Megatile status and test-beam analysis

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CALICE Collaboration meeting Valencia - 21/04/2022

Calorimeter for ILC

Bundesministerium für Bildung und Forschung

AIDA 2020

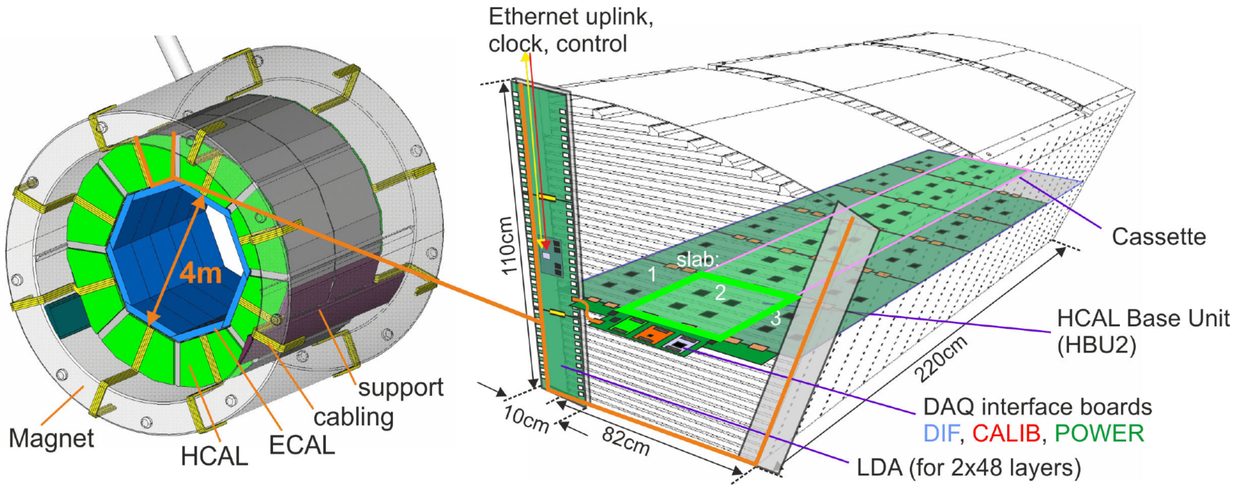
PRISMA+ DETECTOR LAB

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

JG|U

The AHCal baseline design

- **AHCal**: **Analogue Hadronic Calorimeter**
  - Plastic scintillator tiles.
  - **SiPM readout**.
  - Total **8M channels**!



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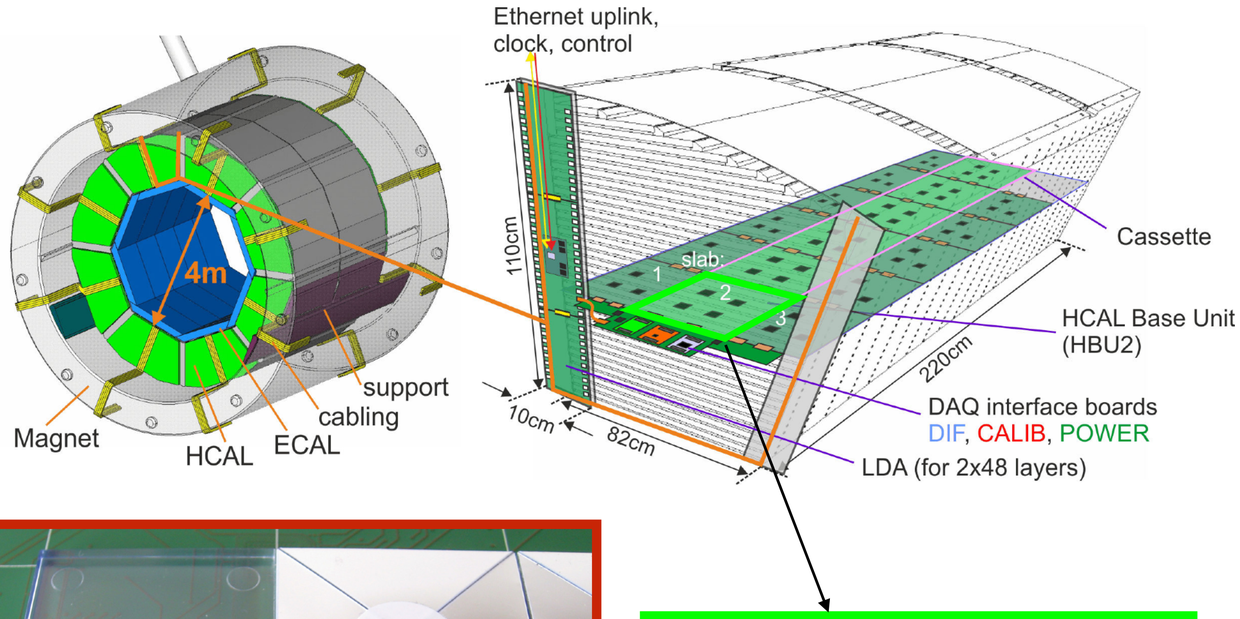
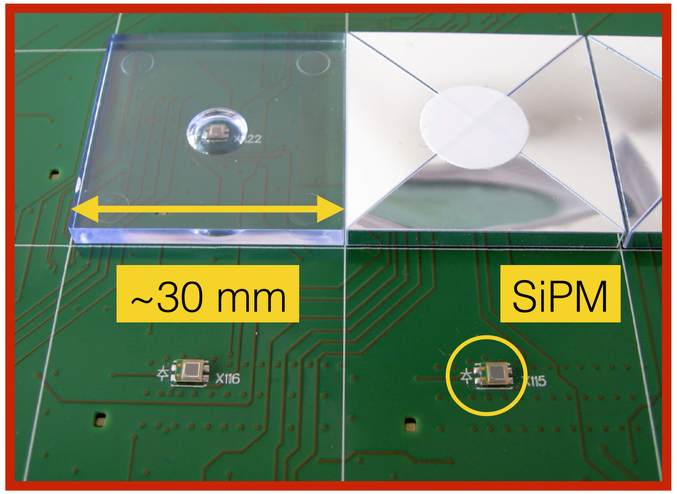
- 1 board = 36x36 cm² (144 channels)
- 1 channel =
  - 1 **SiPM** (Hamamatsu S13360-1325)
  - 1 **scintillator tile** polystyrene (30 x 30 mm², 3 mm thick).
- Individually wrapped in reflective foil and glued on PCB.





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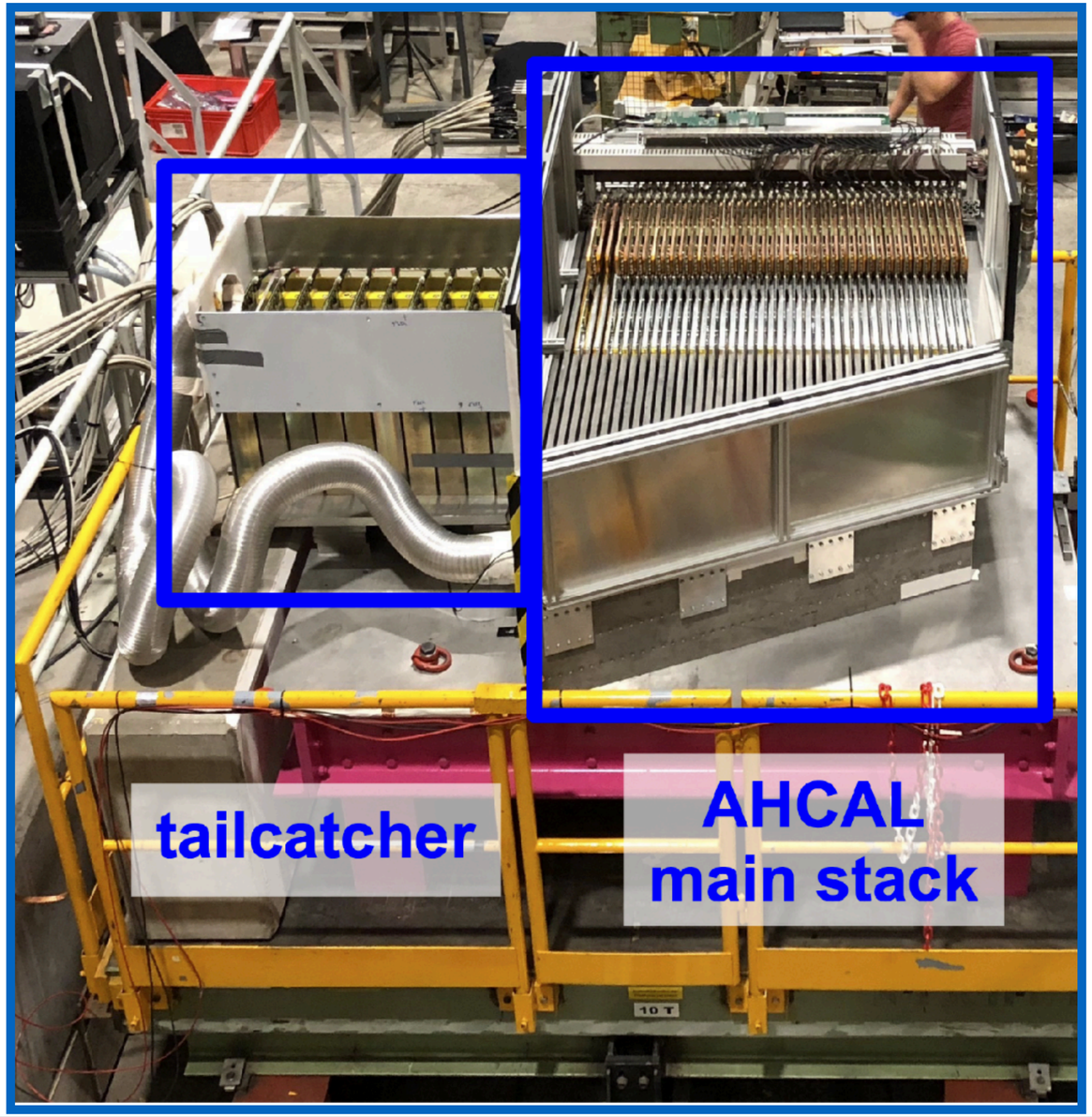
- Large prototype built in 2018, TB at CERN.
- Feasibility demonstrated with 22'000 channels, but tedious assembly.



Megatile concept

- Build **one single** 36x36 cm^2 **tile**.
- **Cut trenches** and fill with **optical insulation**.
- Pour flowing **glue + TiO_2 mixture** → reflectivity.
- Optimal angle: 30°, minimise dead area.

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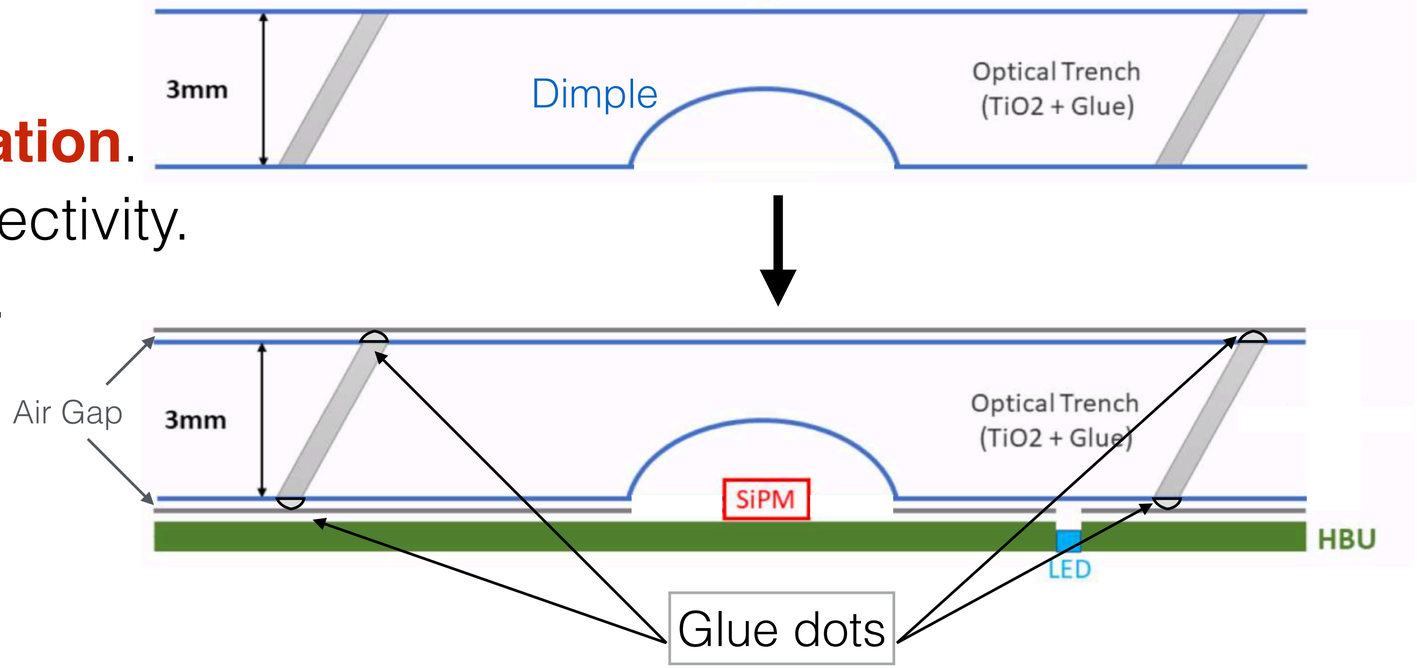

- Glue **reflective foil sheet** directly on the megatile (with laser-cut holes for SiPM)

- **Air gap** (<100 μm) to ensure total reflection.

- <u>No change to SiPM:</u>
  - Same electronics boards.
  - Same readout.

Megatile concept

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- **Cut trenches** and fill with **optical insulation**.
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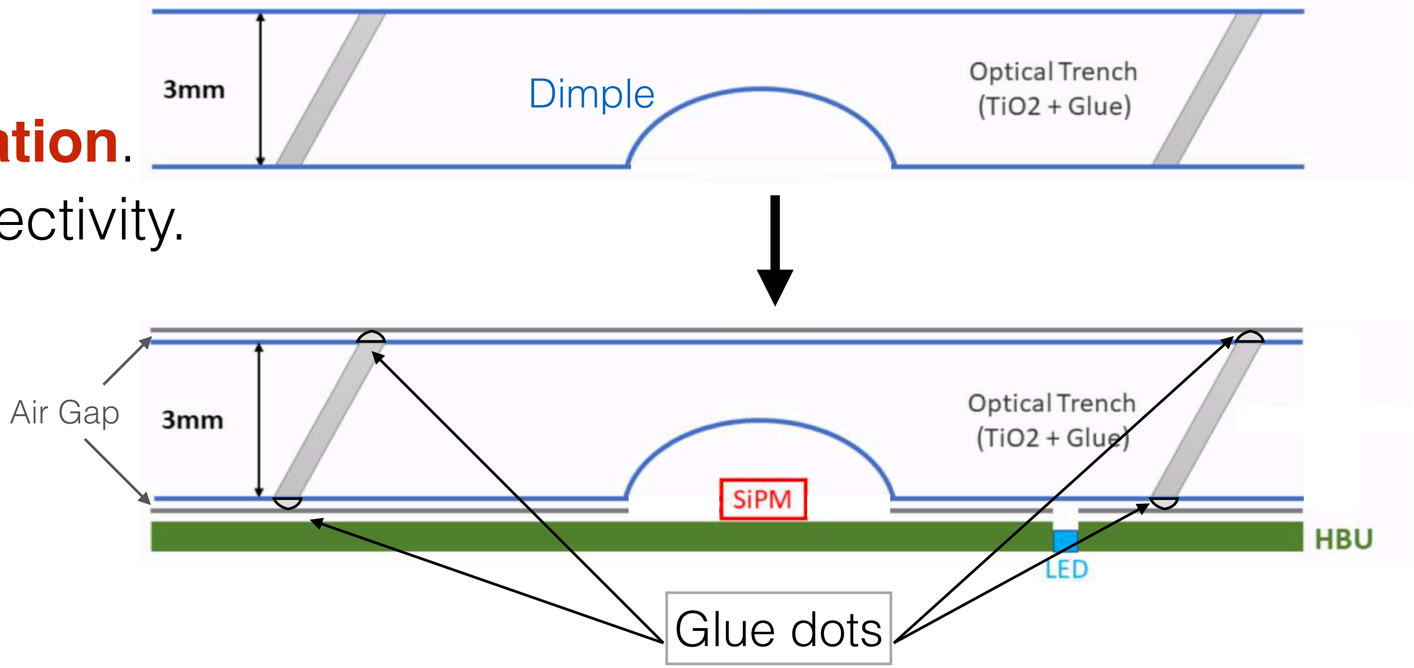
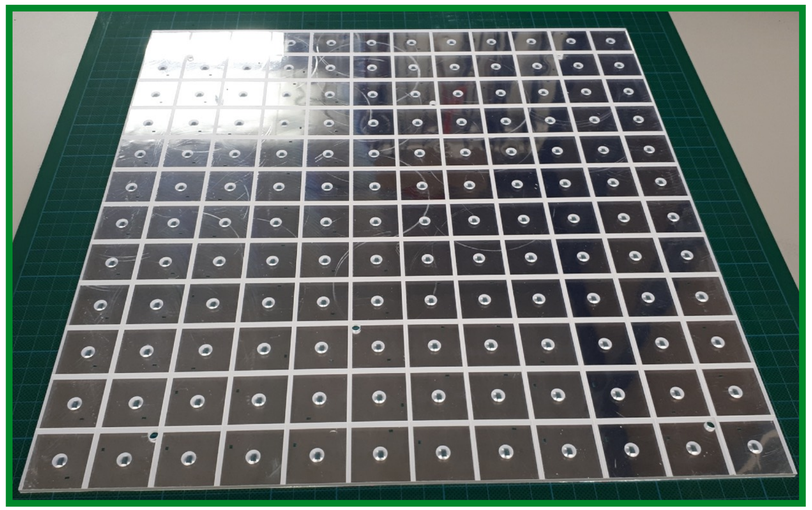


- Glue **reflective foil sheet** directly on the megatile (with laser-cut holes for SiPM)

- **Air gap** (<100 μm) to ensure total reflection.

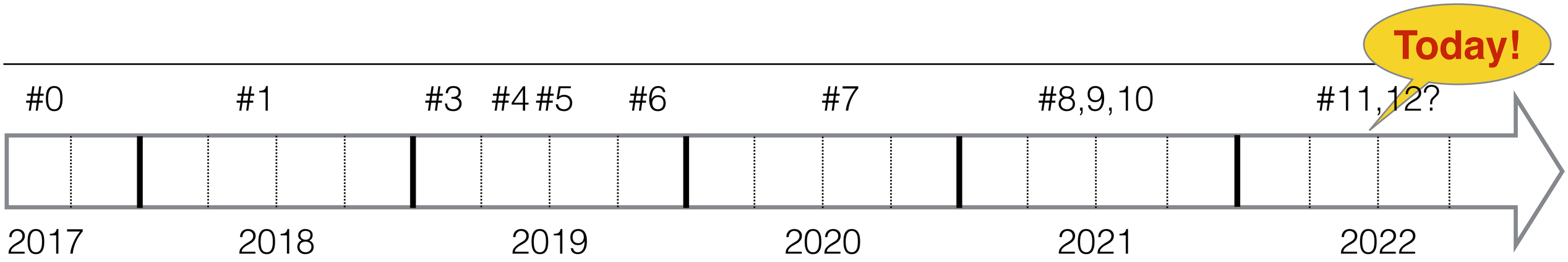
- 👍 ~ **No dead area**!
- 👍 **Easier assembly**.

In real life:



The Megatile experience

- **Project started in 2017**.
- **Already 10 prototypes built** with **continuous improvement**.



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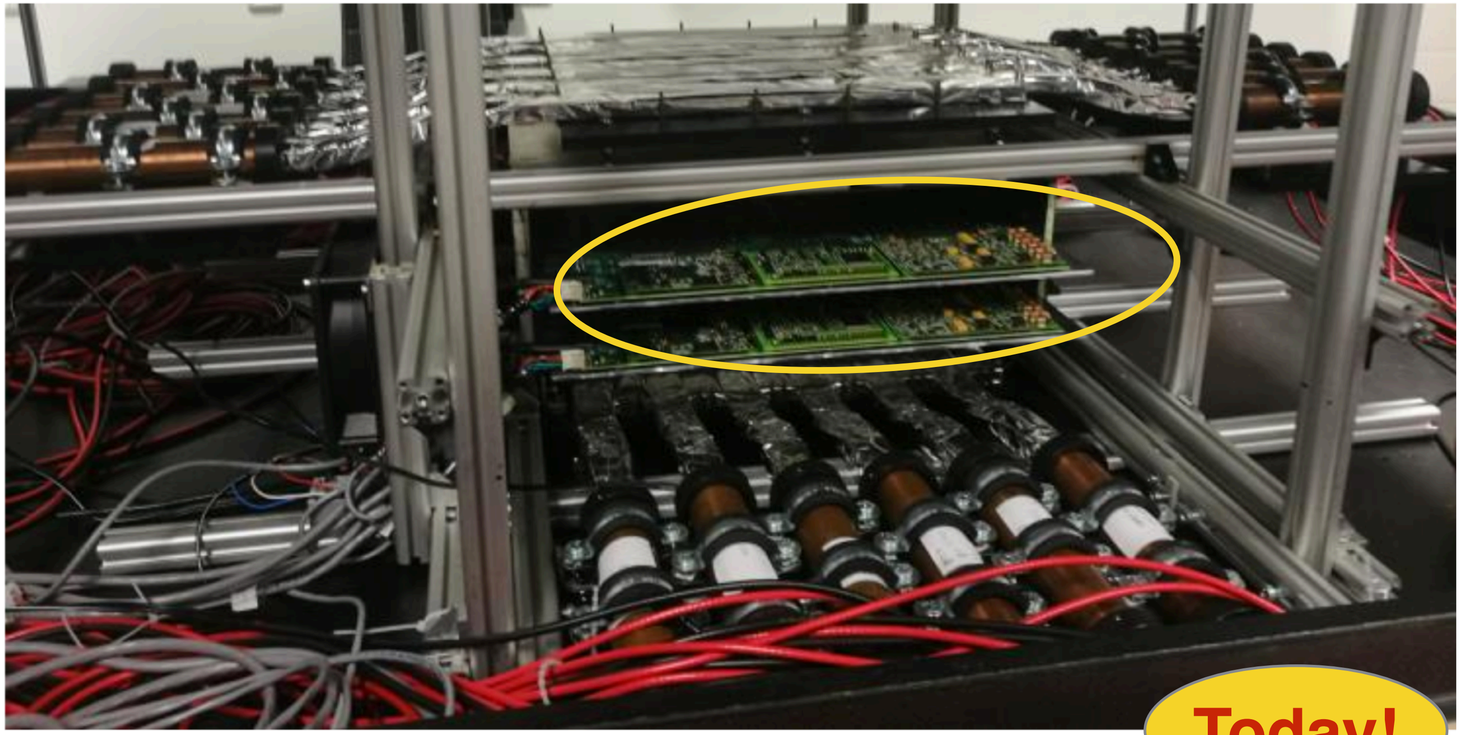
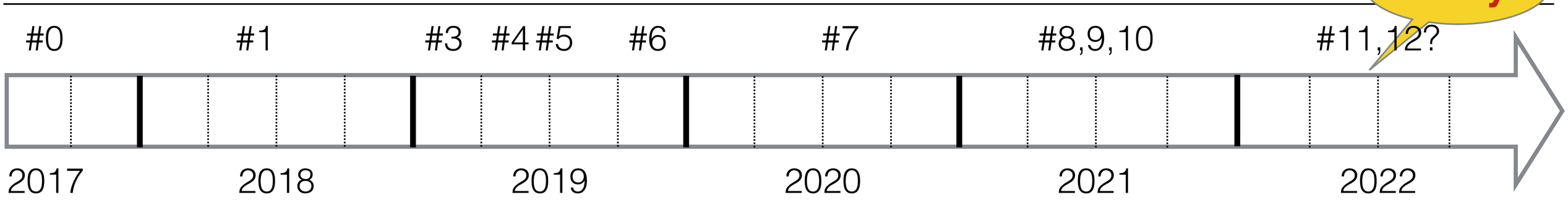
- **Continuously tested** in **cosmic test stand @ Mainz**.

Cosmic test stand @ Mainz detector lab



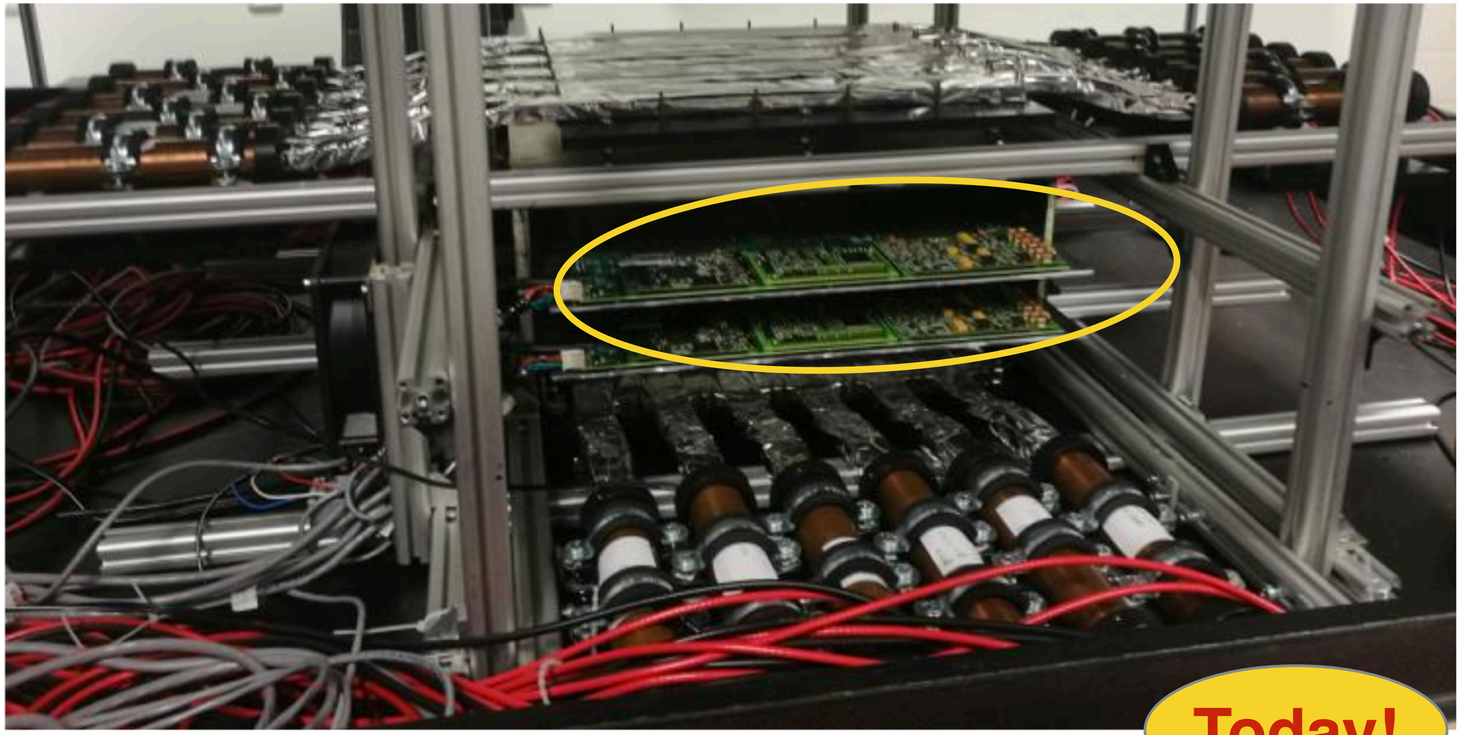


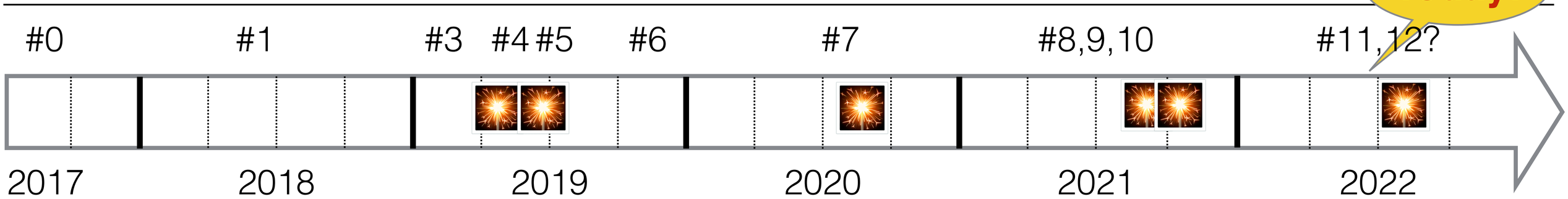
The Megatile experience

Cosmic test stand @ Mainz detector lab

- **Project started in 2017**.
- **Already 10 prototypes built** with **continuous improvement**.

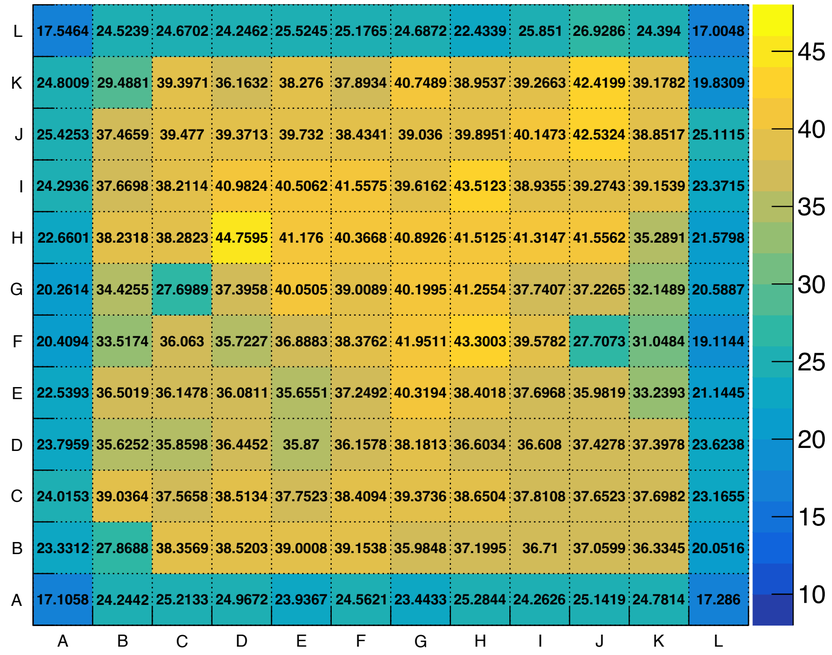
- **Continuously tested** in **cosmic test stand @ Mainz**.
- Already **5 test beams @ DESY II**
  - Last TB with KLauS-5 HBU!

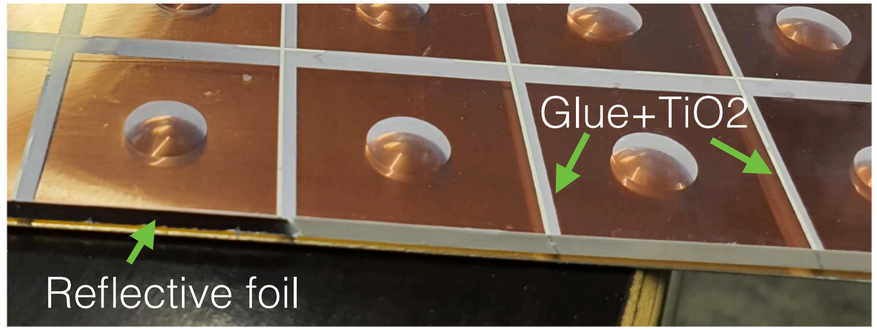




Megatile performance from cosmic and test-beam data

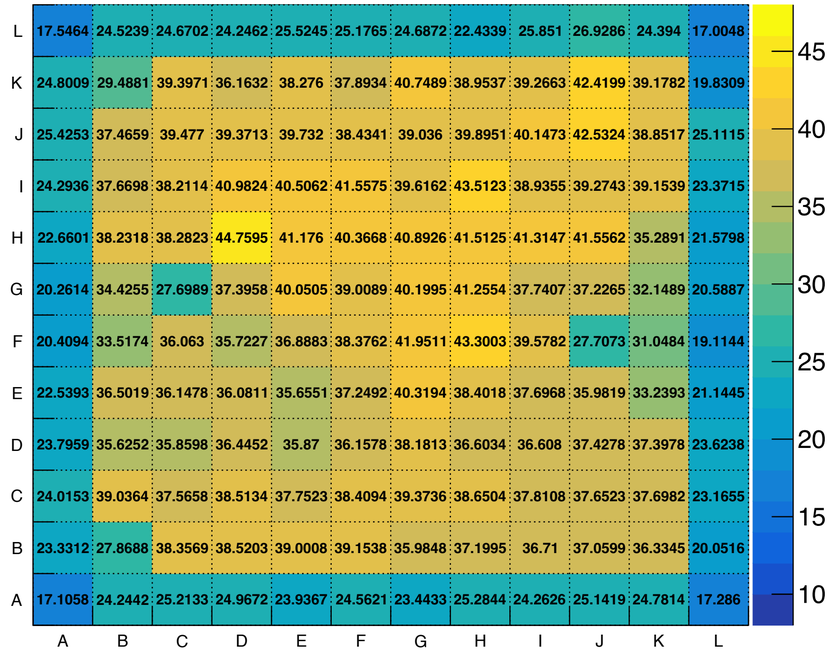
Edge treatment

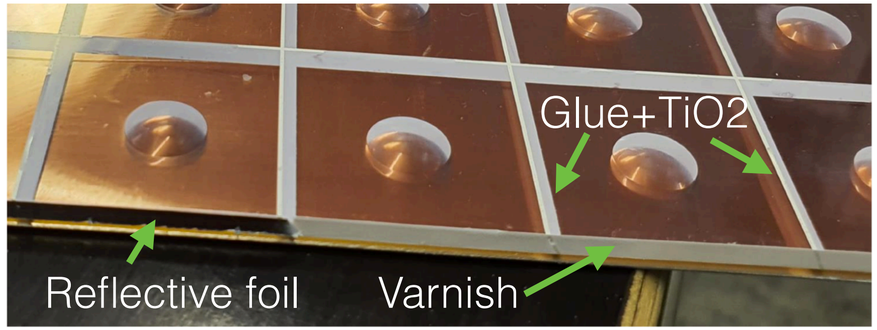




- **High and uniform light-yield**, except for the edge channels (~30–50% lower).
- **Reason: coating of edge channels is difficult**.
  - Baseline solution: stick an auto-adhesive reflective foil, but limited improvement.

Edge treatment





- **High and uniform light-yield**, except for the edge channels (~30–50% lower).
- **Reason: coating of edge channels is difficult**.
  - Baseline solution: stick an auto-adhesive reflective foil, but limited improvement.
  - **Improved solution: spray a white varnish**.
    - **Up to perfect recovery**, yet with large efficiency variation. **Encouraging**!
    - Due to variations in spraying. Systematic method **under development**.

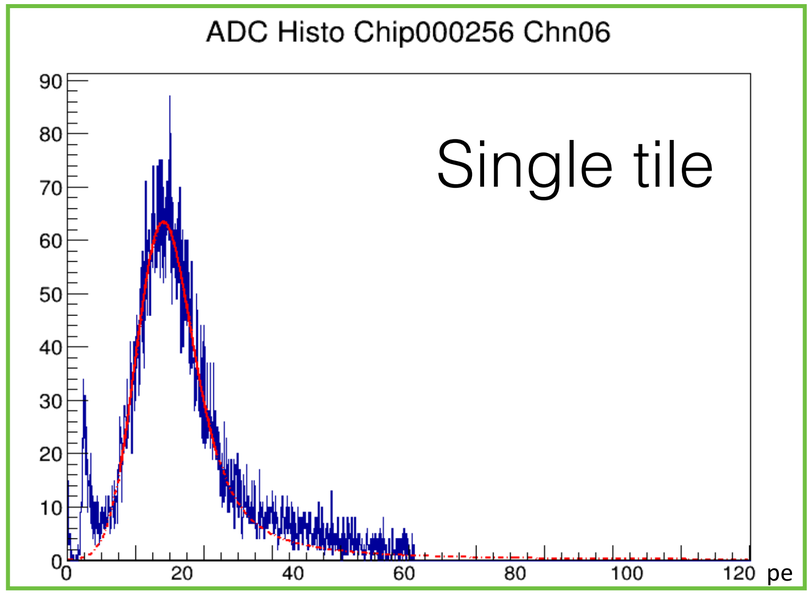
Light-yield

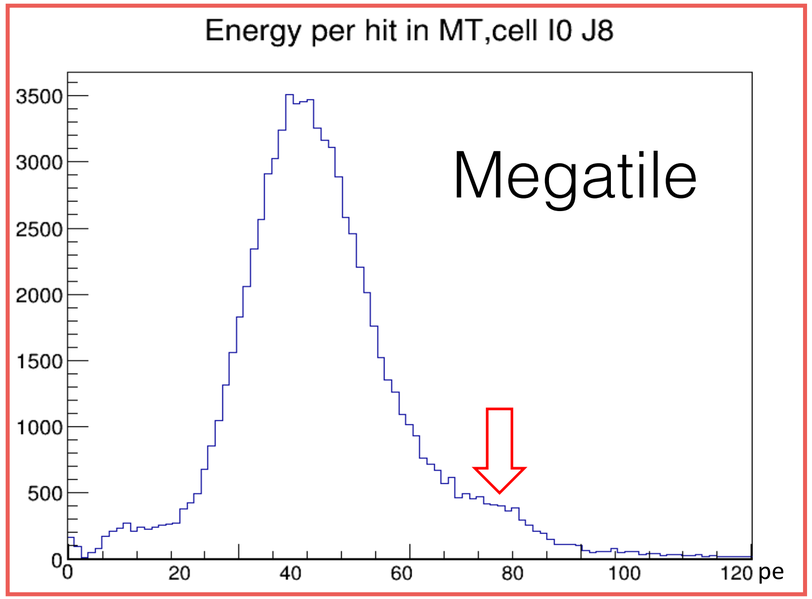
- Light yield of newest prototypes (MT10) too high for the current electronics settings!

- **<u>Light-yield</u>**:
  - **Single tile** layers: ~**15 p.e. / MIP**
    => readout in **high-gain**.
  - **Megatile layers**: ~**35-40 p.e. / MIP**
    => readout in **high-gain or low-gain**!

- **MIP peak in the gain transition region**:
  - Difficult gain intercalibration needed.
  - Landau fit often imprecise due to bump in tail.

- Discovered during Sept. 2021 TB.
- **Settings to be corrected for next test beam** (CERN).



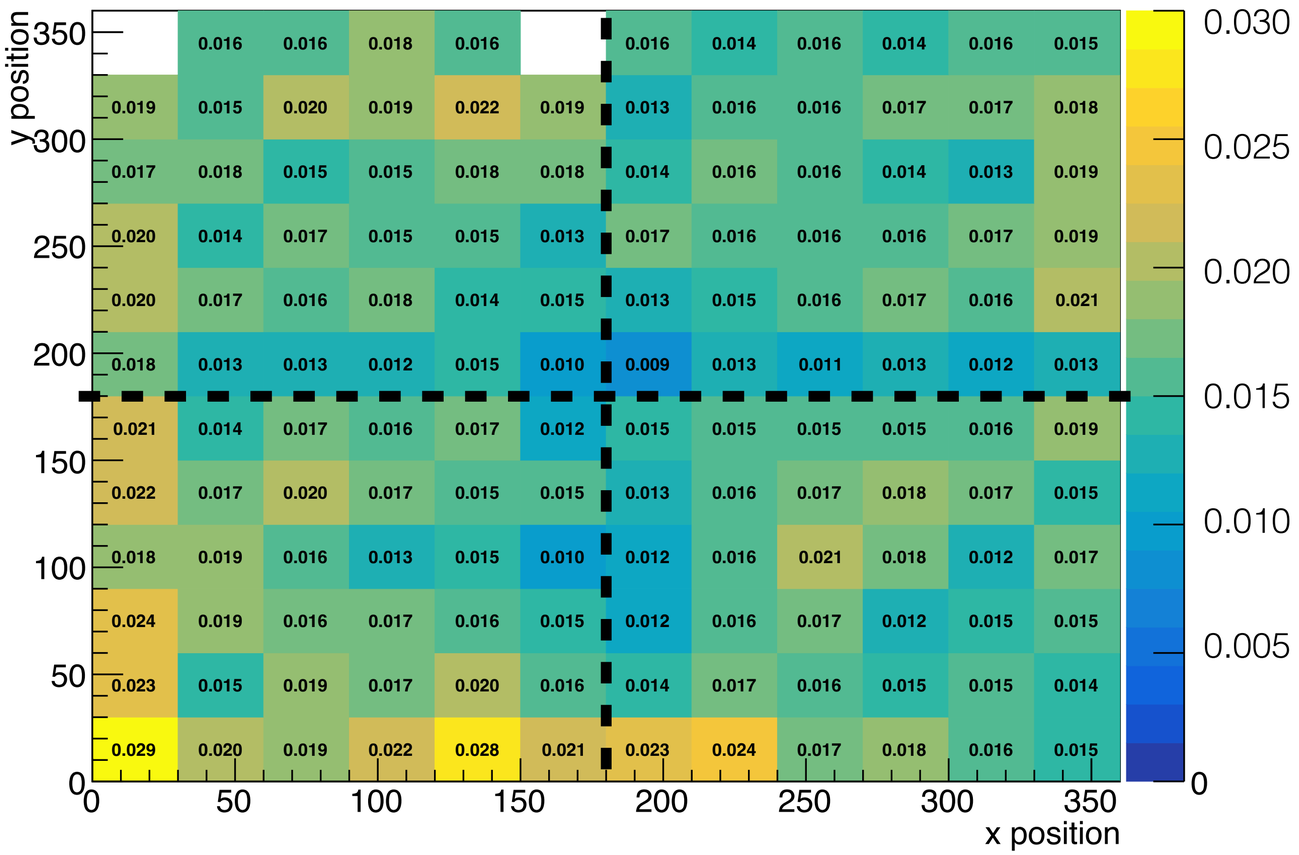


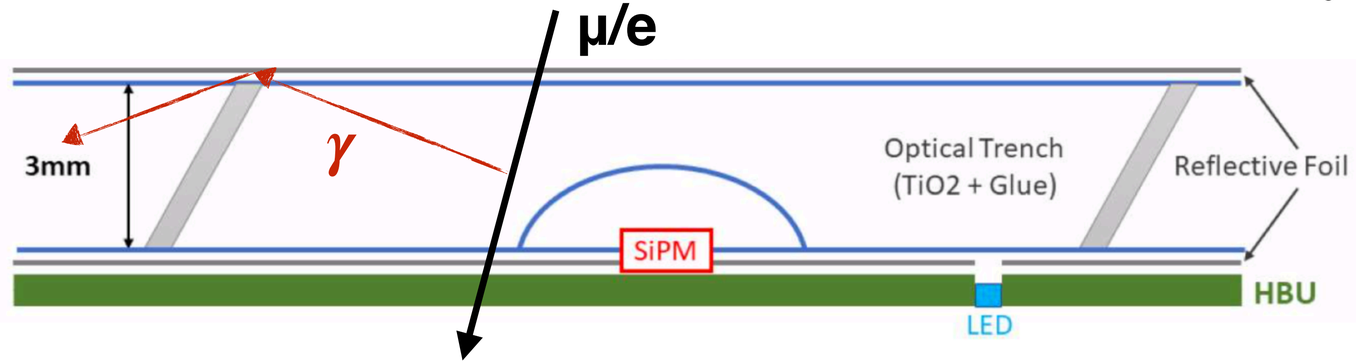
Cross-talk

- **Must be careful with air gap**:
  - Too large → optical cross talk.
  - Simu: **3.5%** for 100 µm.

- No need for 0% cross-talk: expect hadronic showers.

- **Using August 2020 TB data**:
  - **uniform cross-talk ~1.6 %**.

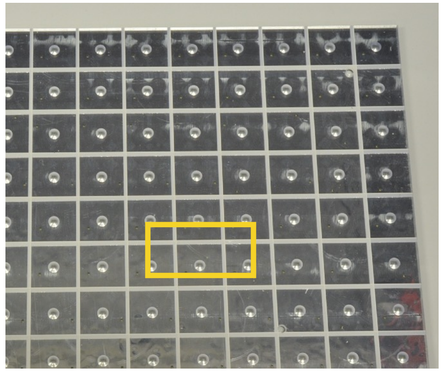




“Minimal dead area”

- **Test beam in 2020 and 2021: lots of data taken with a telescope setup**.
- Precise positioning of particles => very fine scan of the transition between two channels.

Scanned area



“Minimal dead area”

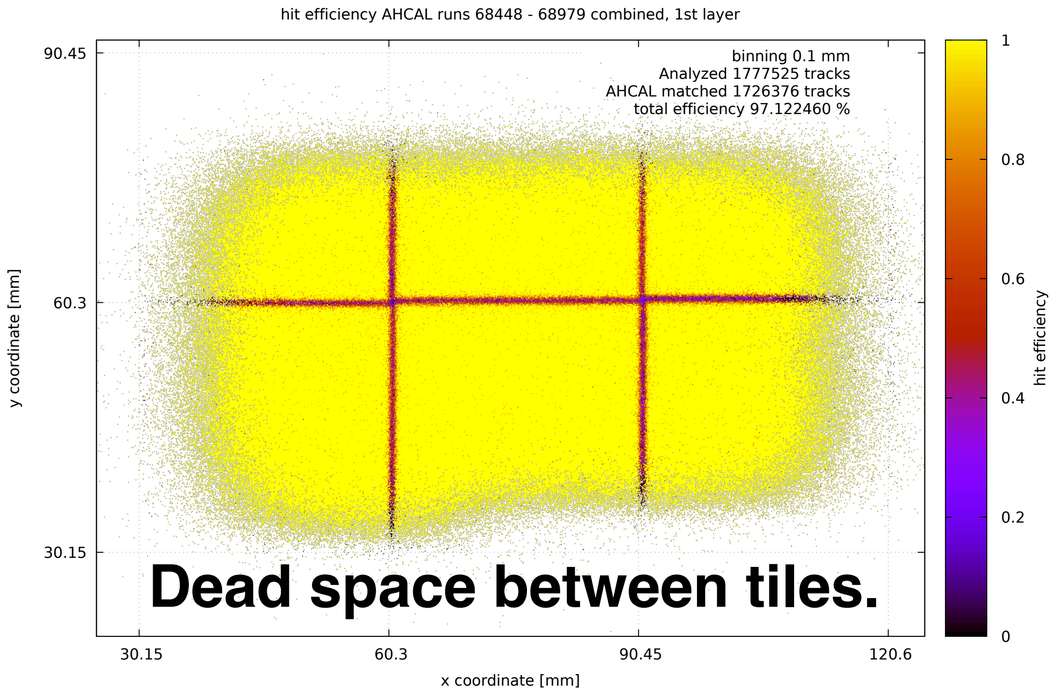
- **Test beam in 2020 and 2021: lots of data taken with a telescope setup**.
- Precise positioning of particles => very fine scan of the transition between two channels.
- **Hit efficiency map**: given a track in the telescope, was it detected in the tile layer?

Individual tile layer:

100% inside, **50% between tiles**

Megatile layer:

100% everywhere.



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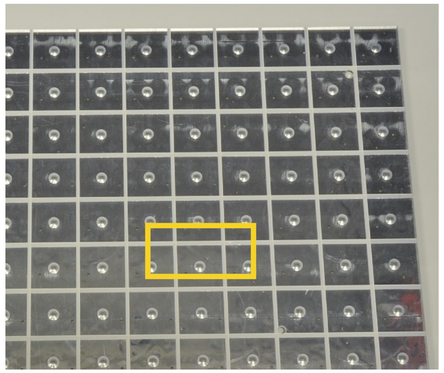
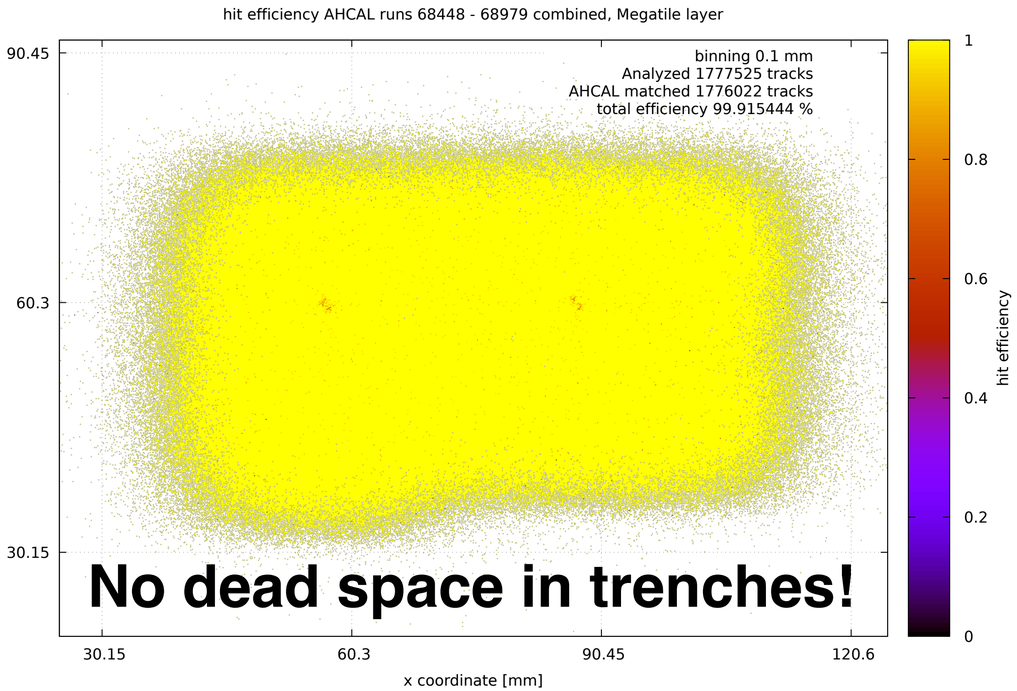
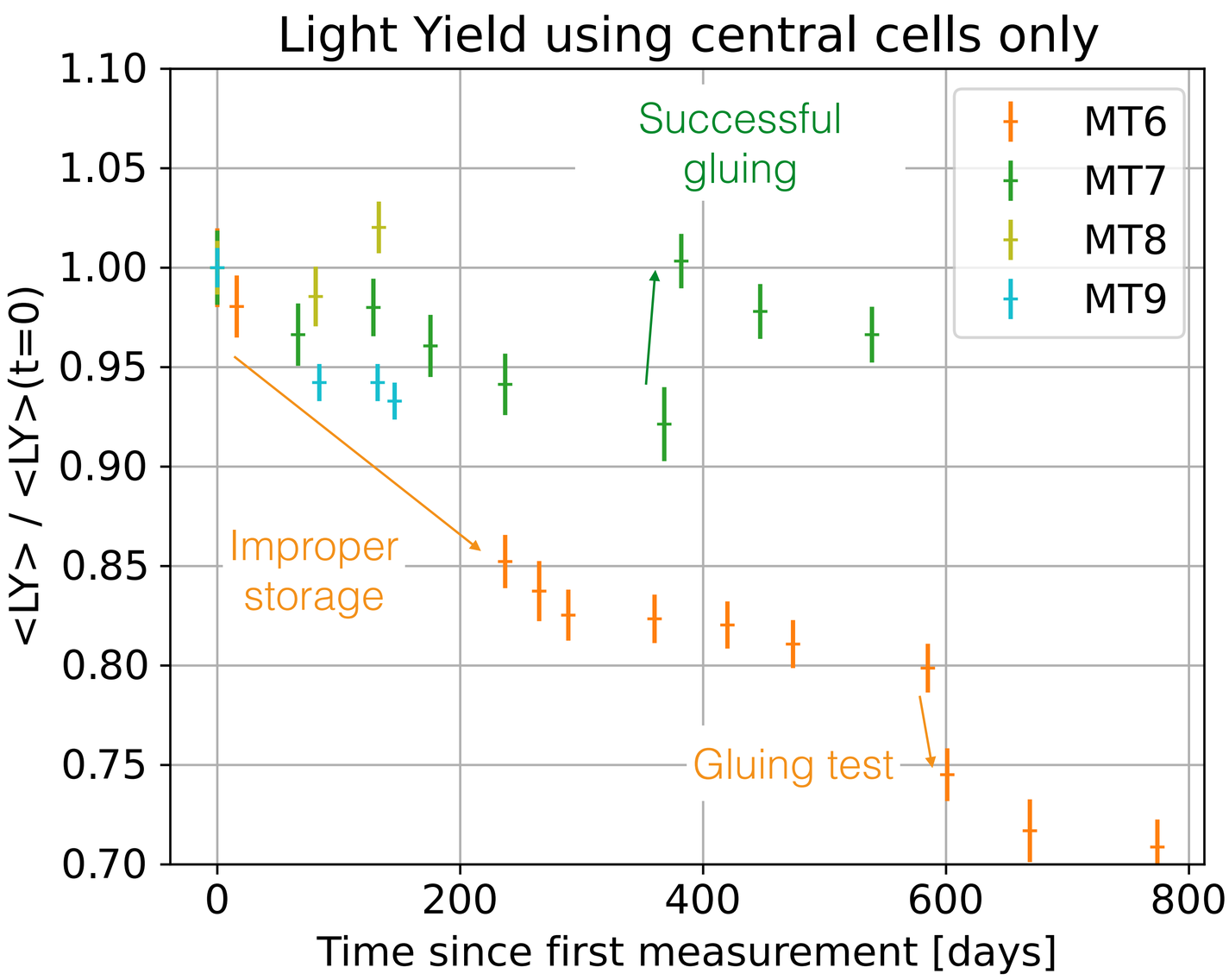




Preliminary plots from Jiri Kvasnicka

Ageing studies



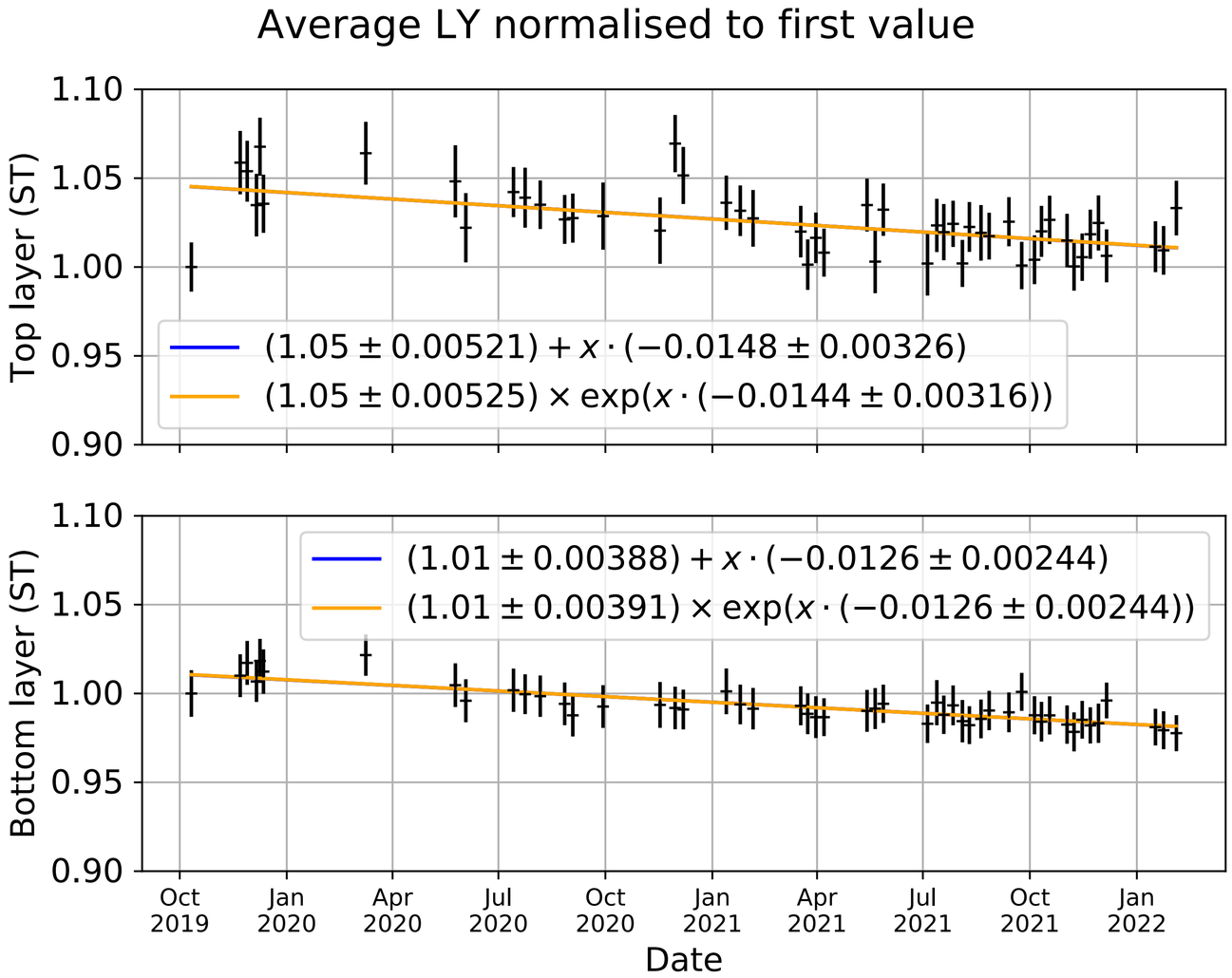
- Initially **prompted by sudden drop** in measured LY **of proto #6**.
- **Continuous monitoring** (regular measurements) since then.
- **Average light-yield: observe slow decrease of ~5% / year** in all prototypes.

Single tile layer monitoring

- Same monitoring on **single tile layers**:
  - **1-1.5 % / year**.

- **Hypotheses**:
  - **Intrinsic ageing** of the scintillator?
  - **Reaction** due to glue+TiO_2 **mixture**?

- **Tests ongoing**:
  - Build single tile from megatile scintillator.
  - Put glue mixture on a single tile.
  - Controlled light exposure.



Conclusions

Megatile = promising concept: improves mass production
while maintaining a high light-yield, low cross-talk and improving hit efficiency!

- **Edge channels**:
  - Coating is difficult, but spraying a **white varnish recovers the performances**.
  - **Optimisation** and systematic method **under development** (# varnish layers).

- **Foil gluing** on top and bottom of the megatile:
  - Improves the overall light-yield.
  - **Cross-talk under control: ~1.6 %**.

- Long term monitoring still ongoing. Goal: **determine cause of slow light-yield decrease**.

- Recent TB analysis showed we **must be careful with electronics configuration**.

Ongoing and future tests

- **<u>Ageing tests under way</u>**:
  - **Intrinsic ageing** of the scintillator?
  - **Reaction** due to glue+TiO_2 **mixture**?
  - **Light exposure**?

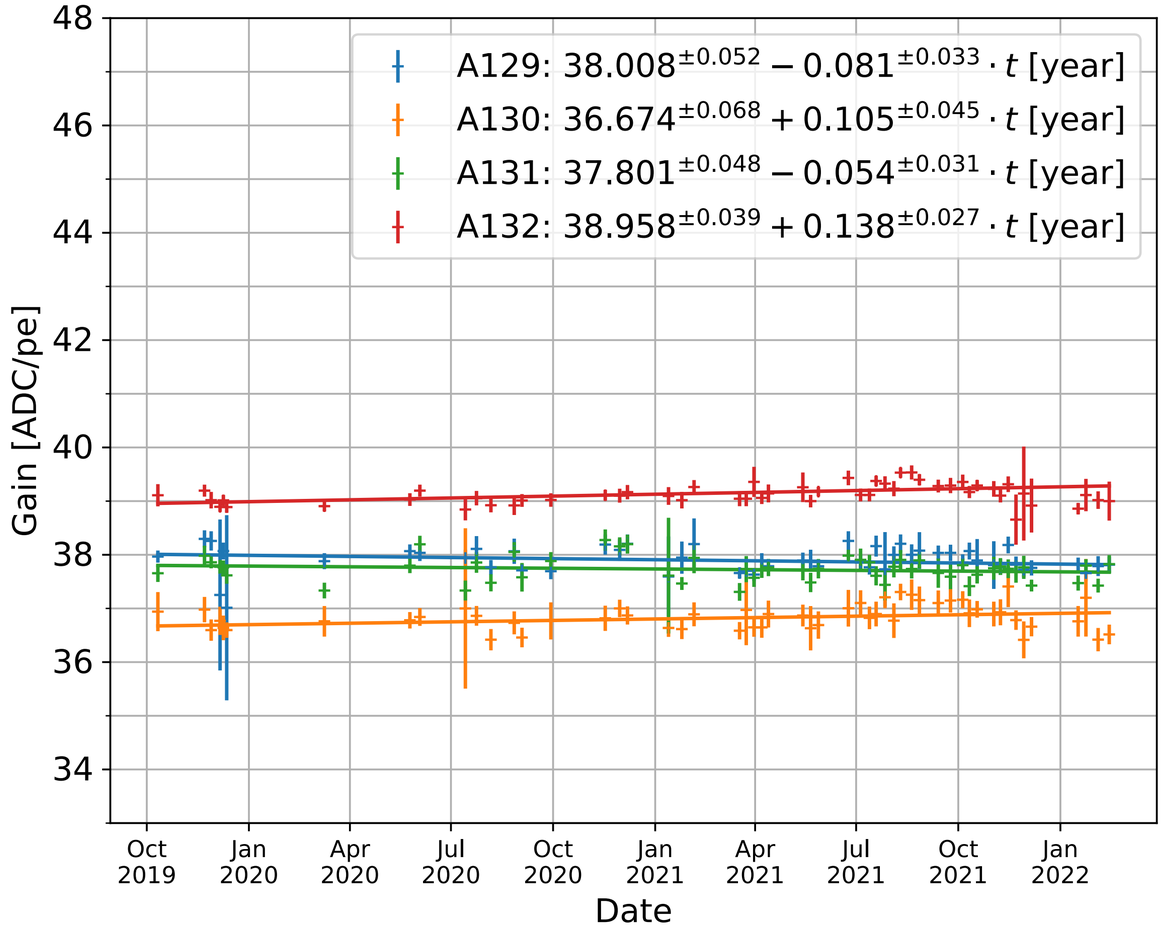
- **Looking forward to the CERN Testbeam**: hope for a **full Megatile layer** (4 boards).
  - Combined run with KLauS HBU?
  - Efficiency between Megatiles?
  - First hadron beam for the Megatile!

Issue with worldwide supply of glue :(

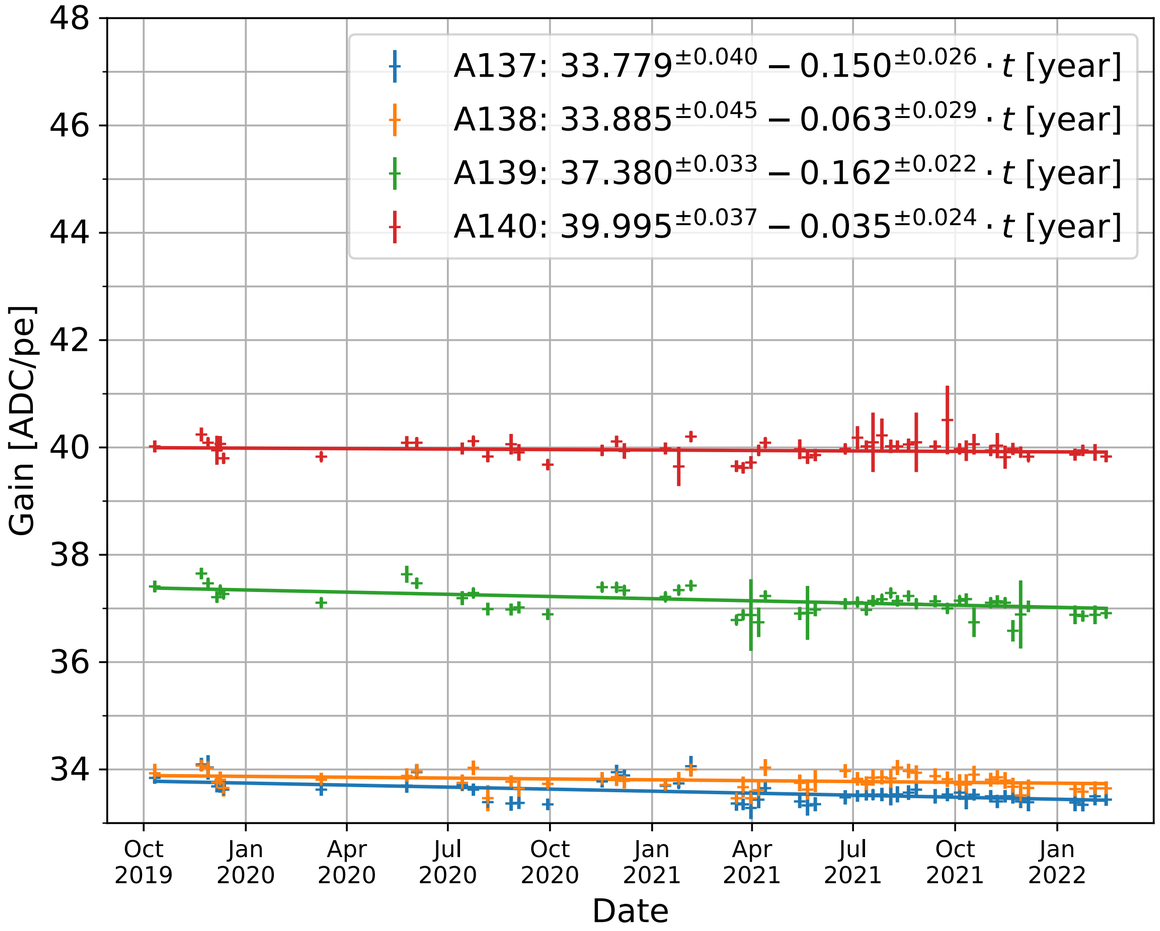
BACKUP

Single tile gain evolution

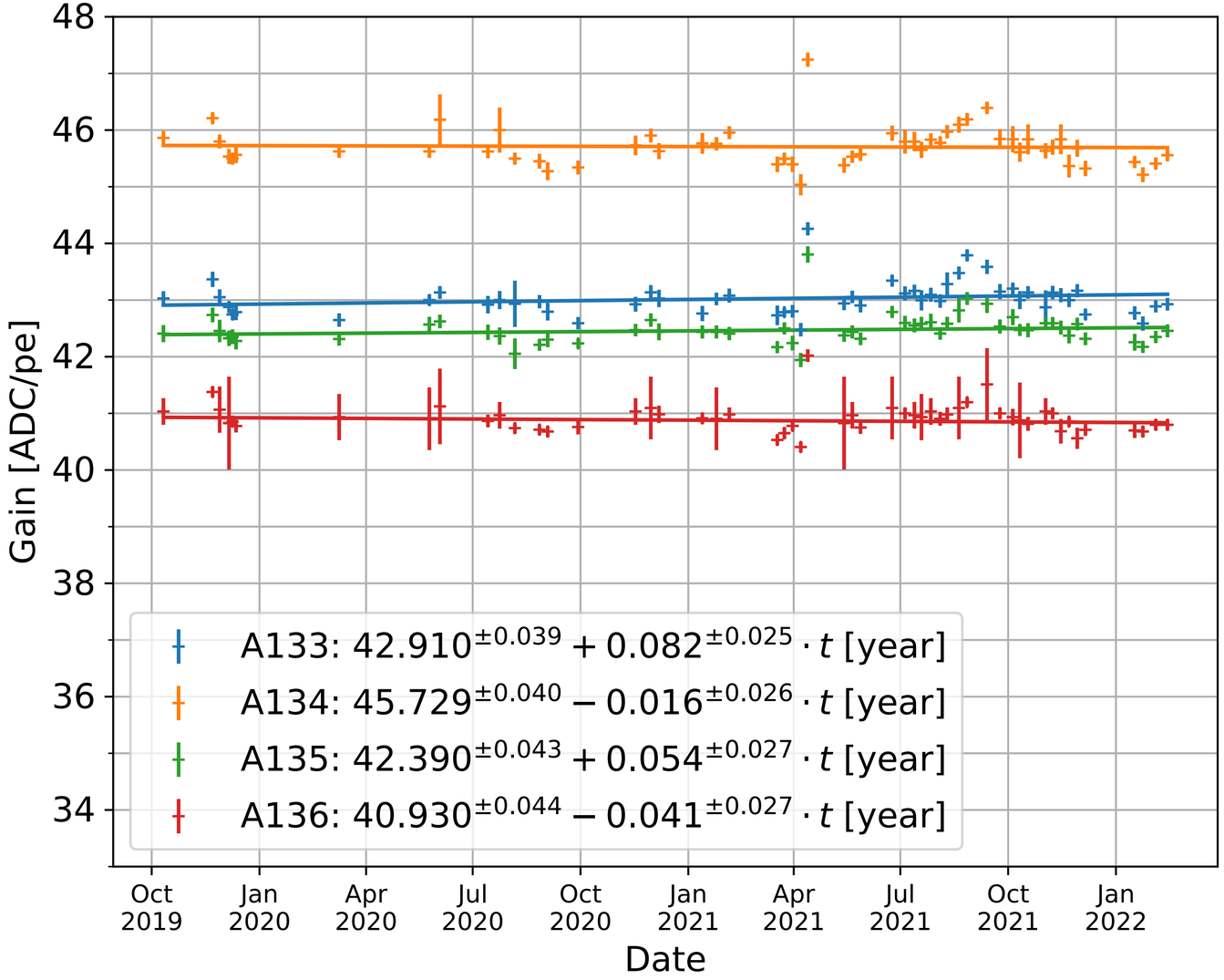
Bottom layer



Top layer

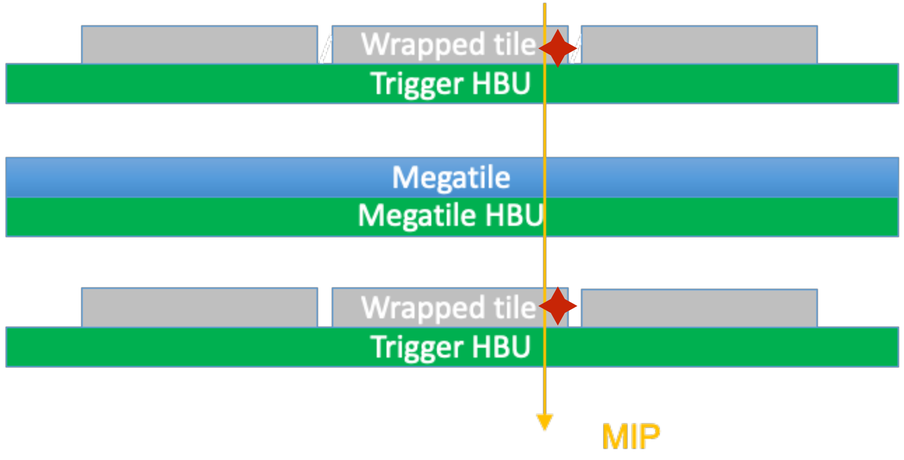


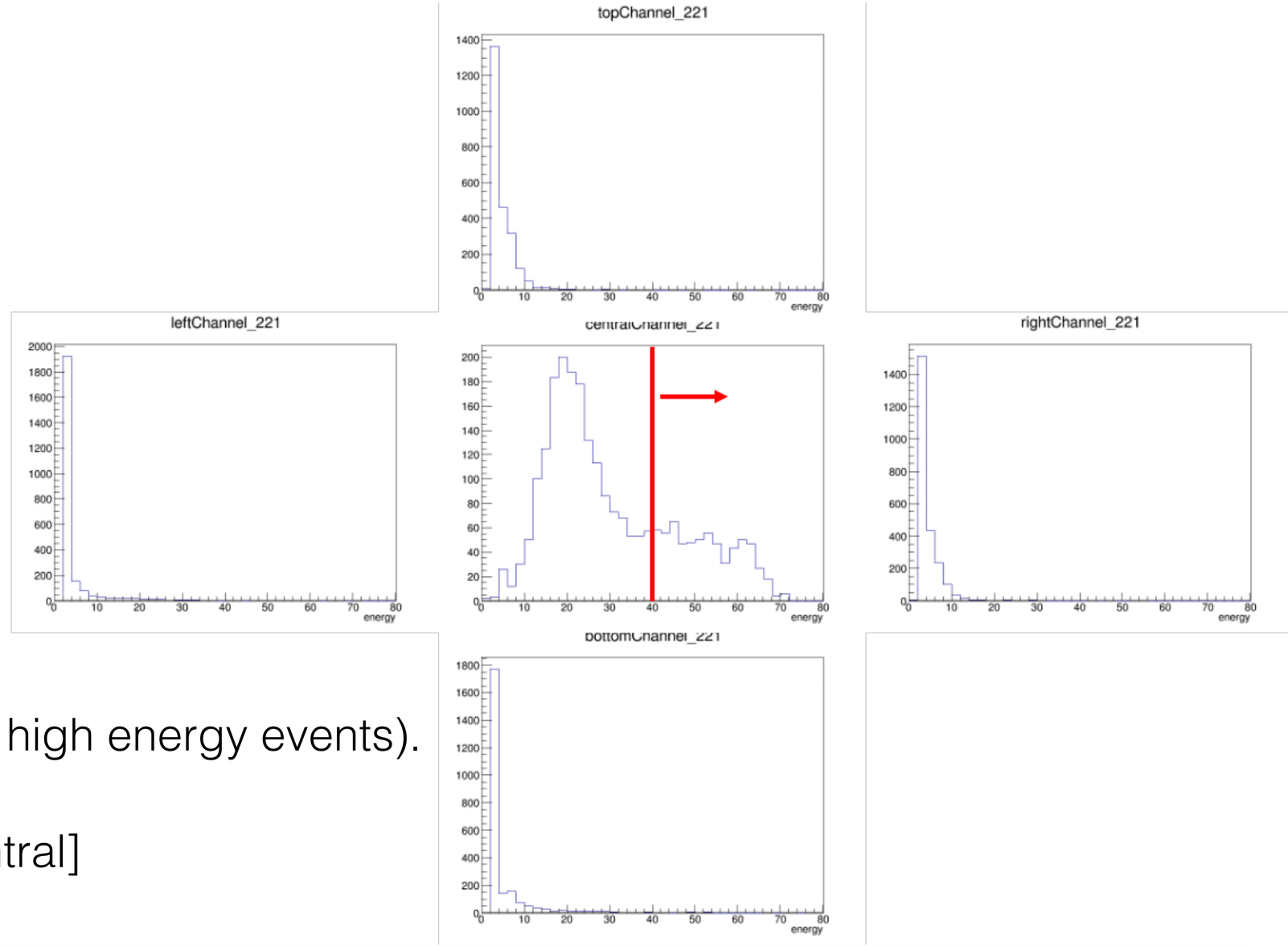
Megatile gain evolution



Cross-talk analysis

1. Central tile defined as Megatile channel aligned with two single tile channels in coincidence.





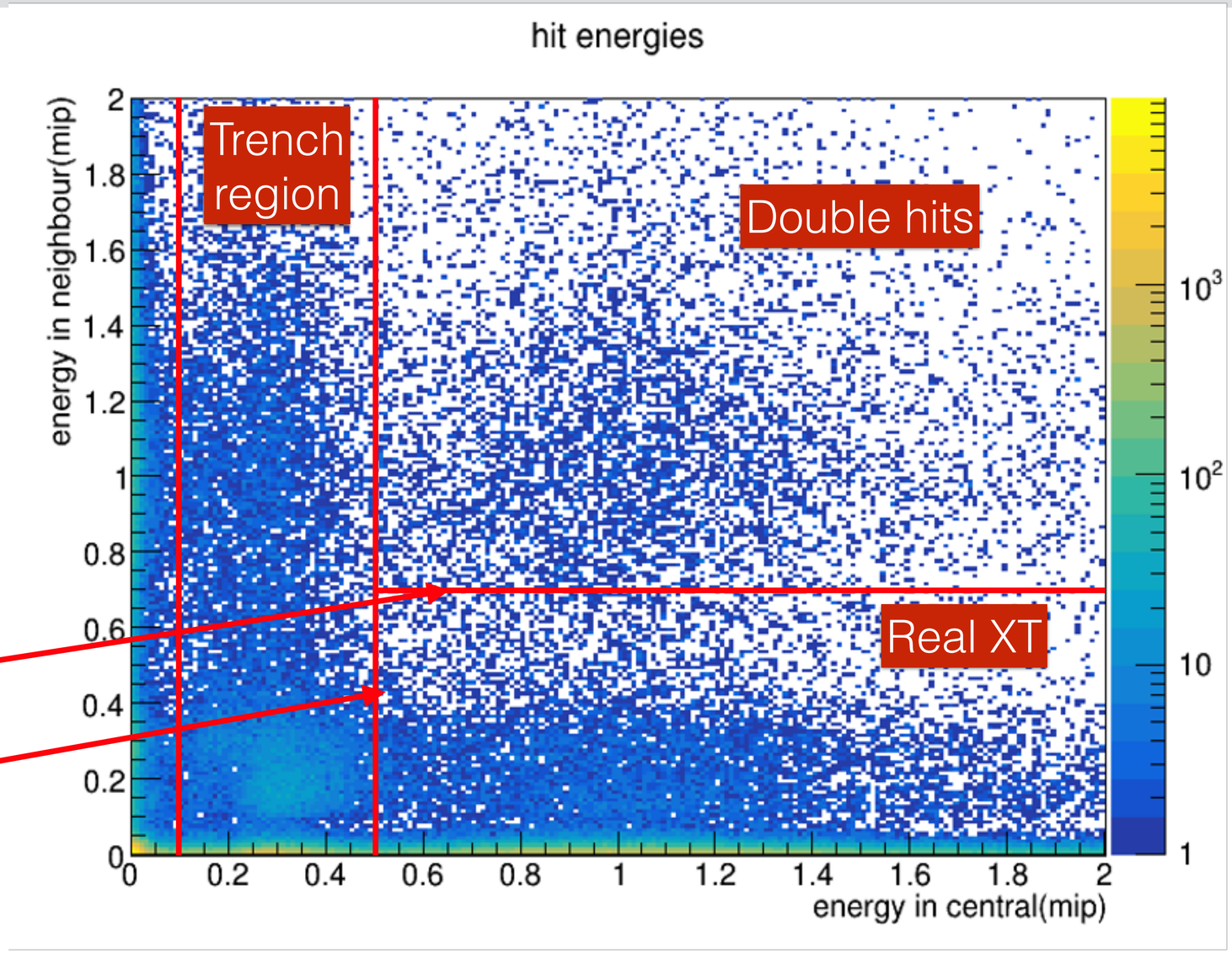
2. Cut on central tile p.e. (select only high energy events).

3. XT < [pe in neighbour] / [pe in central]

Cross-talk analysis

Event selection:

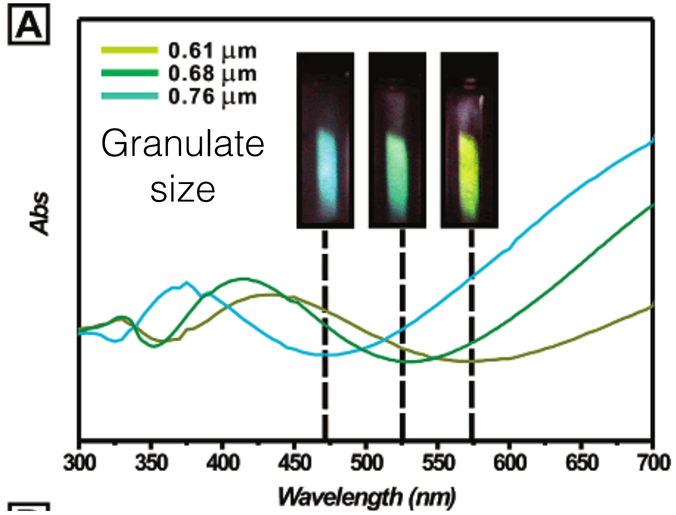
- Exactly 1 hit in each single tile layer.
- Hit energy in single tile layer > 0.7 mip.
- Energy in neighbour < 0.7 mip.
- Energy in central > 0.5 mip.



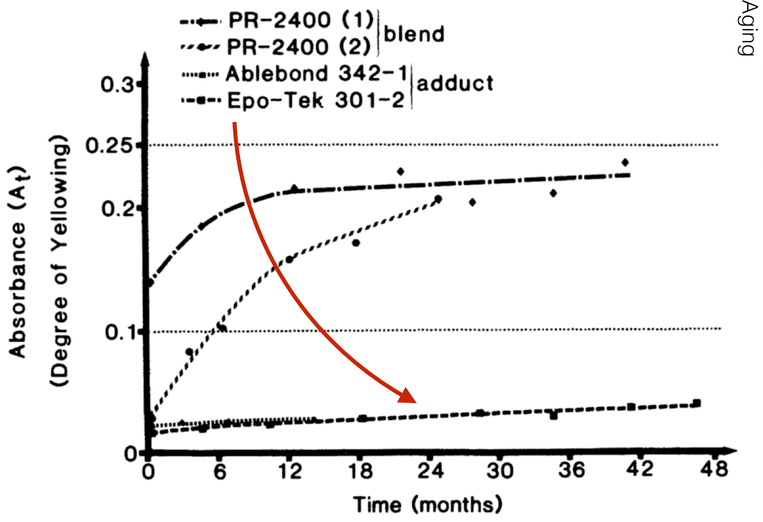
Glue + TiO_2 mixture

- **Light yield depends on** what **glue + TiO_2 mixture** is filled in the trenches:
  - Absorption/reflection vs λ depends on **concentration, size and shape/phase** (rutile vs anatase) **of TiO_2 granulates in the glue**.
- Trade-off:
  - **Liquid enough** to flow in the trenches.
  - Adequate granularity for **reflection** (impact light yield).
- **Tested optical properties** of various Glue + TiO_2 mixtures.
- **Improved in latest prototypes** (good baseline since proto #5).
- Glues are known to **acquire a yellow shade with time**.
  - **Amplified** in presence of **light** (UV) and **additives** (like TiO_2).
  - **Current choice is one with lowest ageing effect** (10% yellowing threshold after > 15 years).

→ Epotek 301-2-**FL**



Min Chiao Tsai et al., J. Phys. Chem. C, Vol. 112, No. 7, 2008
Tailor Made Mie Scattering Color Filters Made by Size-Tunable Titanium Dioxide Particles



Jane L. Down, Studies in Conservation Vol. 29 No. 2 (1984)
The Yellowing of Epoxy Resin Adhesives: Report on Natural Dark Aging