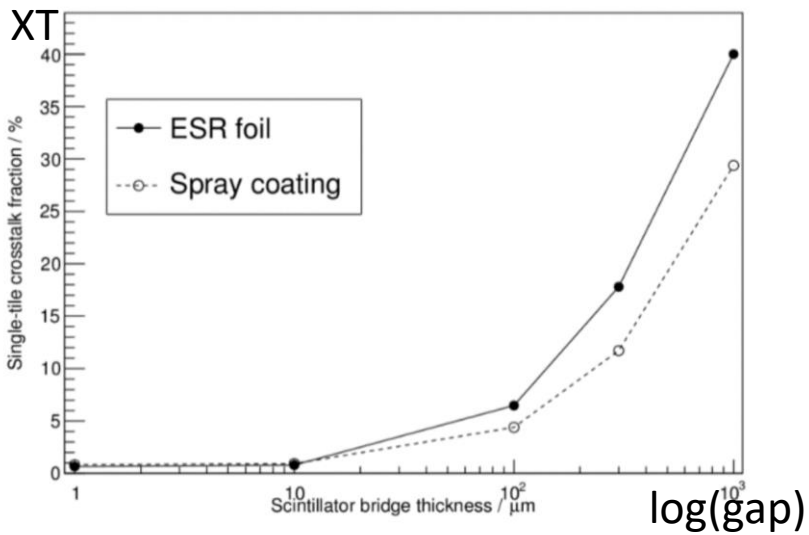
Test Beams

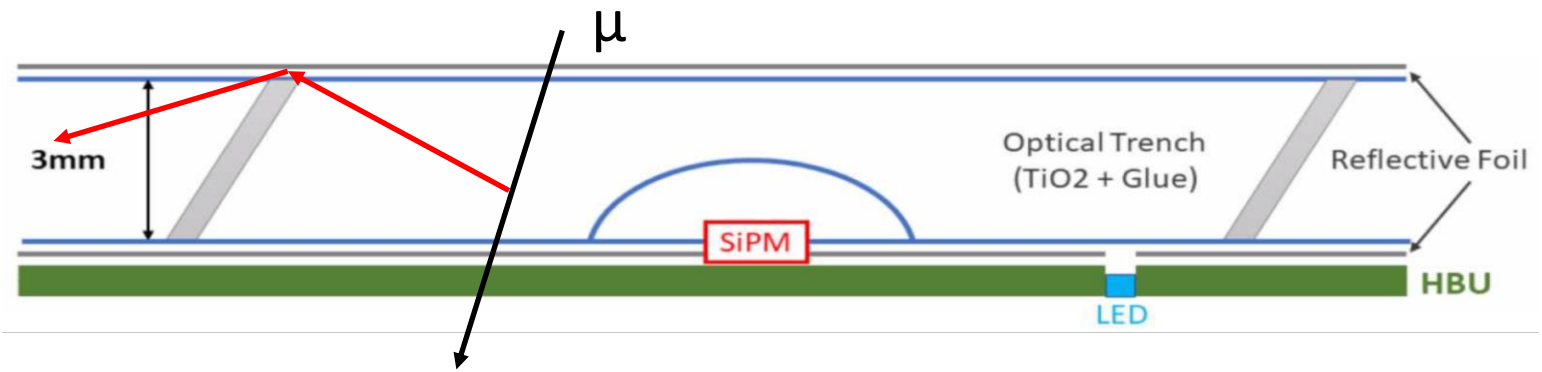
- 3 test beams at DESY II: 2019 with MT4 and 2020 with MT6
- Electron beam at 3 GeV
- Megatile layer (MT), 2 single tile layers, beam telescope in front



Cross Talk

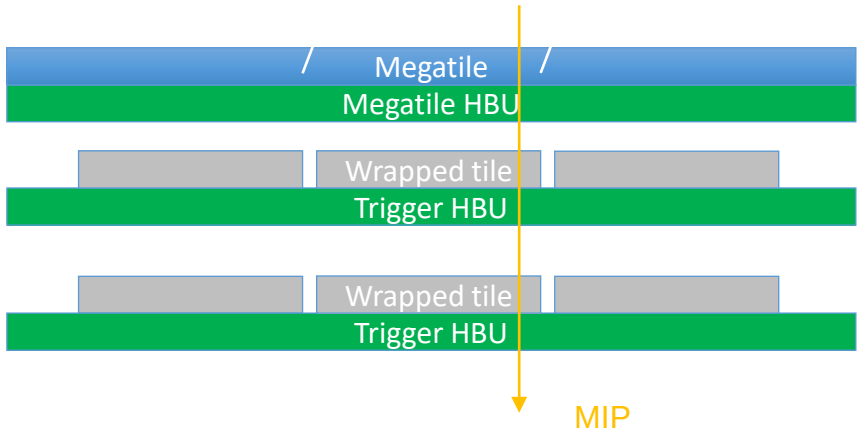
- Light escaping central cell through airgap
  - ⇨CT depends on air gap
  - ⇨Sim: 3.5% for 100 µm
- CT = energy in neighbour channel / energy central channel



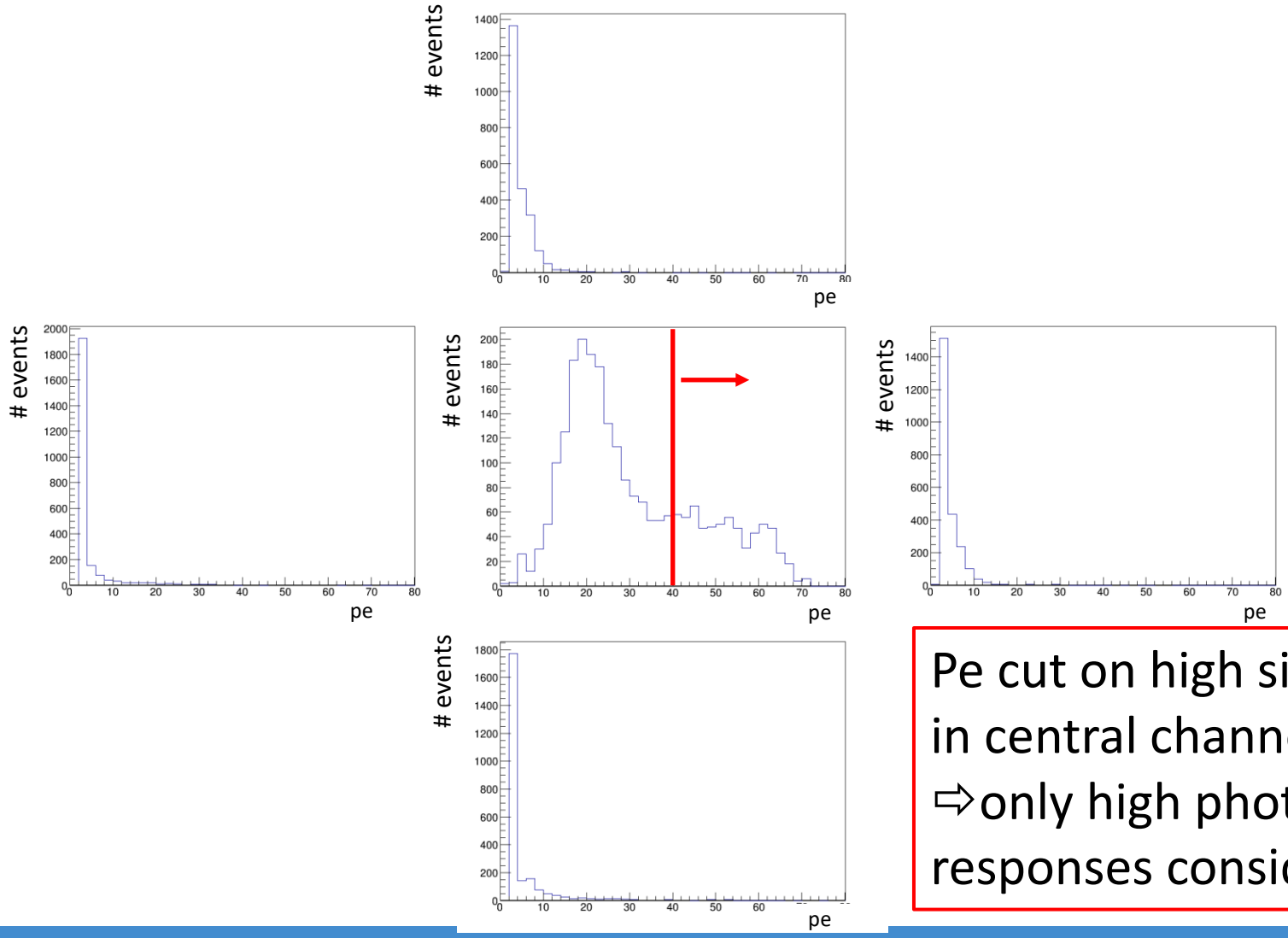


Measurement of Cross Talk

1. Central channel of MT defined by coincidence in single tile layers

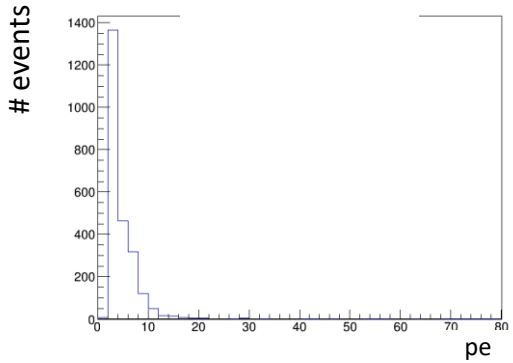


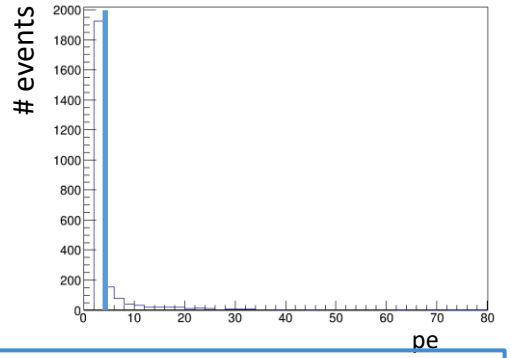
Measurement of Cross Talk

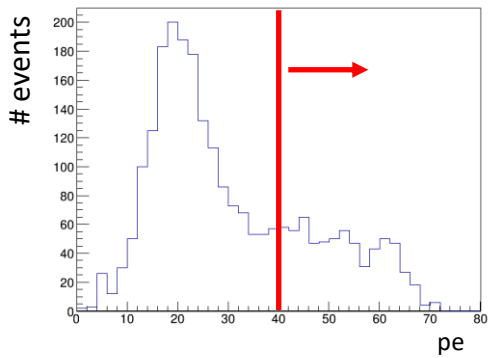


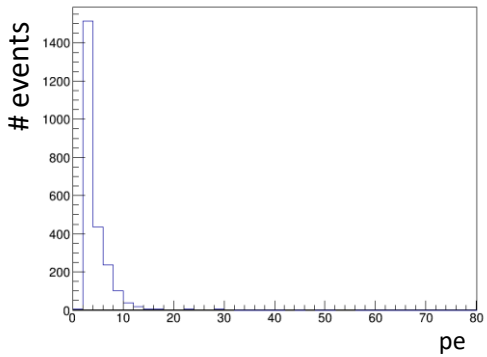
Pe cut on high signal in central channel
⇨only high photon responses considered

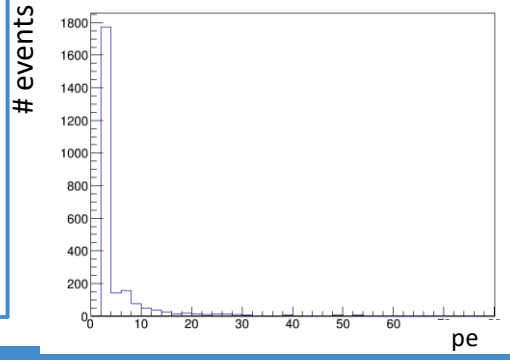
Measurement of Cross Talk









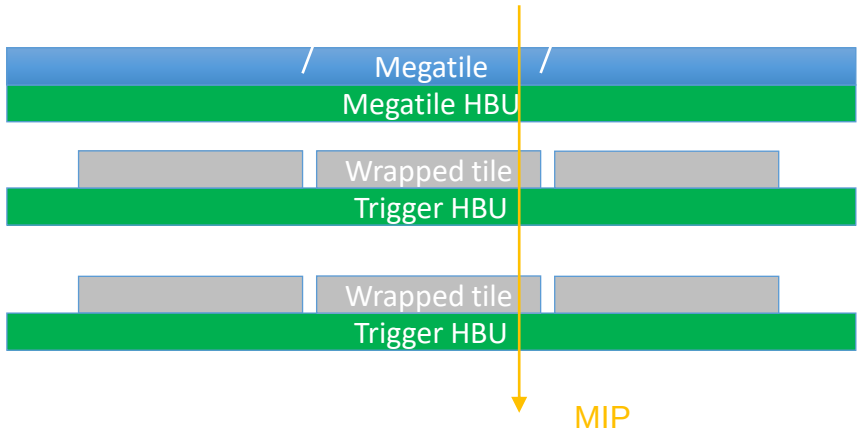


Fill trigger threshold value for events w/o signal
⇨Upper limit on CT

Pe cut on high signal in central channel
⇨only high photon responses considered

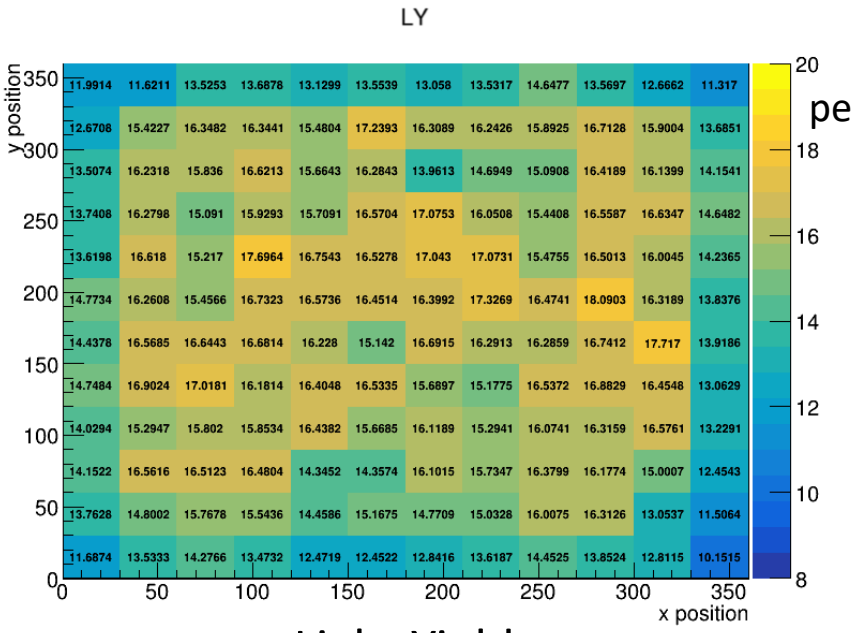
Measurement of Cross Talk

1. Central channel of MT defined by coincidence in single tile layers
2. Pe cut on central tile
3. Fill not triggered channels with threshold value (3 pe)
4. CT ≤ pe neighbour channel / pe central channel

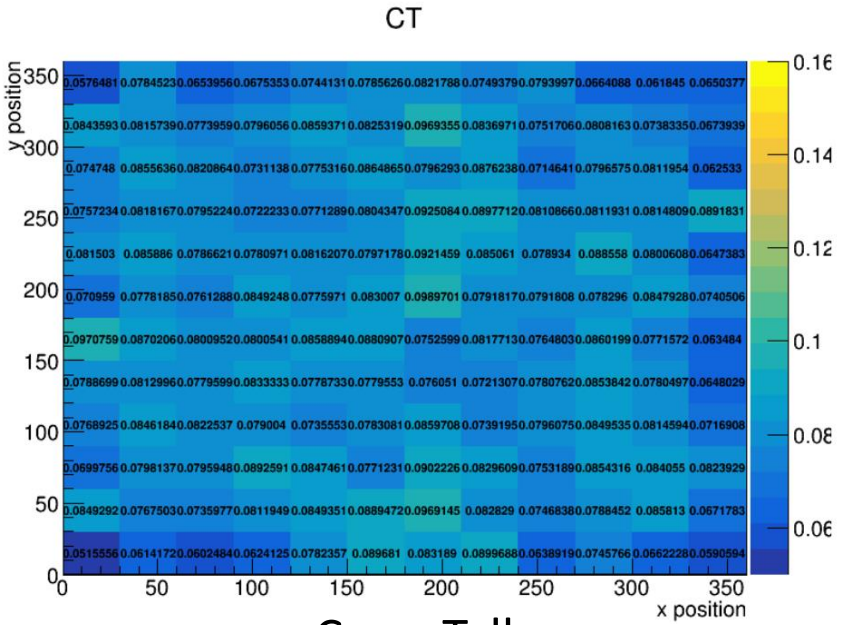


Results of MT4, Cosmic Ray Test Stand

- In Cosmic Ray Test Stand:
  - Very uniform LY and CT in central channels
  - Magnitude as expected



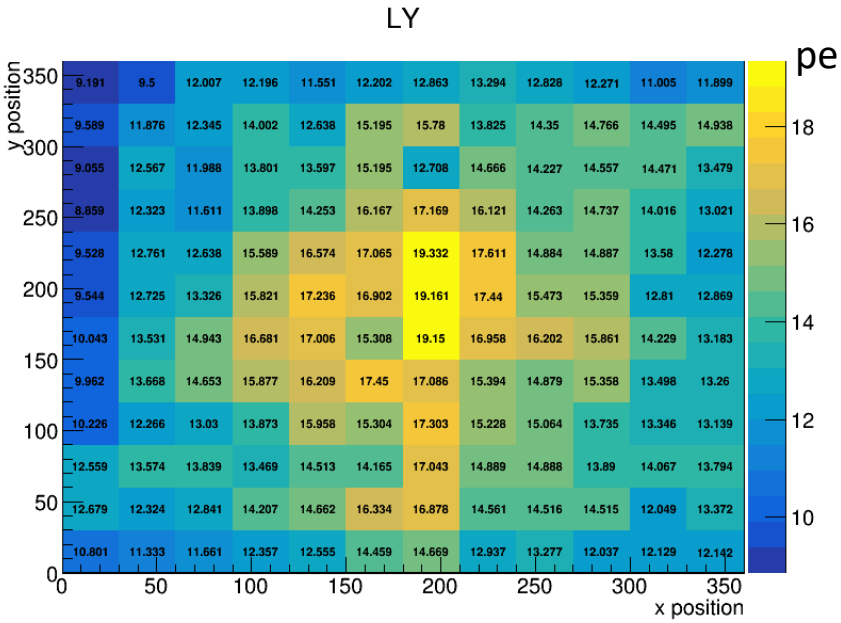
Light Yield

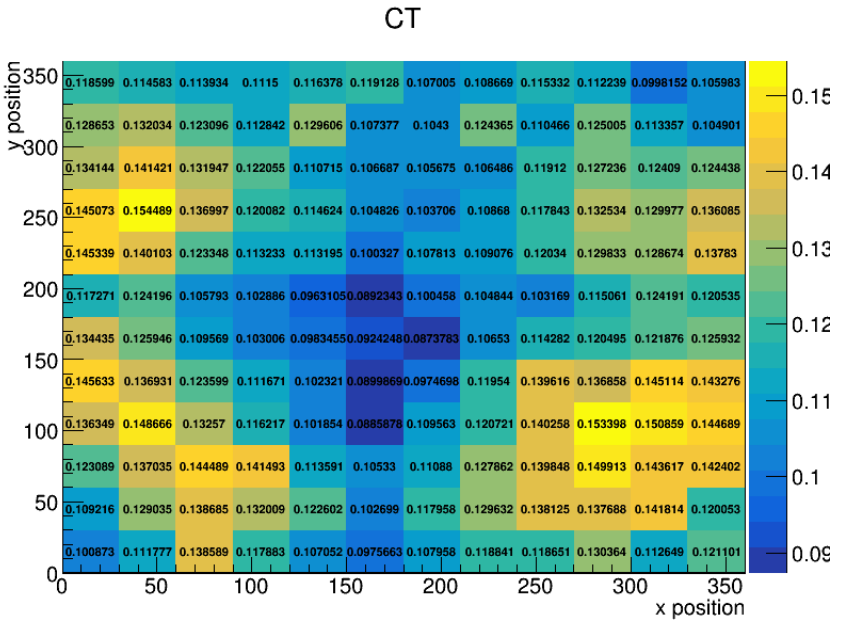


Cross Talk

MT4: First Attempt at Test Beam (2019)

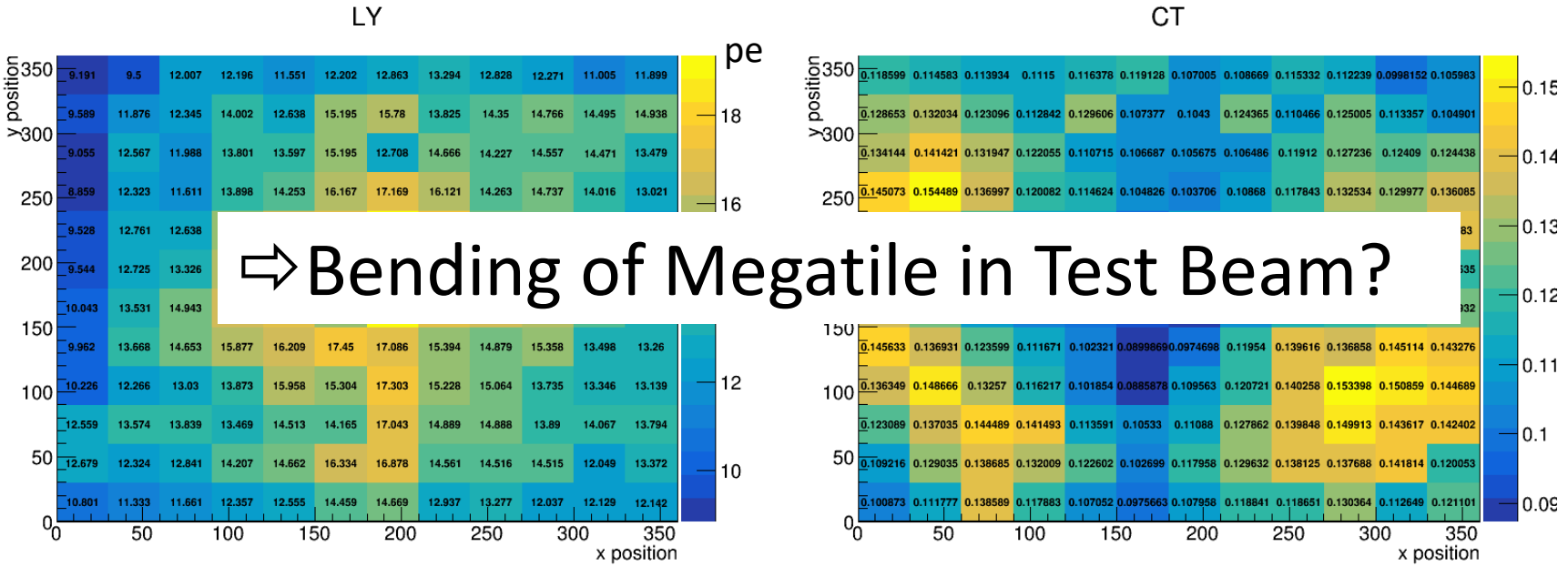
- Values at center of Megatile of expected magnitude
- Not uniform compared to Cosmic Ray Test Stand
- Anticorrelation between LY and CT





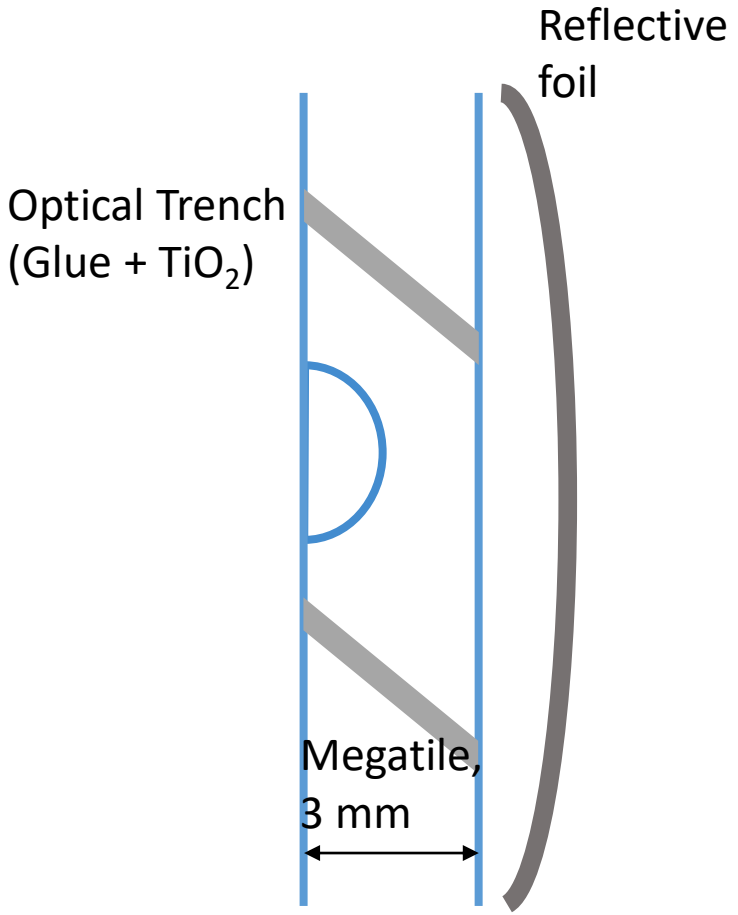
MT4: First Attempt at Test Beam (2019)

- Numbers in center of expected magnitude
- Not uniform compared to Cosmic Ray Test Stand
- Anticorrelation between LY and CT



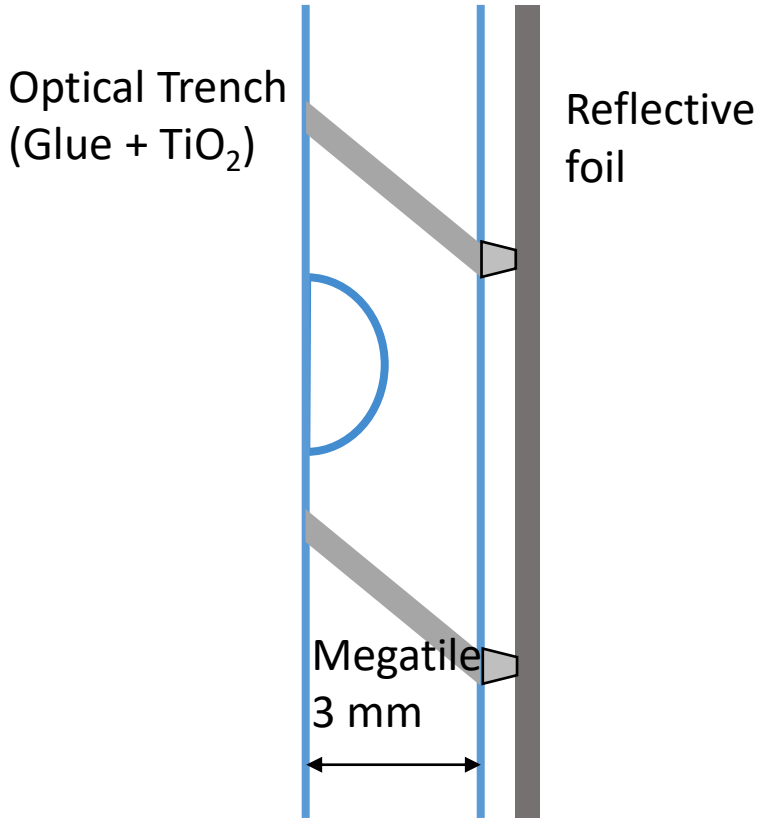
Foil Bending in Air Stack

- In cosmic ray test stand: MT lying flat, heavy metal plate on top
- In TB: MT upright
  - ⇨Foil is bending



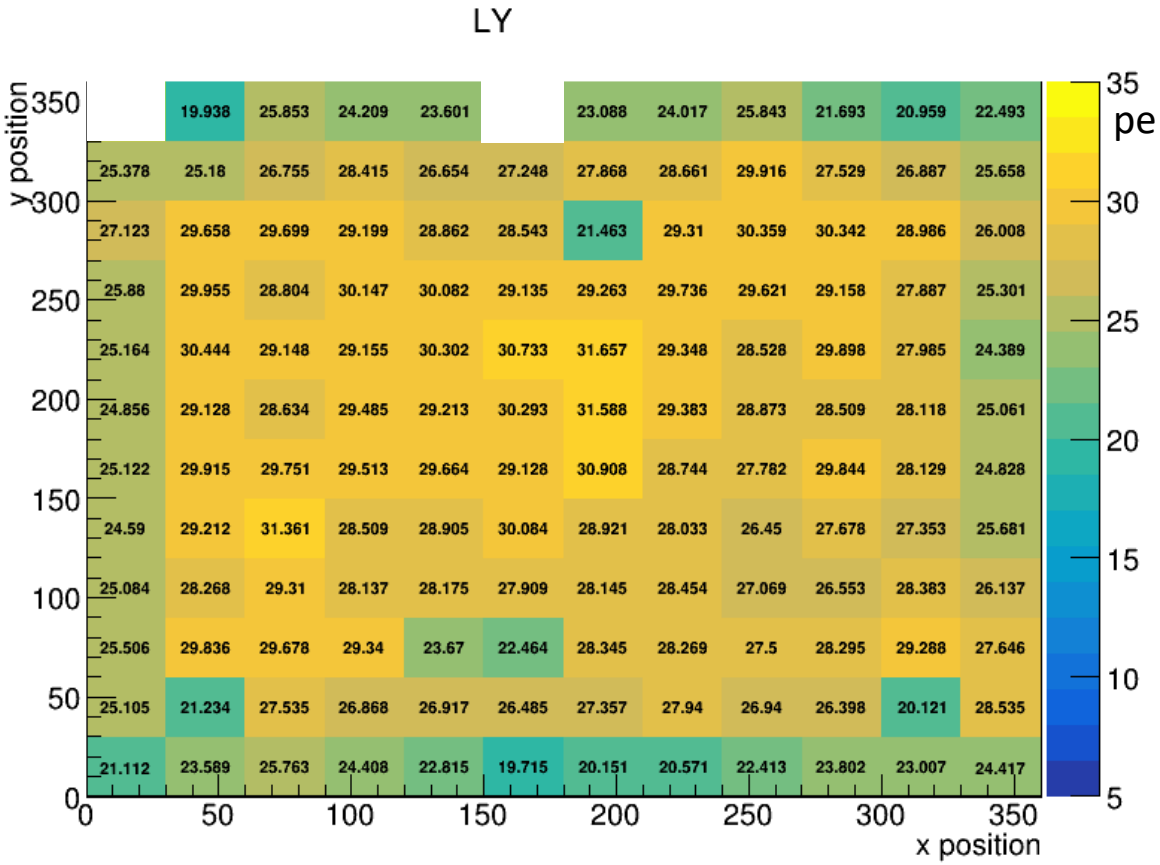
Solution: Glue Foil

- Glue foil to Megatile along the trenches ⇨ MT6



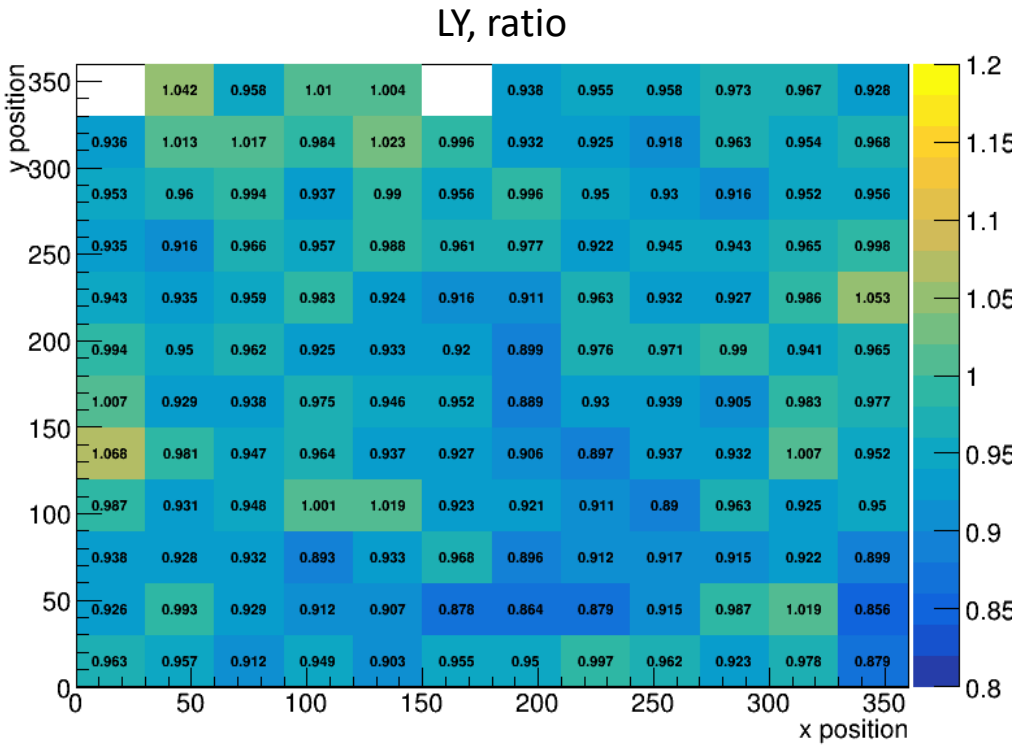
LY of MT6 at Test Beam (2020)

- Quite uniform



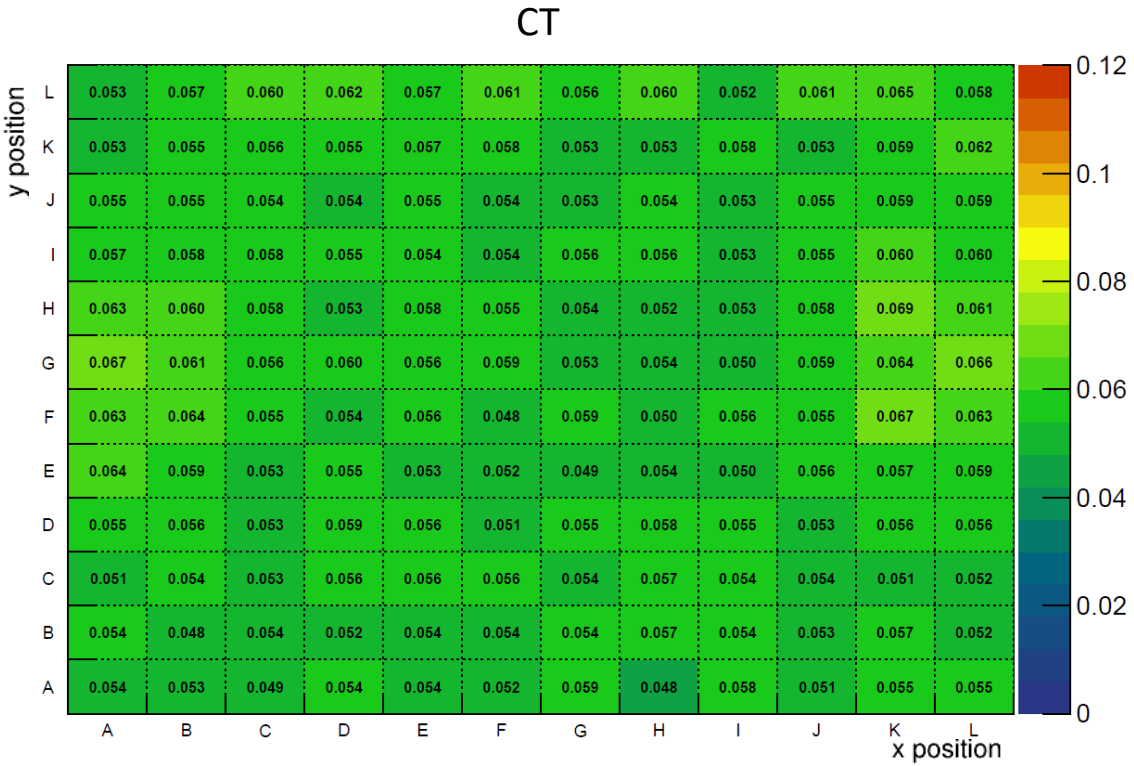
LY Comparison

- Ratio between test beam and cosmic ray test stand results
- Compatible within 15%



Cross Talk in Cosmic Ray Test Stand, MT6

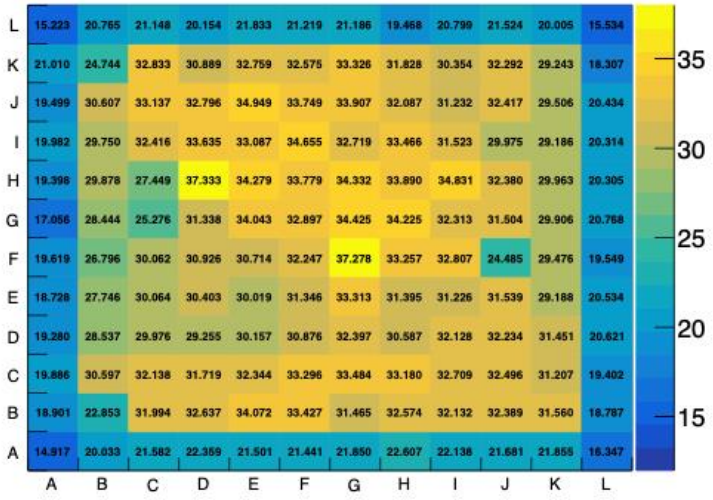
- Similar to MT4
- Cross talk for TB: work in progress



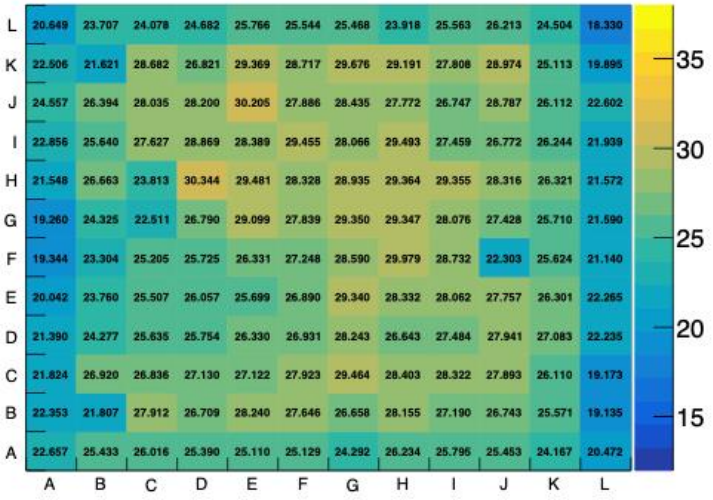
Ageing Studies

- Optical stability of trenches linked to TiO_2 + glue mixture

December 2019



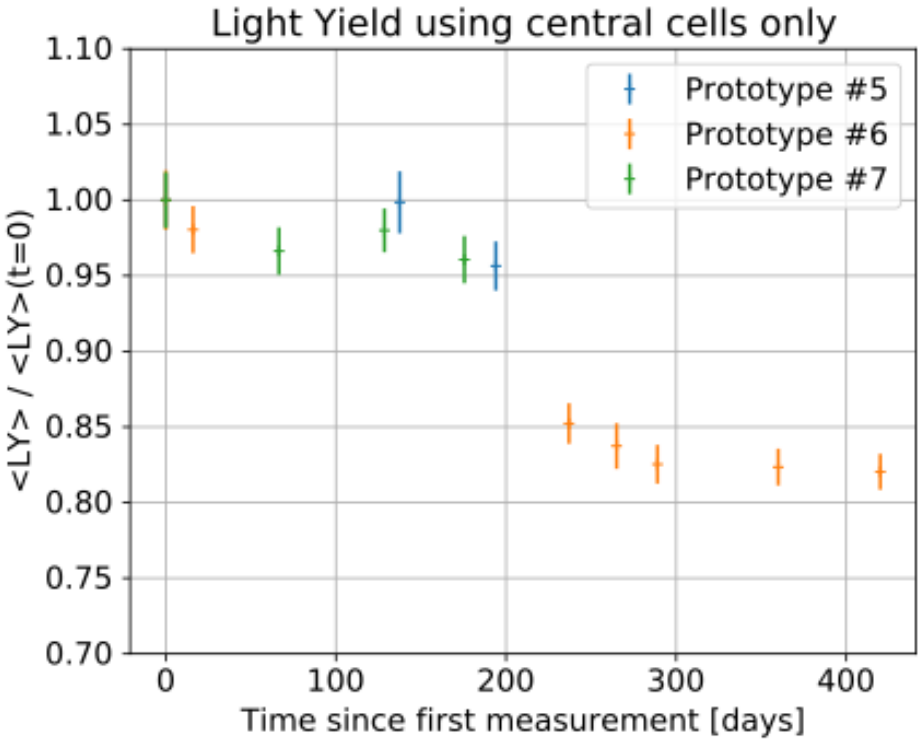
August 2020



- 15% lower LY after 8 month
- Repeat LY measurement periodically (couple month) to spot evolution

Ageing Studies

- MT6 seems to be stabilised after August 2020
- No significant effects in MT5 and 7
- Temperature stable within 0.5°C
  - ⇨Not the cause
- Most likely explanation: accidental exposure to light during first lockdown
- Further tests ongoing



Conclusion

Conclusion:

- LY values in test beam confirm results from cosmic ray test stand
- LY in edge cells on average 84% of central cells
- Airgap between scintillator and foil under control both at cosmic ray test stand and TB
- Cross talk at acceptable level with cosmic ray
- No unexpected ageing observed

Outlook

- Cross talk in 2020 test beam data
- More data available, to be analysed
  - Including uniformity scans with beam telescope
- Ongoing monitoring of ageing

Thank you for your attention!

Backup

Impact of pe Cut on Cross Talk