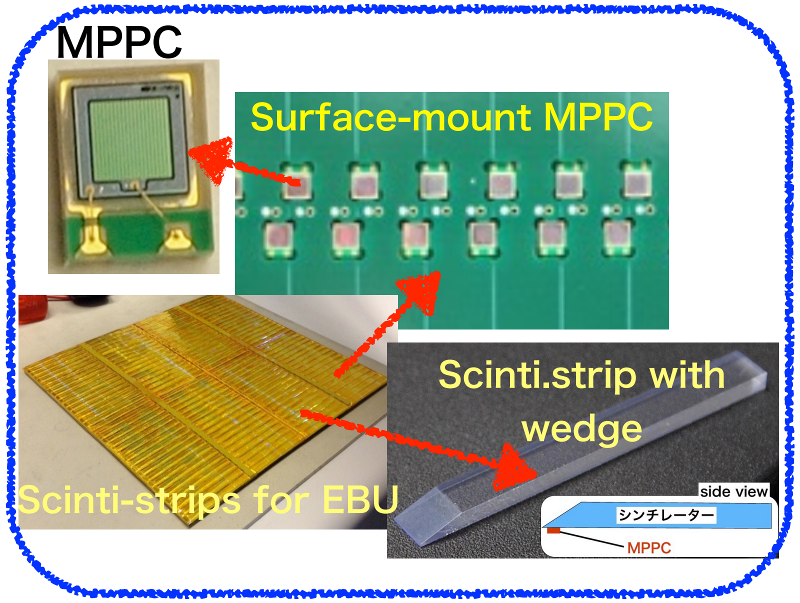
AHCAL Activities in Tokyo

W. Ootani
ICEPP, University of Tokyo

CALICE Collaboration Meeting
Sep. 9-11, 2015 MPP Munich

Scintillator Calorimeter Activities at ICEPP

- Members
  - Prof. Sachio Komamiya
  - Prof. Toshinori Mori
  - Prof. Satoru Yamashita
  - WO
  - Students: Sei Ieki, Naoya Shibata, and some more
- Scintillator ECAL
  - Wedge-shape scintillator strip with surface-mount SiPM
- Scintillator HCAL (AHCAL)
  - Starting recently
  - Optimisation of SiPM optical readout
  - Test with HBU
- SiPM R&D
  - with a close collaboration with Hamamatsu
    ex.) Development of VUV-sensitive MPPC (12×12mm^2) for MEG LXe detector
- Scintillator material R&D
- Radiation hardness for SiPM/scintillator
- Development of scheme for mass test/mass production



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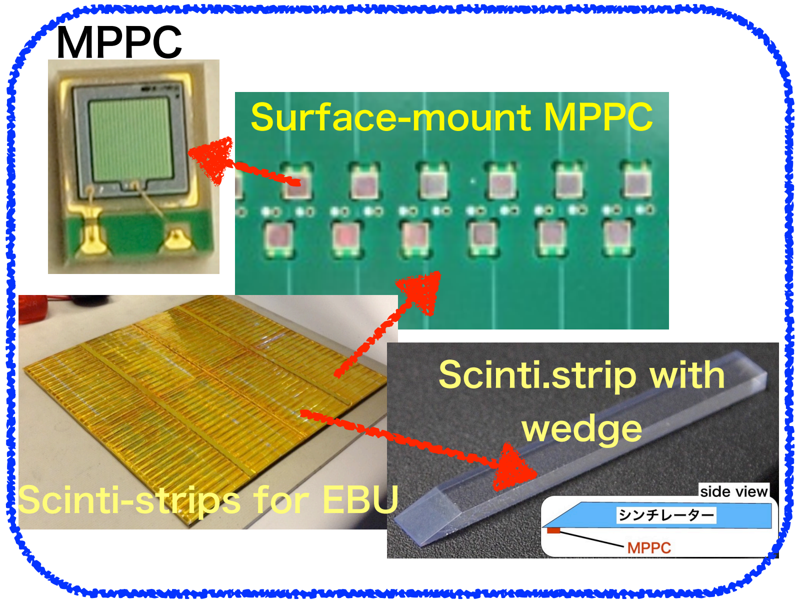


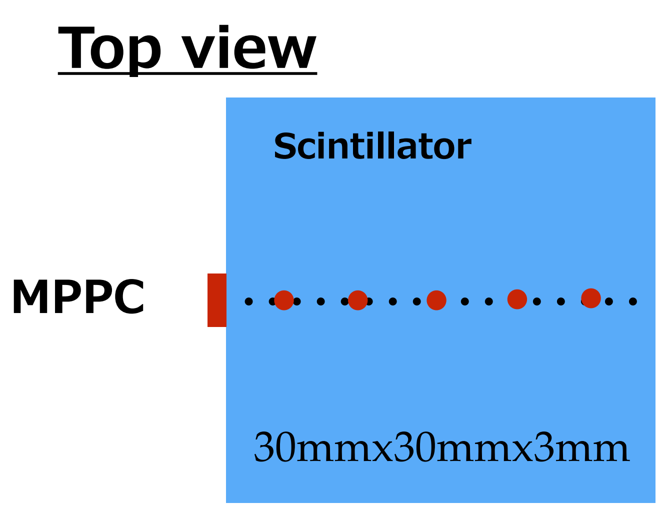
Study on Scintillator Material

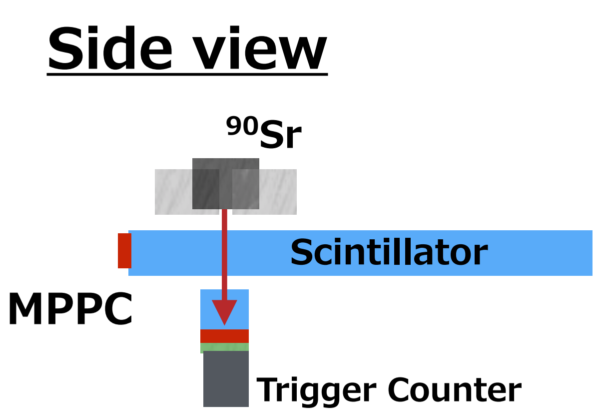
- Typical plastic scintillator materials
  - Poly-vinyl toluene (PVT):
    - Higher light yield 😊
    - Production (casting + machining) is cumbersome. 😥
  - Polystyrene (PS), Estyrene-MS (MS)
    - Moderate light yield 😐
    - Production (injection moulding) is easier. 😊

- We are working on development of plastic scintillator material of better performance especially for PS/MS.
- Light yield was measured with AHCAL cell configuration

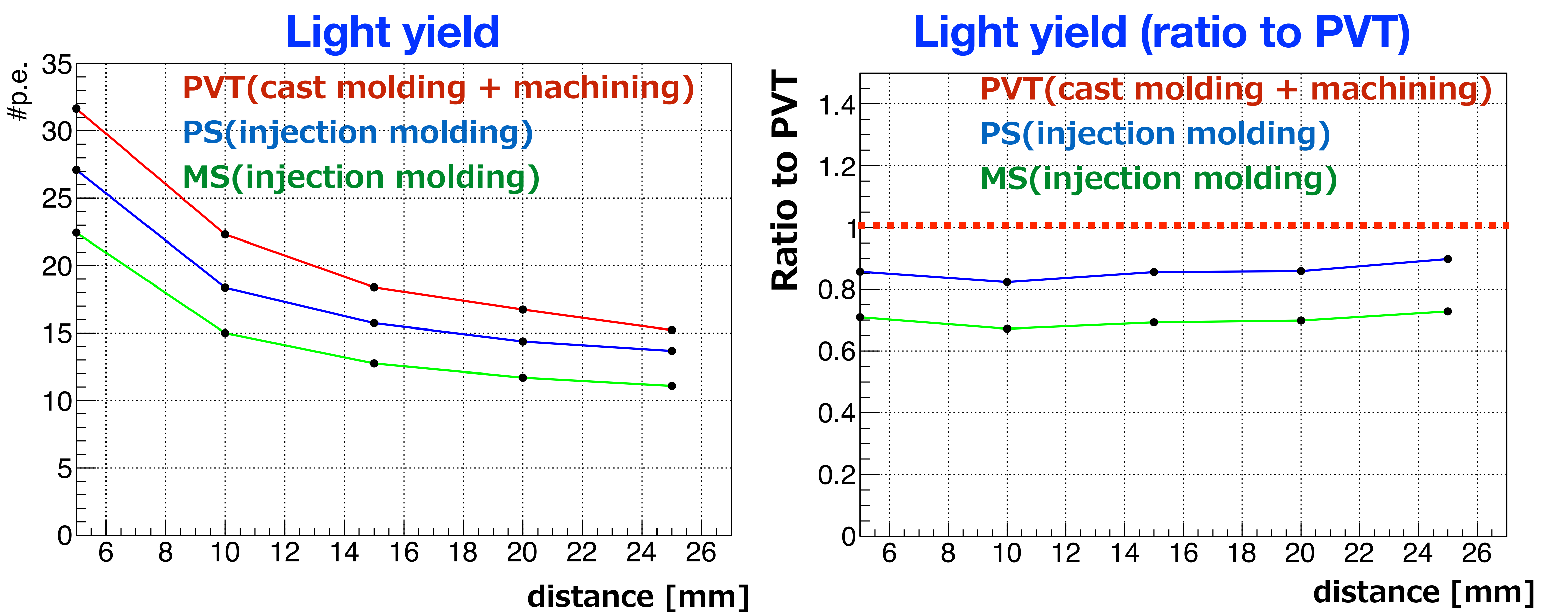
Light Yield Measurement

- Setup
  - Scintillator plate: 30×30×3 mm^3
    - PVT:
      - Eljen EJ-212 (cast moulding)
      - Machining/polishing
    - PS, MS:
      - Cut out from 3mm-thick large plate produced by injection moulding, polished only at edge sides
  - MPPC: S12571-025P (1×1mm^2, 25μm cell pitch)
  - Collimated β from Sr-90 (E<2.2MeV) + trigger counter on the other side





Light Yield Measurement



- PVT shows the highest light yield (as expected).
- The light yield of PS is still reasonably high. 80-90% of PVT
  - PS can also be a good candidate material.
- No visible difference in position dependence.

  →No significant difference in both reflection and attenuation
- Further optimisation of ingredient of PS/MS is planned to maximise light yield.

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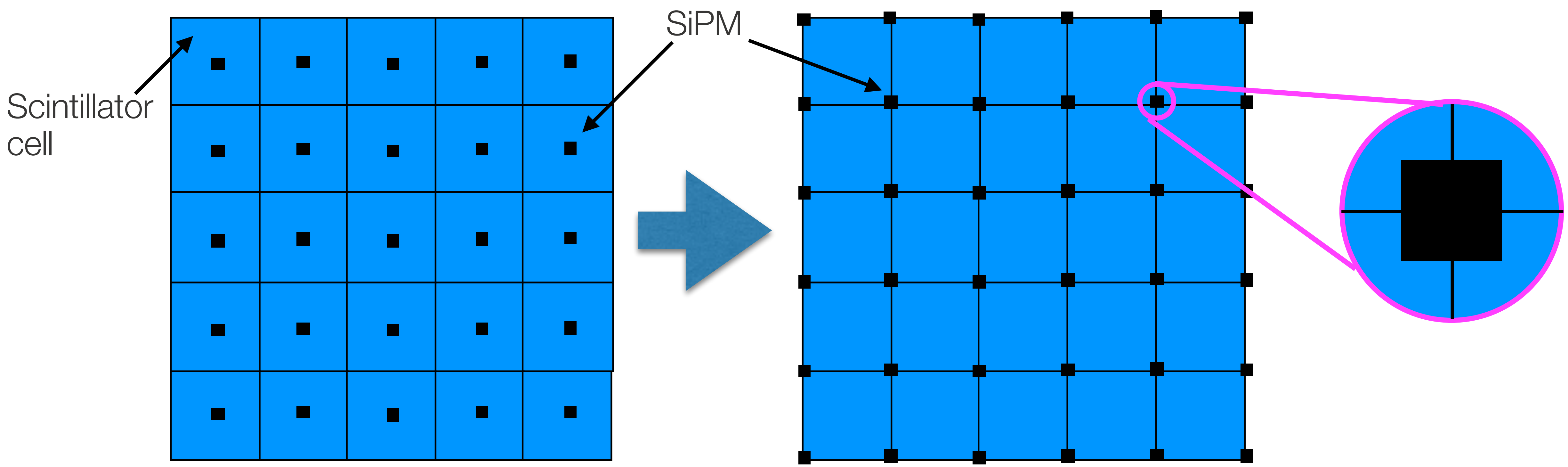
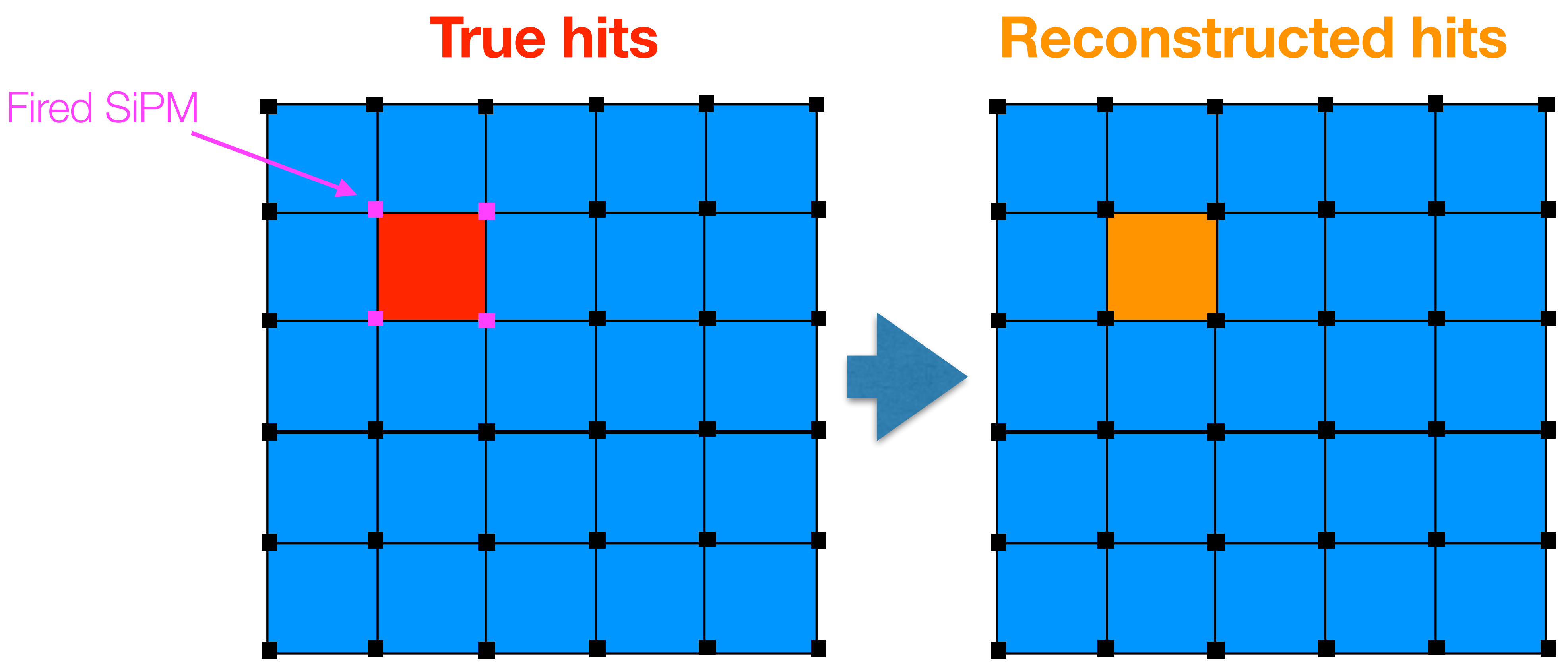
New Optical Readout Scheme

- A new optical readout scheme is under study as another possibility for surface-mount SiPM readout.
- "Four-corners readout"
  - SiPMs are located at vertices of scintillator cells and detect scintillation light from four adjacent cells.
  - Each SiPM is shared by four adjacent cells.
  - Cell hit is defined by taking a coincidence on four SiPMs belonging to the cell.
  - SiPM charge is split to hit cells if shared by adjacent cell.



How It Works

- Reconstruction of cell hit and cell charge
  - Cell hit is defined by taking a coincidence on four SiPMs belonging to the cell.
  - Cell charge is reconstructed by
    - Summing up charges for four SiPMs
    - If SiPM is shared by adjacent cell hits, SiPM charge is split to hit cells.



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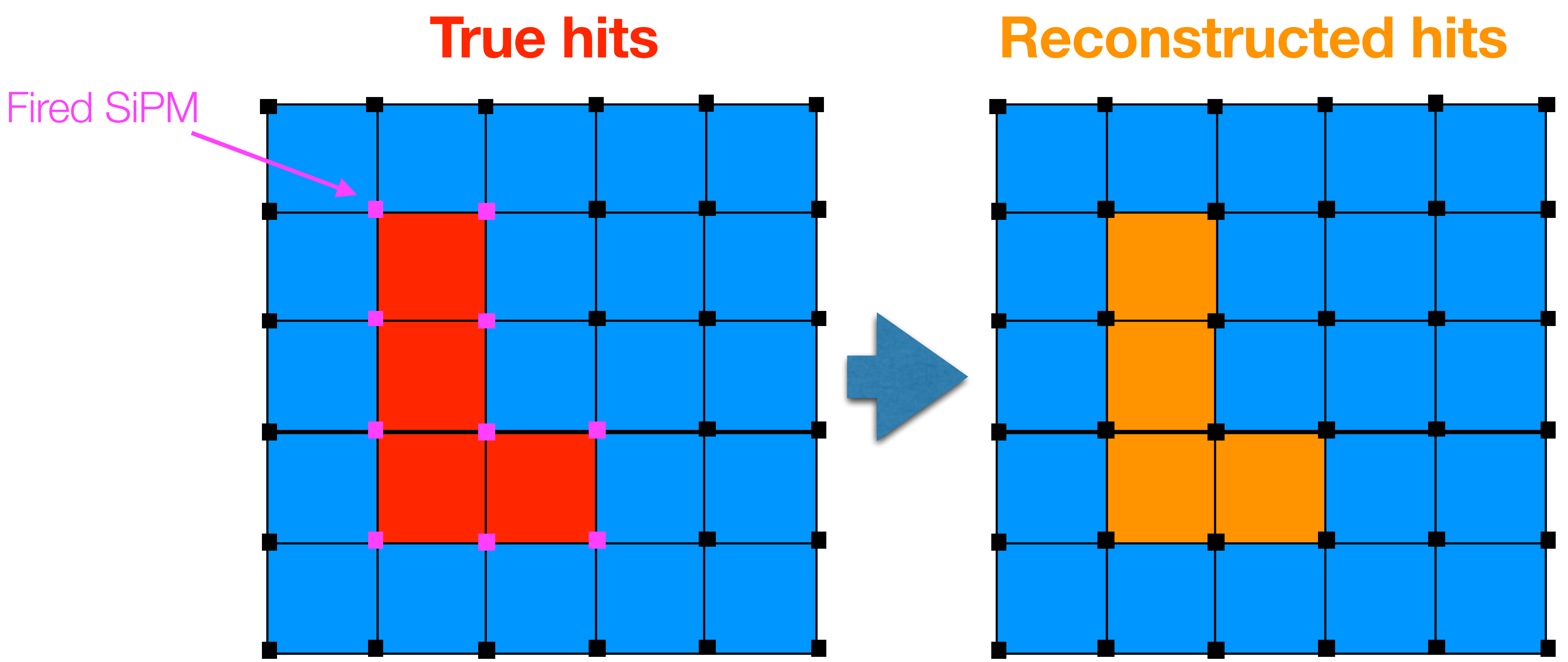

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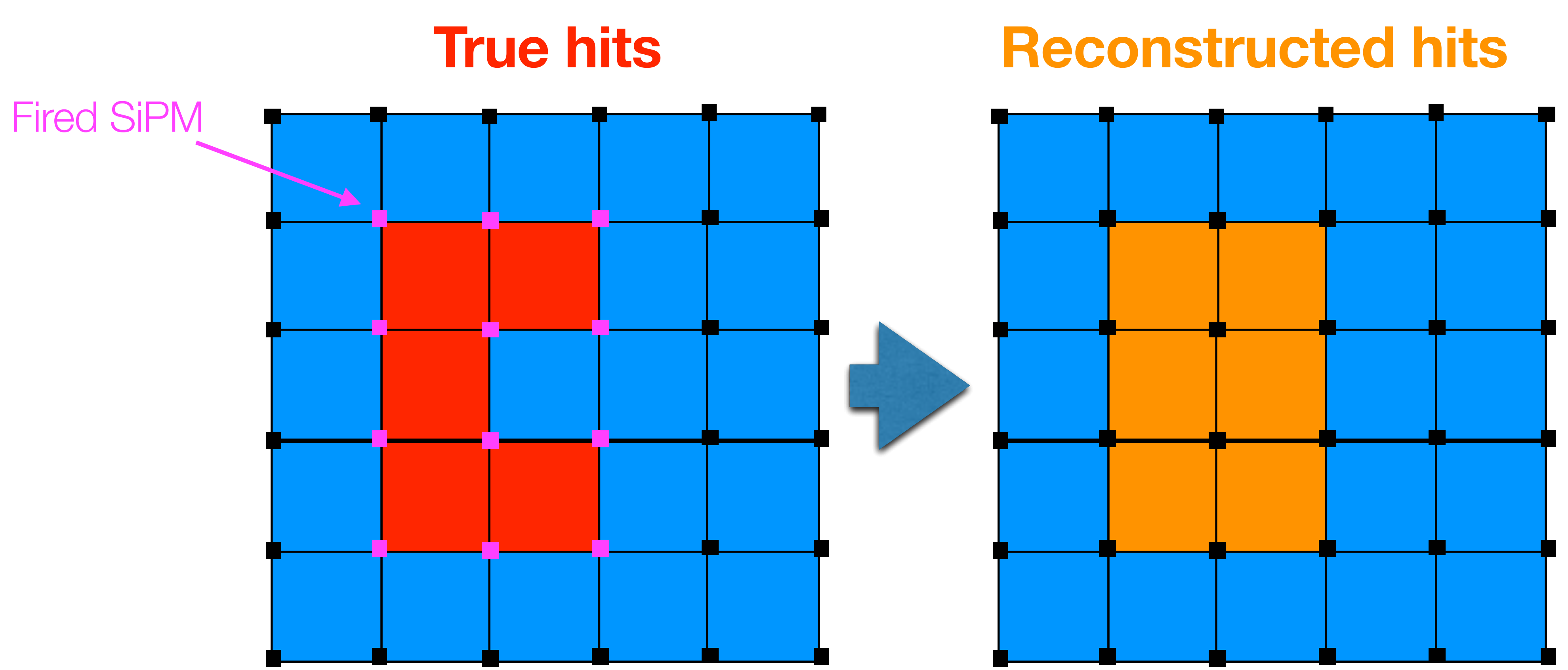

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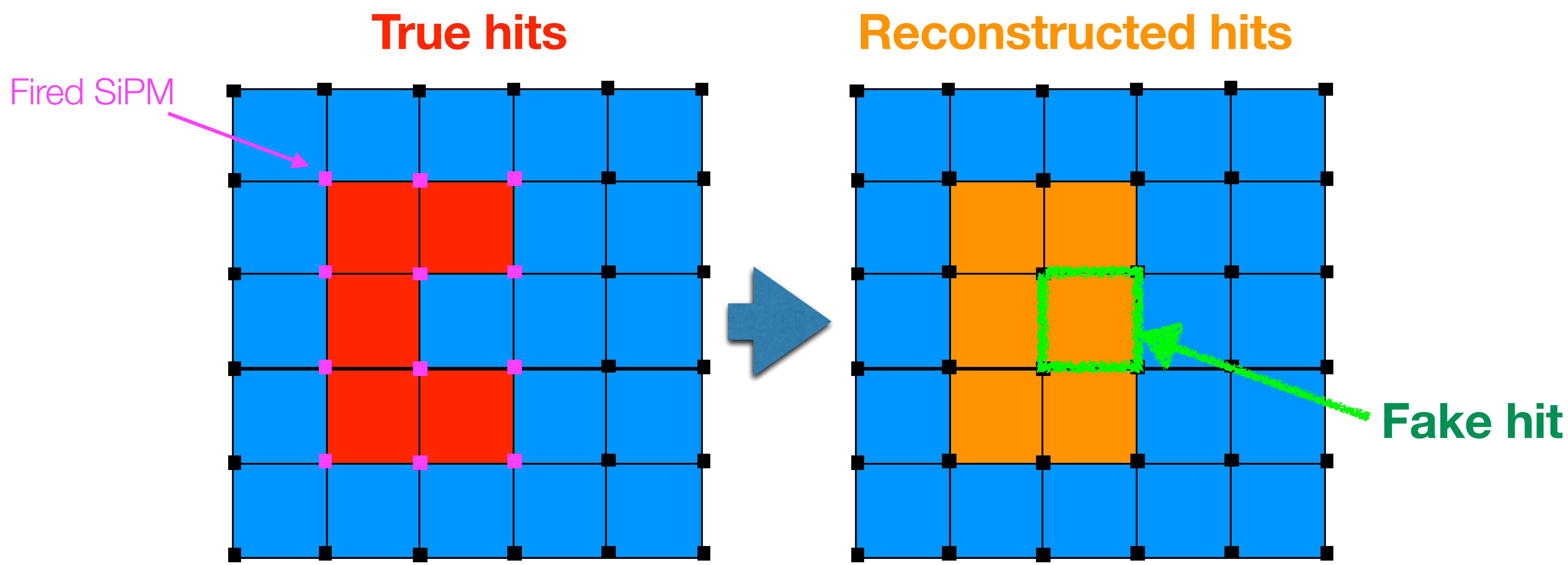


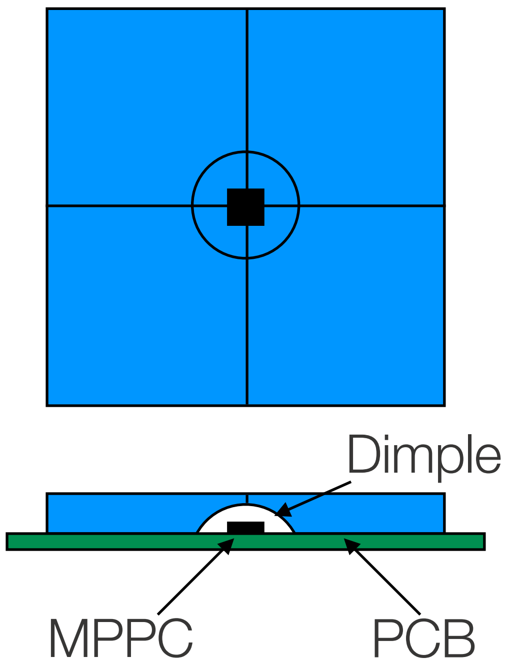
Pros & Cons

- Possible advantages
  - Random hit due to dark noise and electric noise of SiPM is highly suppressed by taking coincidence on SiPMs at four vertices (quad coincidence!)
  - Better uniformity of inside-cell response
  - Higher light yield
  - Cell is still operational even with dead SiPM channel(s)
  - # of calibration LEDs can be reduced. Each SiPM can be calibrated using any of four cell to which the SiPM belongs.
- Possible issues
  - Smearing of cluster due to fake cell hit surrounded by true hit cells
  - How to split charge to adjacent hit cells.
  - Light leakage to neighbouring cell
  - Increase of total number of SiPMs
  - How to implement the scheme?

Possible Implementation

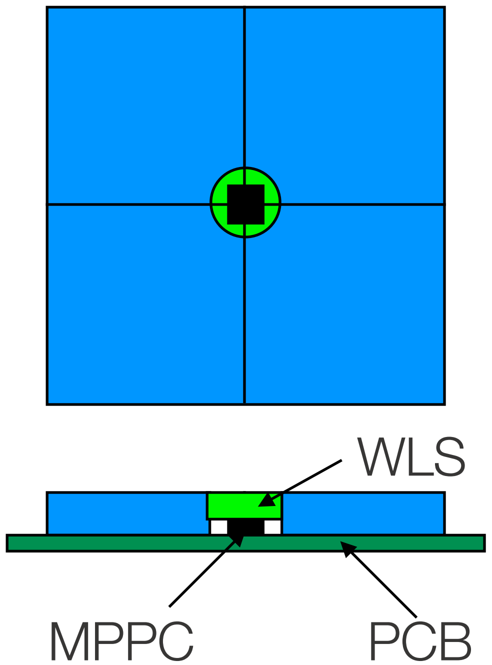
- Possible optical coupling of SiPM + Scintillator at cell vertex

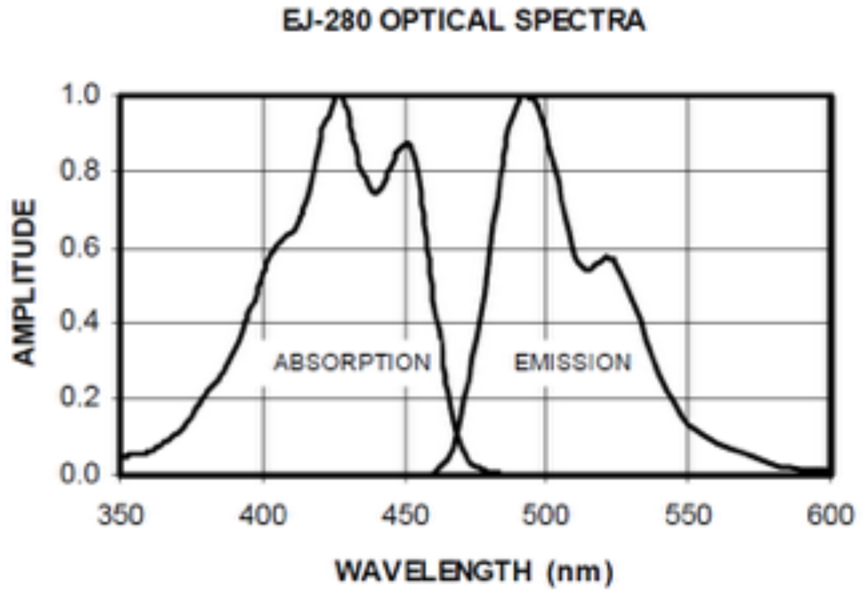
Dimple at vertex



- Easier assembly
- Larger cross-talk?

Wavelength shifter (WLS) at vertex





- Complicated assembly
- Less cross-talk?
- Higher light yield?
- Dead region (~1%)

no absorption (and emission) of light from WLS at neighbouring cell

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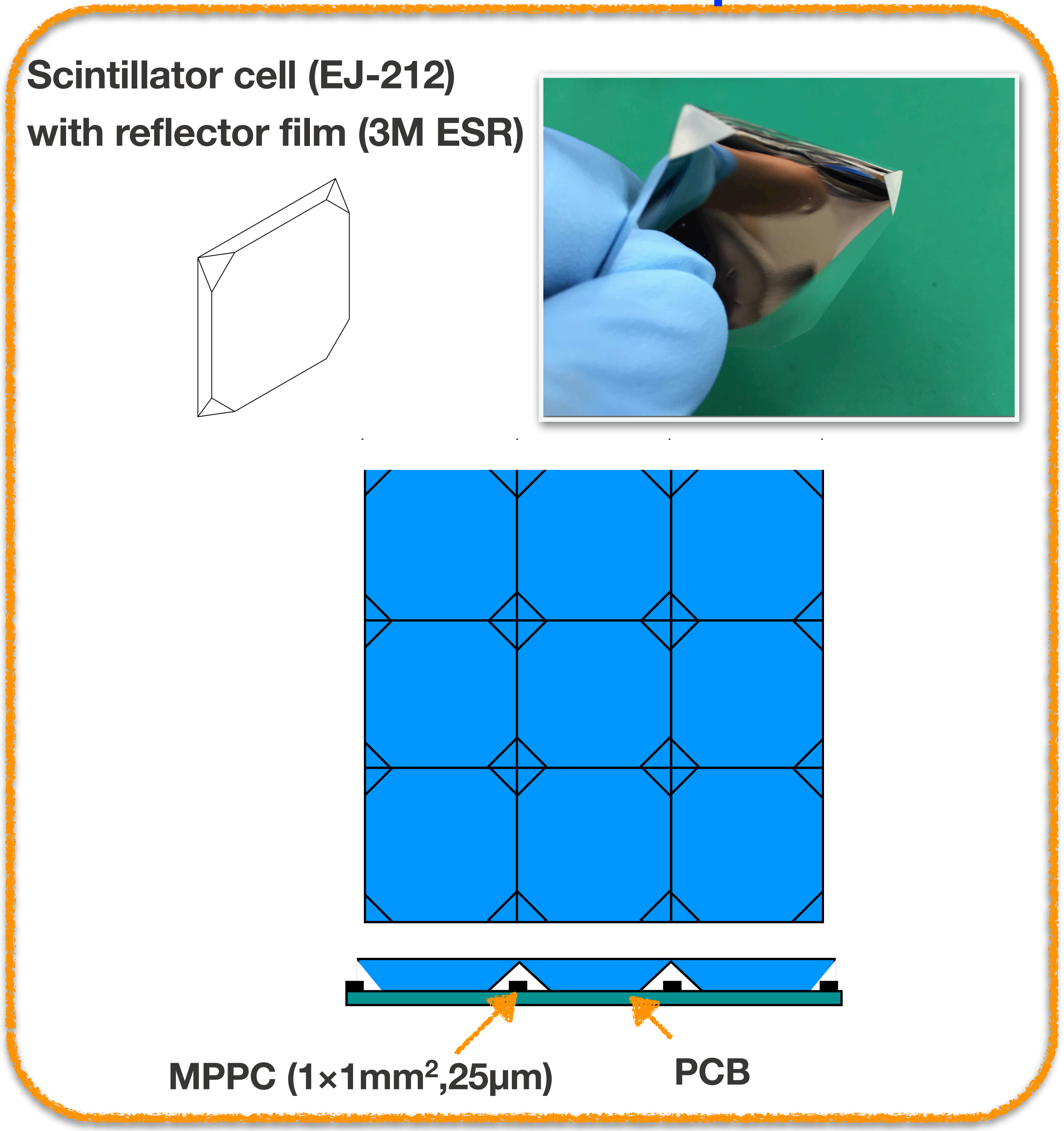
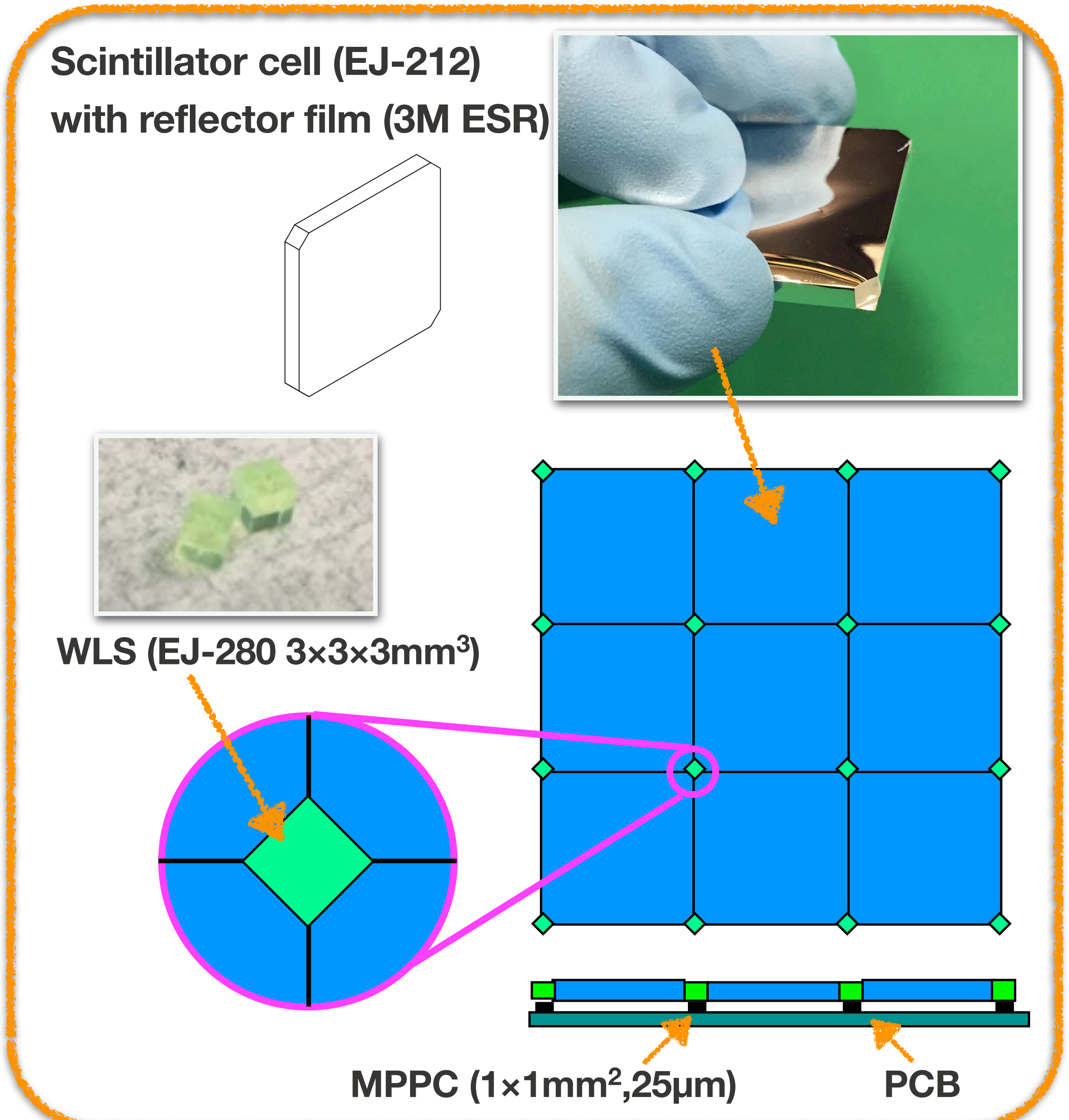
Prototype Test: Setup

- Two cell geometries were tested.

Corner cut to form “dimple”

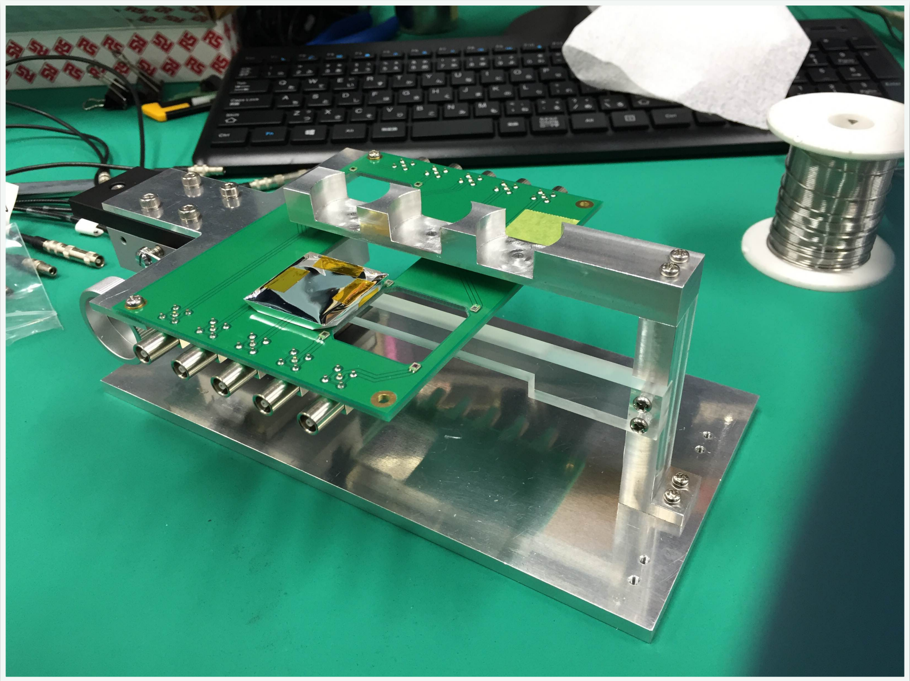


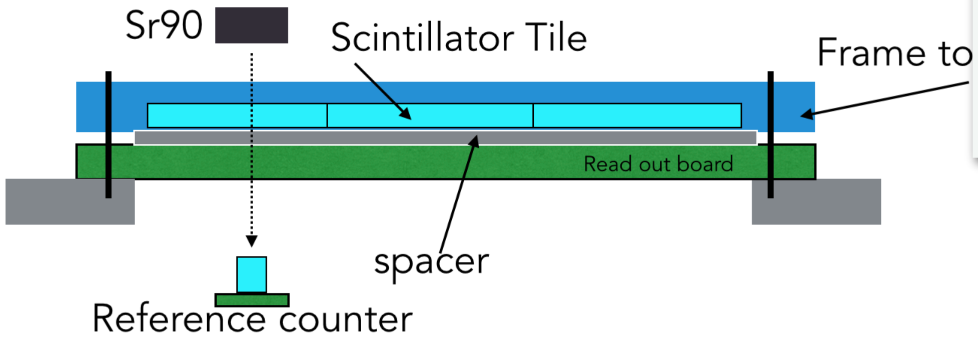
WLS



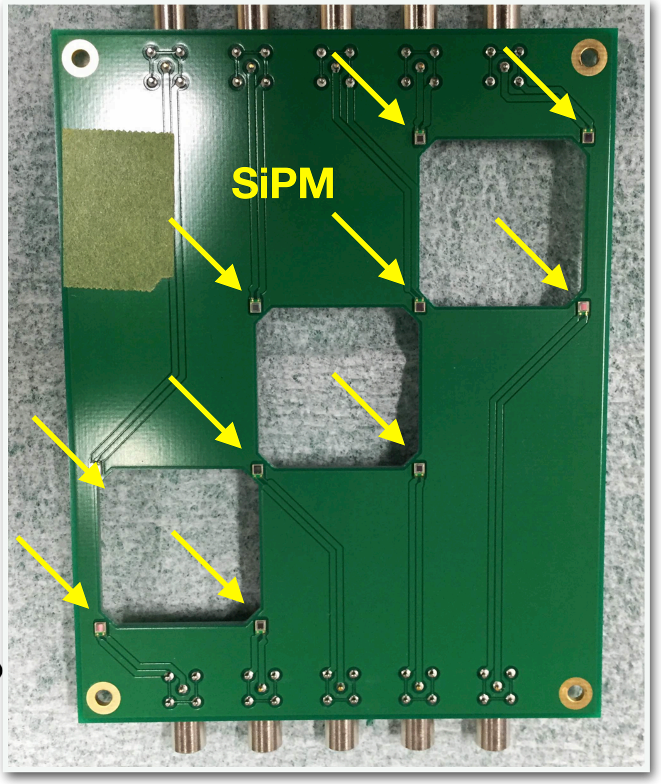
Prototype Test: Setup

- Test PCB with surface-mount SiPM
  - 9 × scintillator cells + 10 × SiPMs on PCB
  - SiPM: MPPC S12571-025P (1×1mm^2, 25μm cell pitch)
  - Scintillator: EJ-212, 30×30×3mm^3

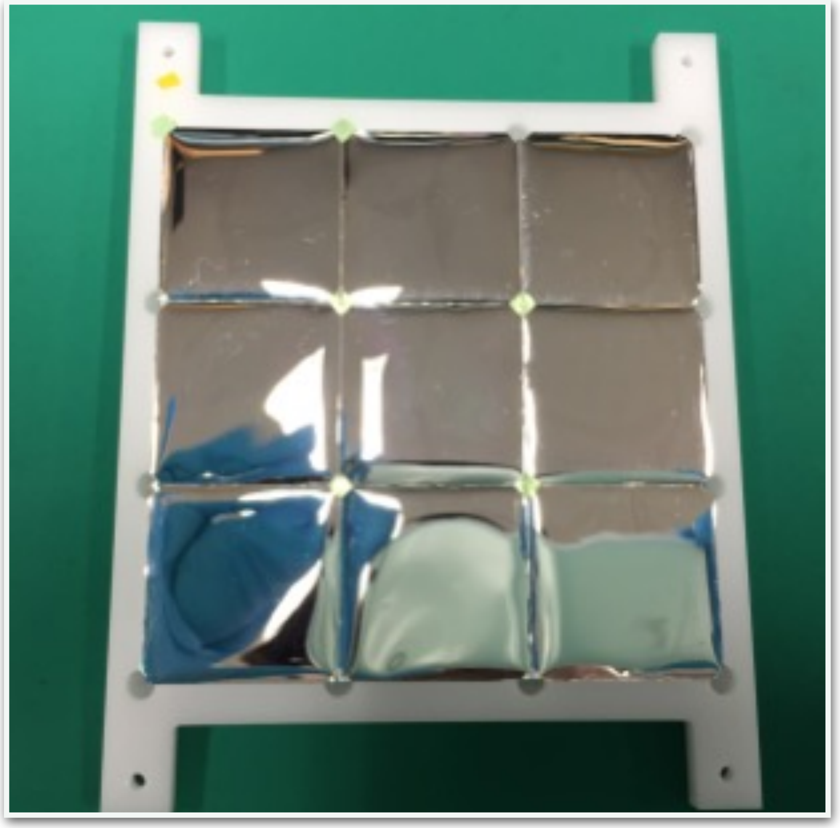




PCB with surface-mount SiPMs



3×3 scintillator cells with WLS in a plastic frame



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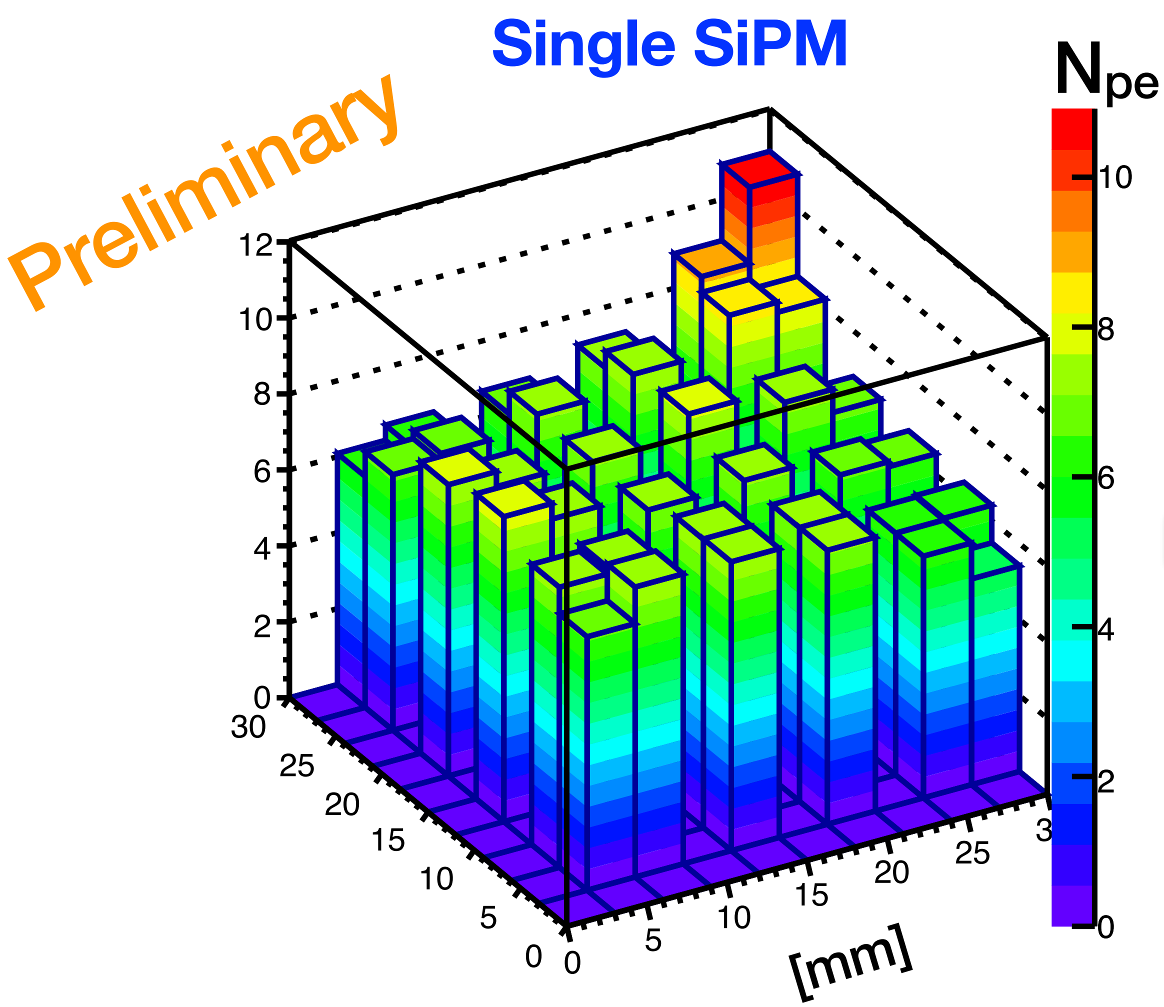
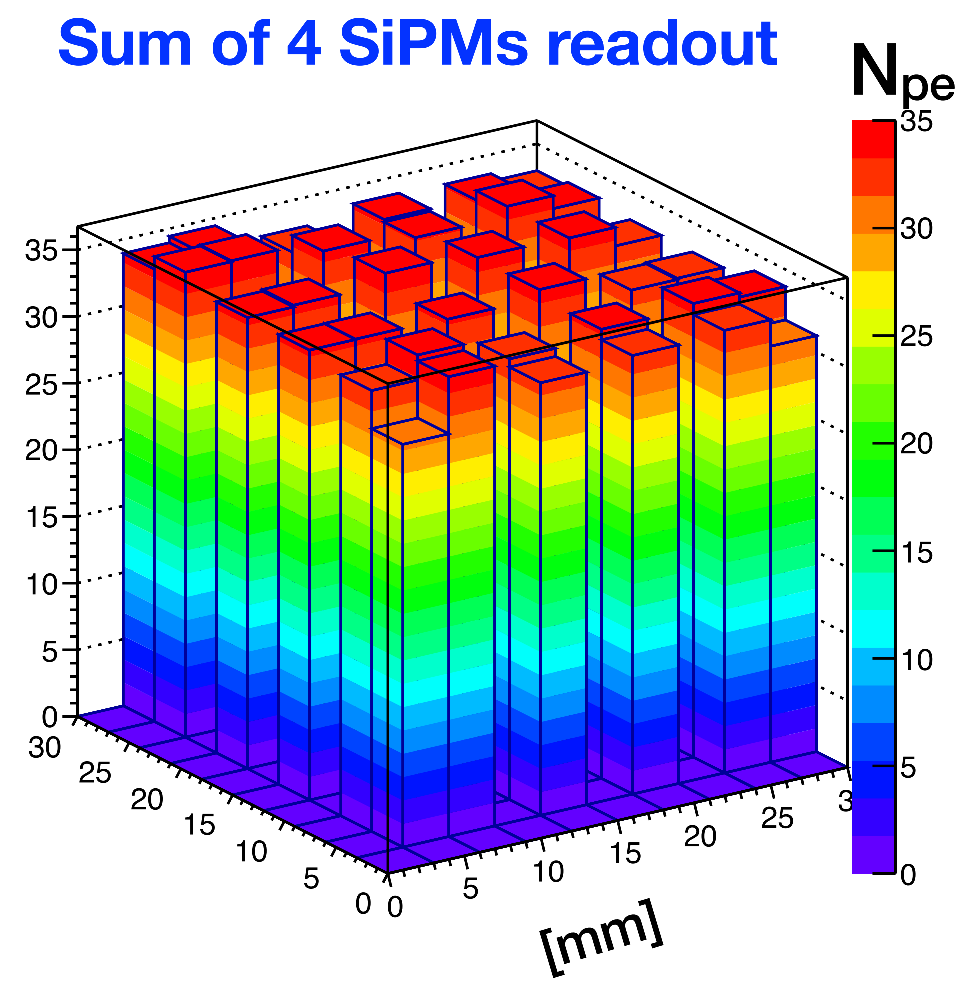
Light Yield (Dimple)

- Excellent uniformity when summing up four corner readouts
- Light yield: 30-35pe for 4 SiPMs readout





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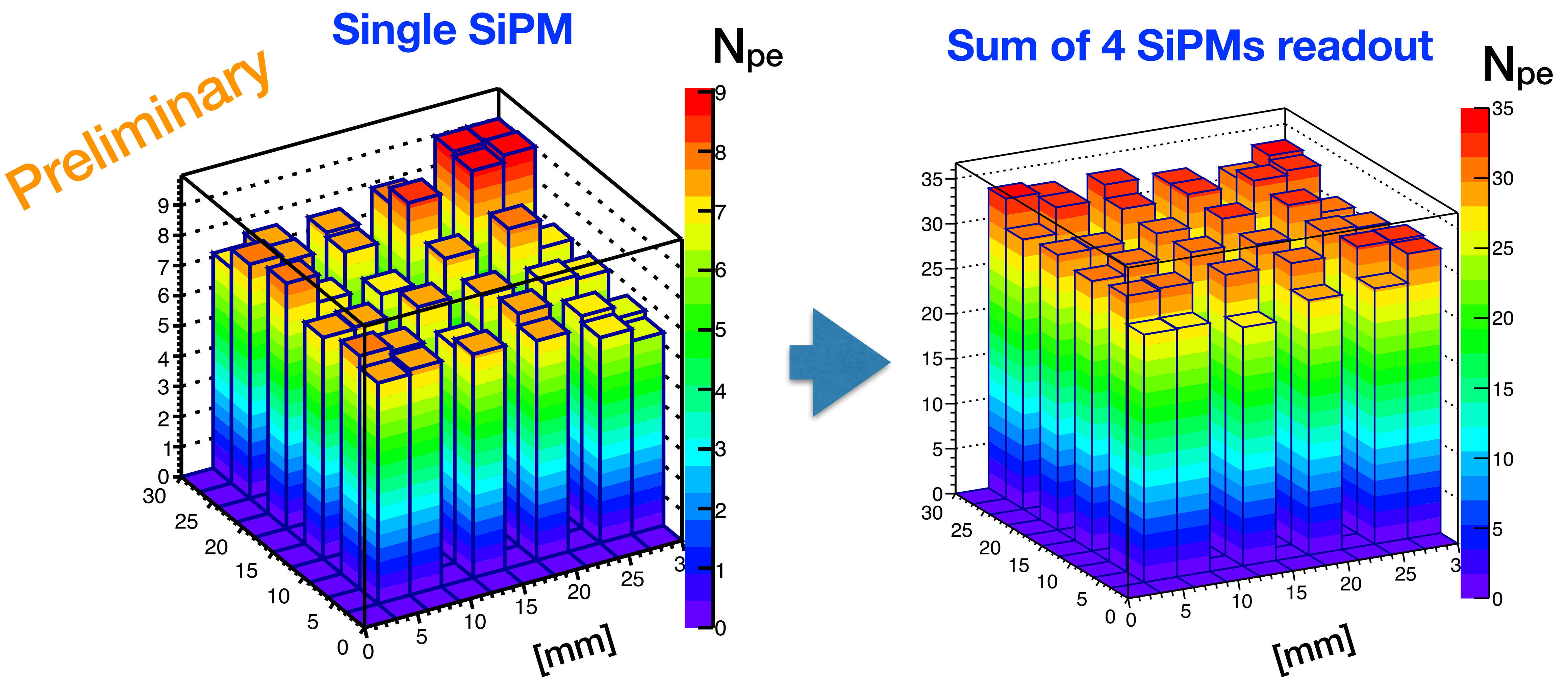
Light Yield (WLS)

- Excellent uniformity with four corner readout
- Light yield: 27-33pe for 4 SiPMs readout



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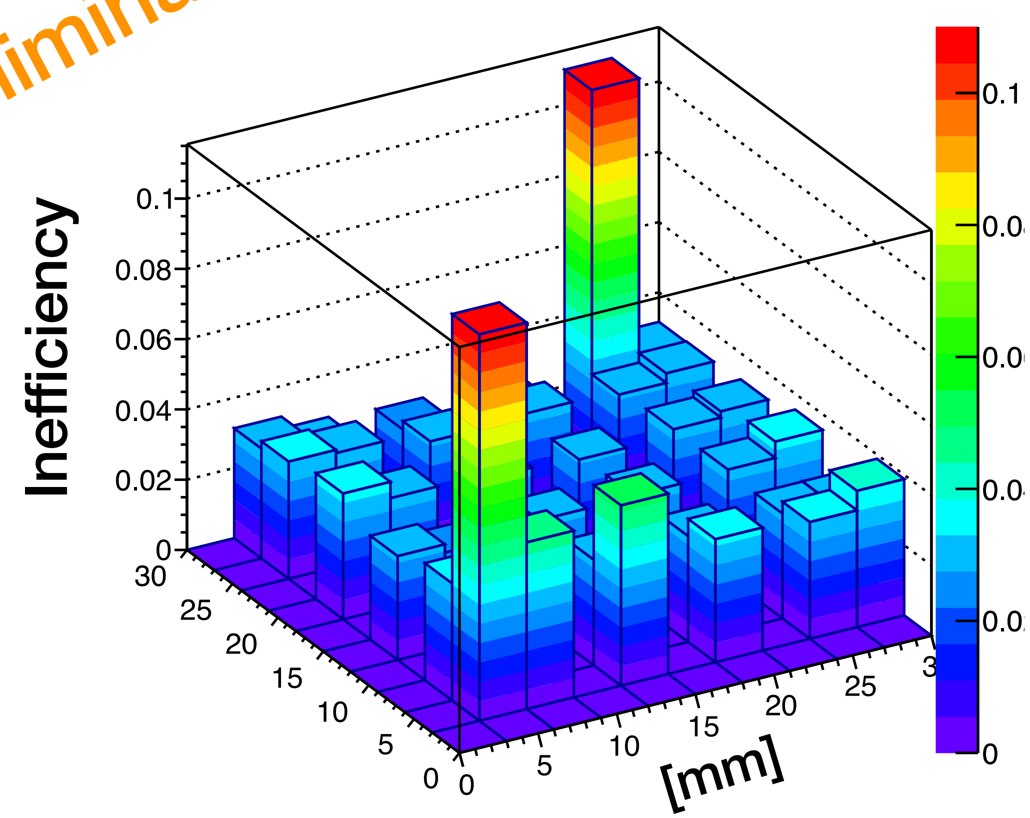
Inefficiency

- Small chance of N_{pe}=0 at each SiPM if light yield is moderate. No hit is defined when taking a coincidence in this case. → inefficiency!
- Measured inefficiency ~ a few %
- Can be mitigated with improvement of light yield or higher threshold for coincidence. Note that optical coupling is not optimised yet.

Preliminary

WLS



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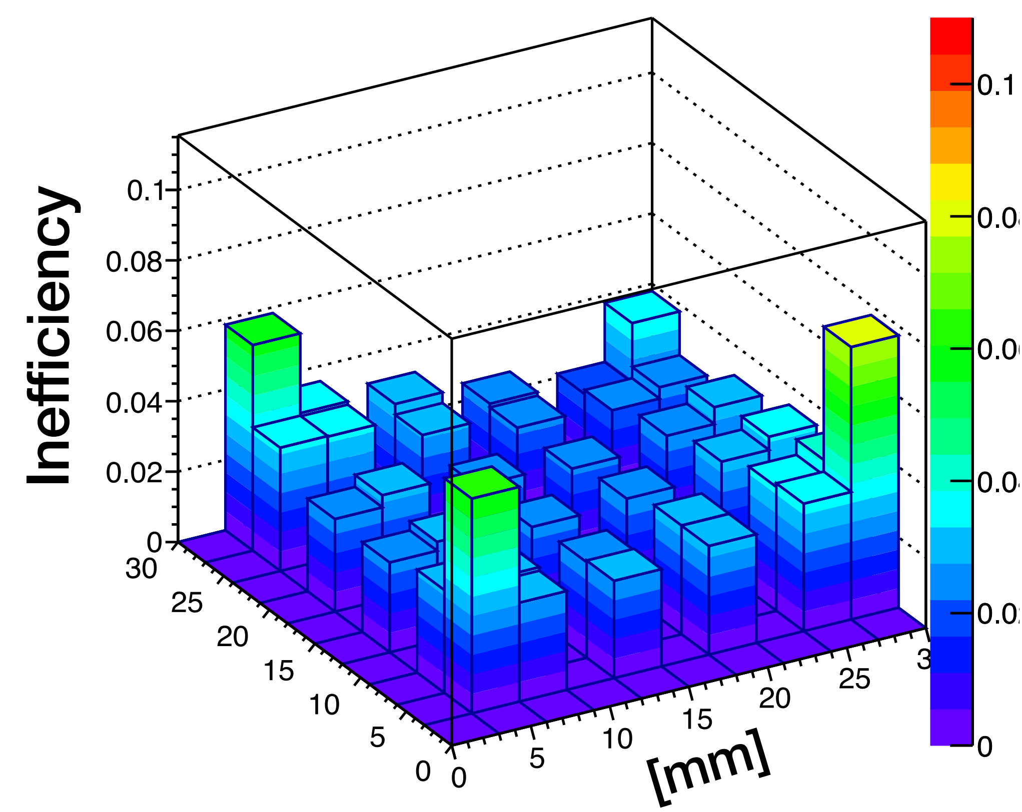

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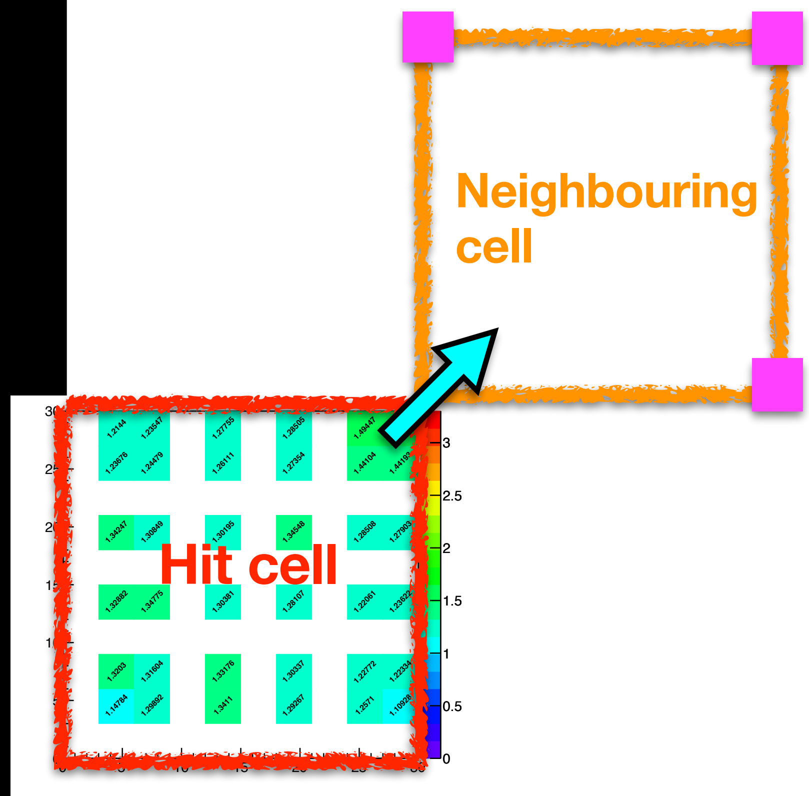
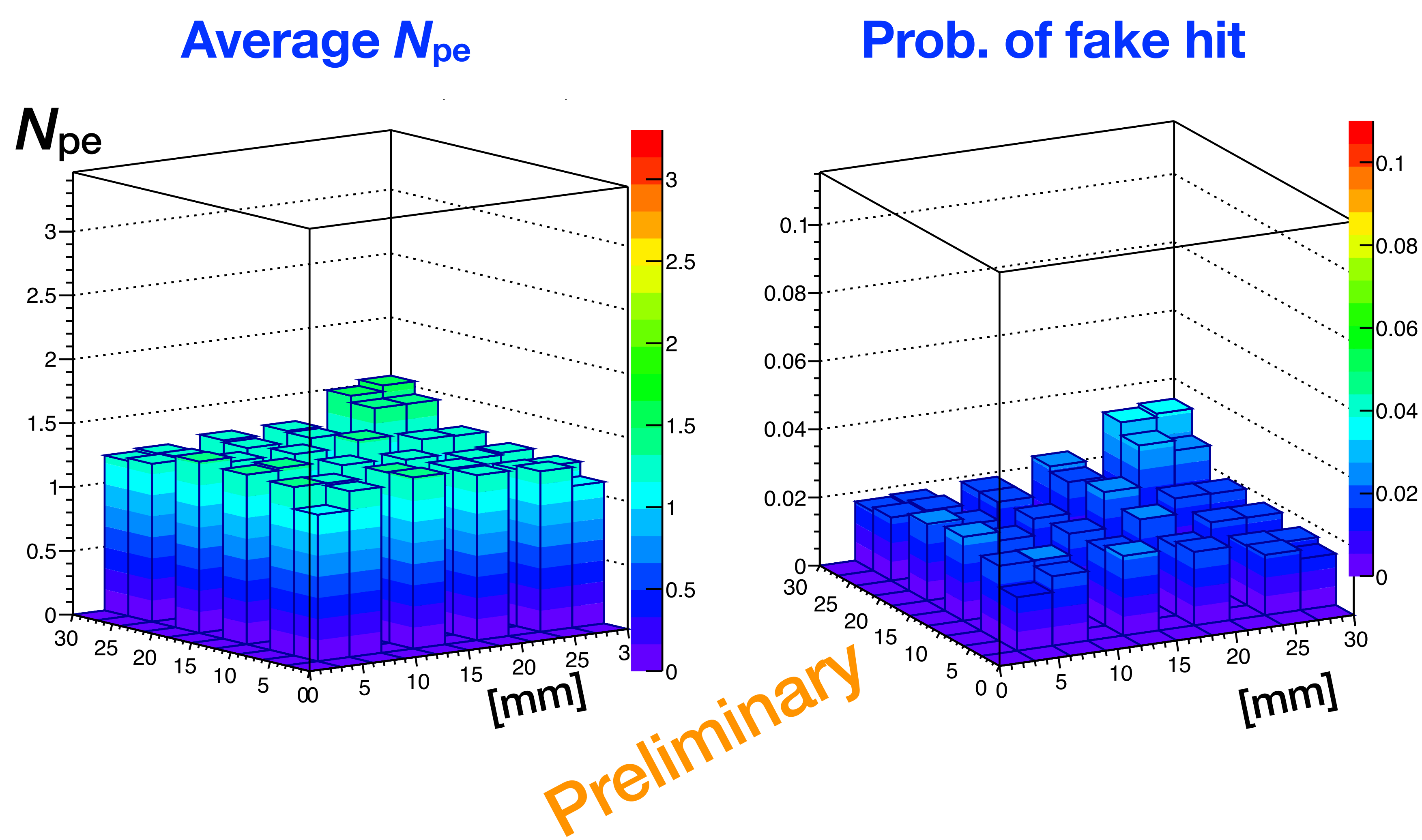
Cross-talk (Dimple)

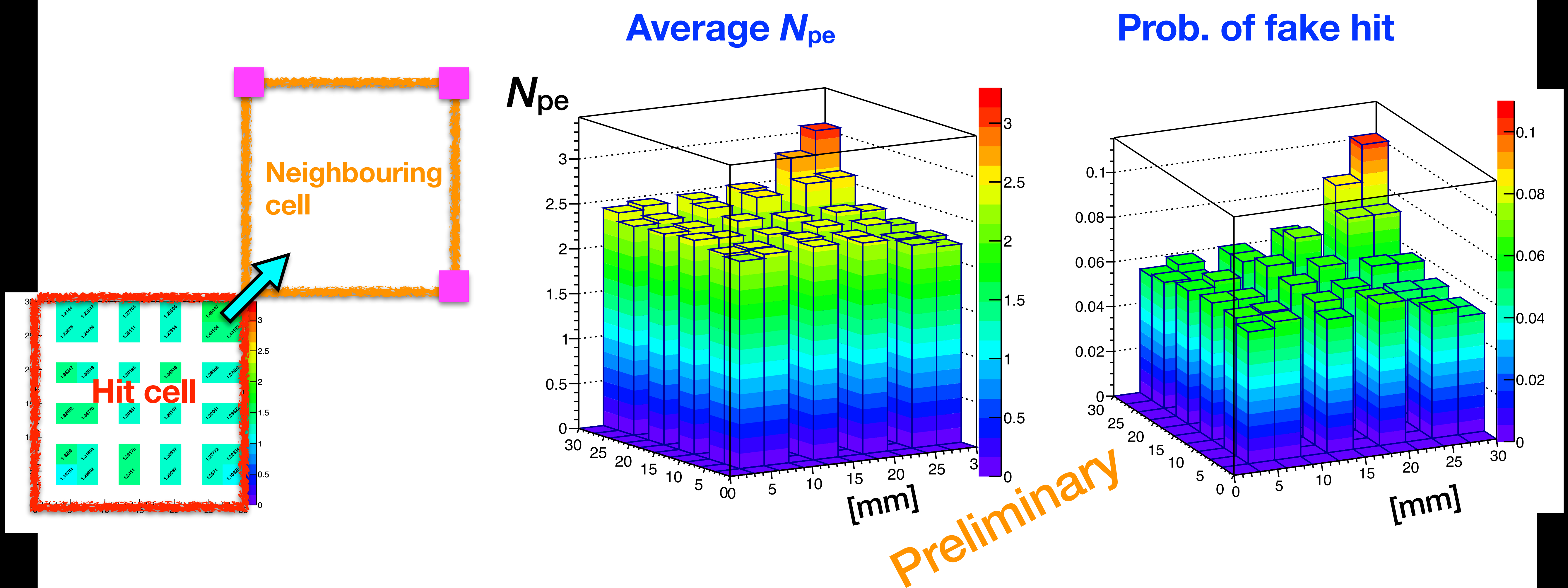
- Light leakage from hit cell to neighbouring cell was measured.
  - Sum of # of p.e. detected at three SiPMs in neighbouring cell ~1p.e.
  - Probability of fake hit at neighbouring cell triggered by light leakage (when taking quad coincidence) ~2%





Cross-talk (WLS)

- Light leakage from hit cell to neighbouring cell was measured.
  - Sum of # of p.e. detected at three SiPMs in neighbouring cell ~2.5 p.e.
  - Probability of fake hit at neighbouring cell triggered by light leakage (when taking quad coincidence) ~5%



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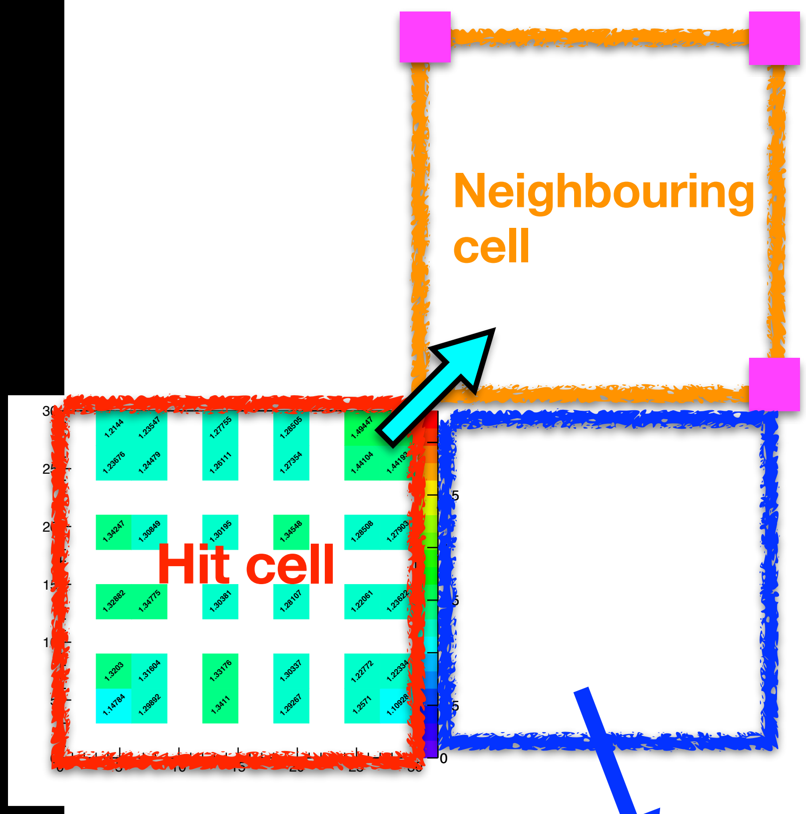
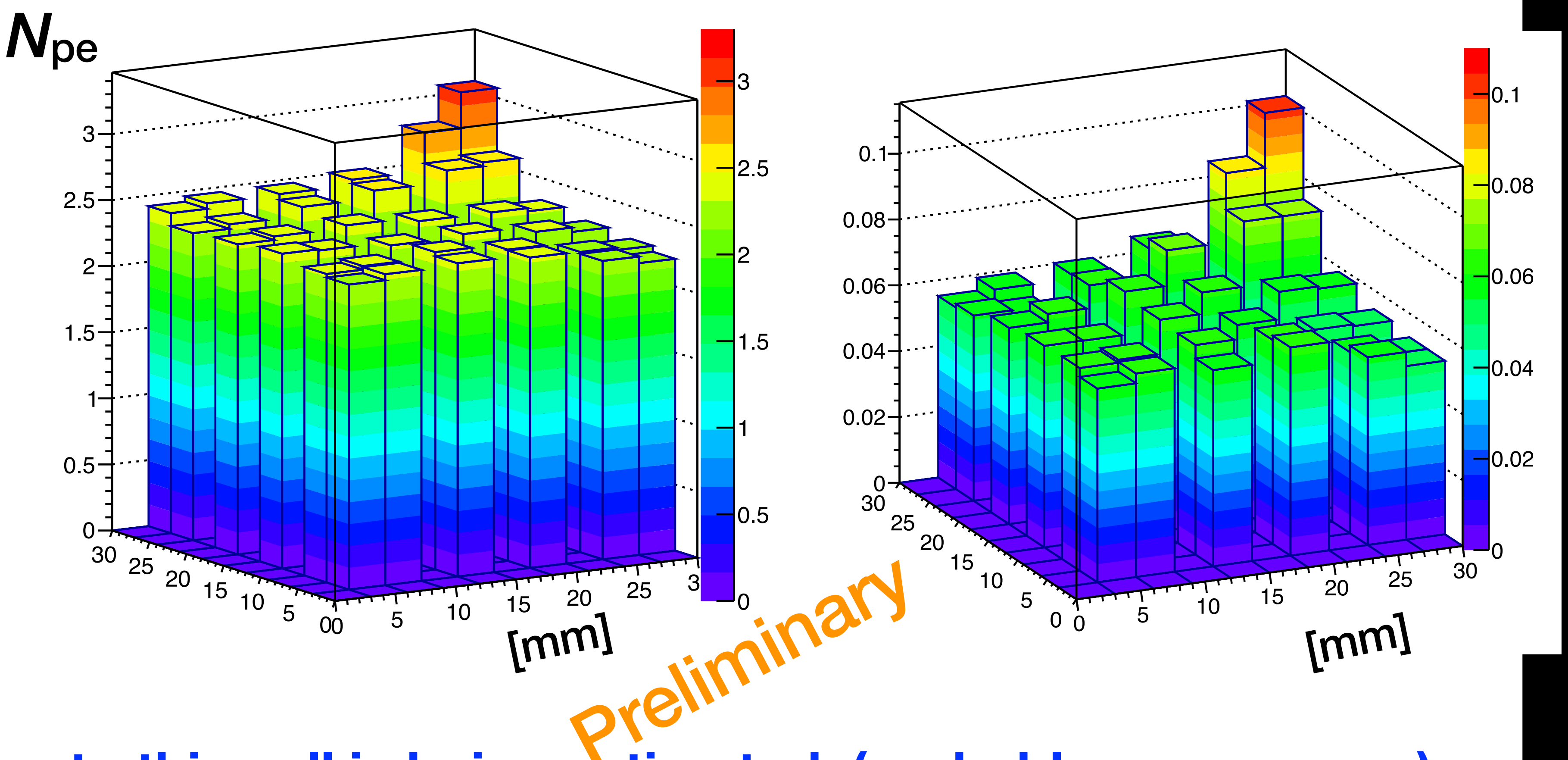
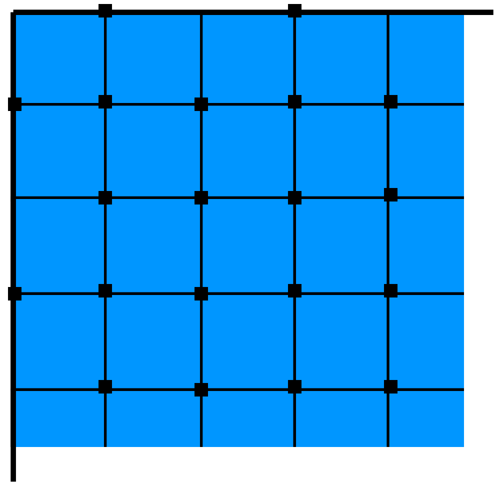




Light leakage to this cell is being estimated. (probably even worse.)

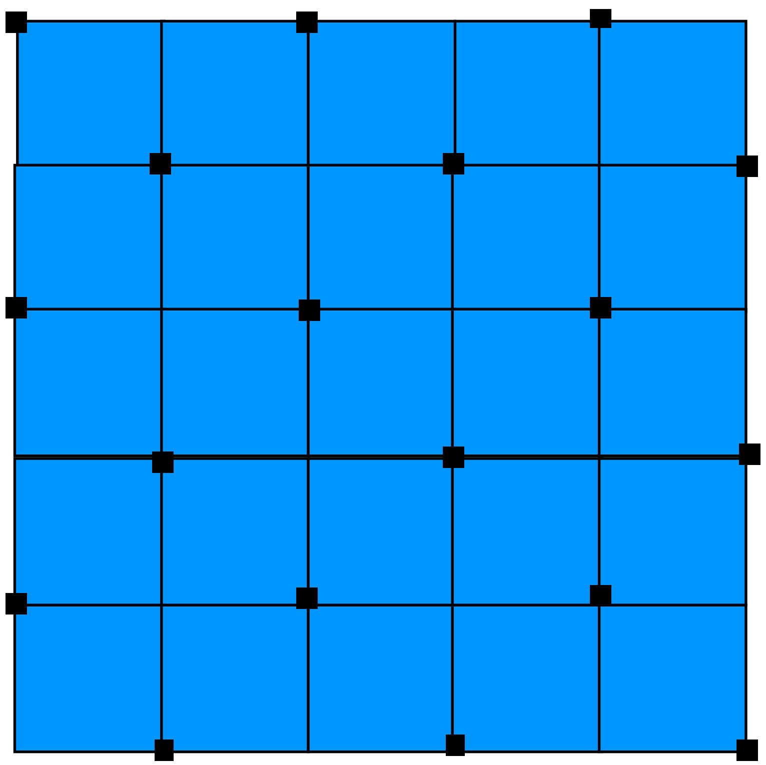
Comments on Possible Issues

- Light leakage to neighbouring cell
  - To be improved by optimising optical coupling
- How to split charge
  - Under study. Equally split to the hit cells? or some more intelligent split?
- Smearing of cluster due to fake cell hit surrounded by true hit cells
  - Effect of smearing on calorimeter performance is under study by a MC simulation.
  - N.B. no double count and no loss of detected charge due to wrong charge split and fake hit
- Increase of total number of SiPMs
  - Nominal: 12×12=144, Four-corners: 13×13=169
  - If necessary, it can be reduced with three SiPMs at HBU boundary cell instead of four.



Extreme Option...

- We may be able to reduce # of sensors by a factor of two.
- Possible issues
  - Less uniformity of cell response
  - Larger cluster smearing
  - Coincidence on two SiPMs instead of four
  - Larger influence of light leakage



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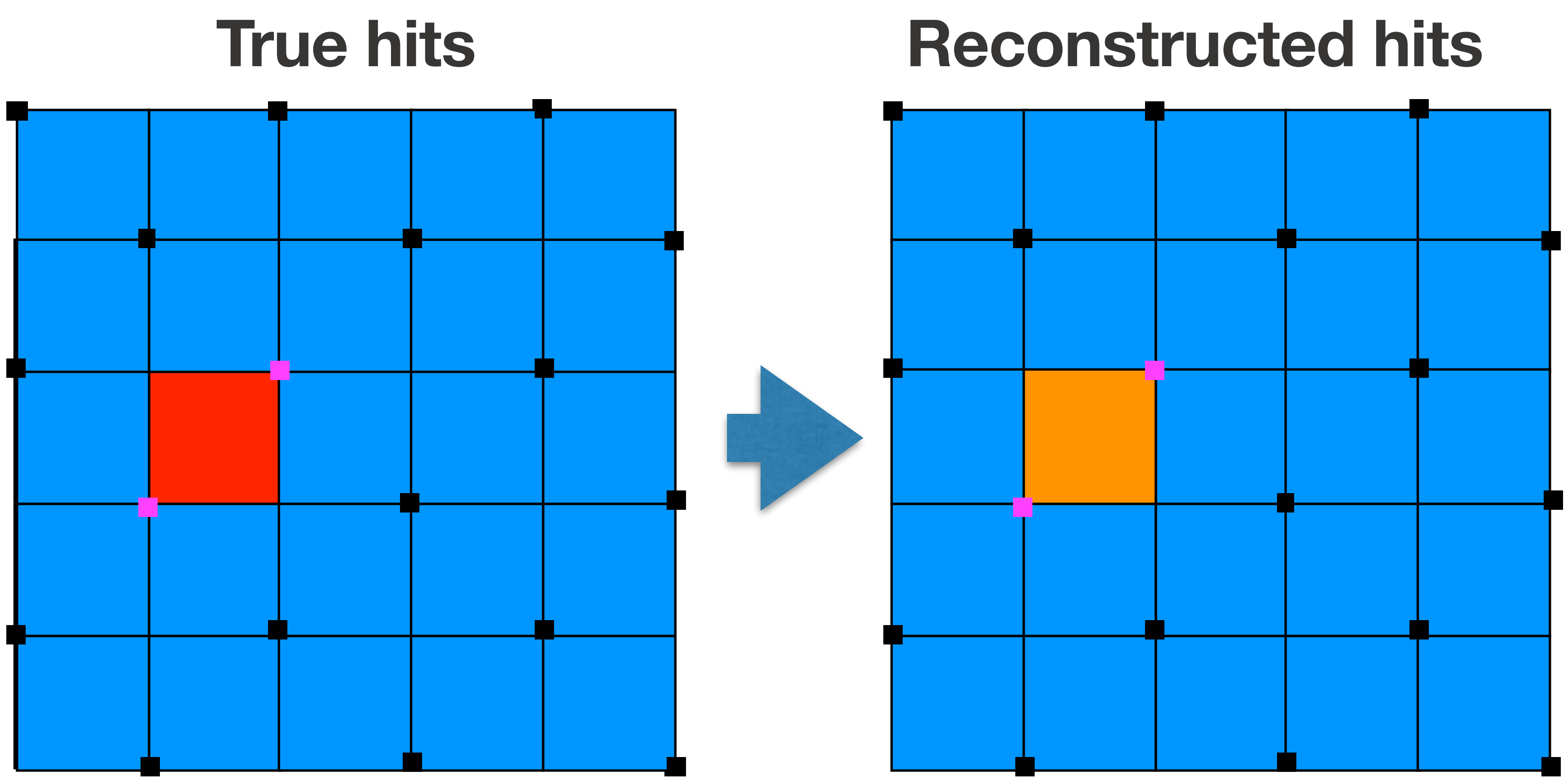

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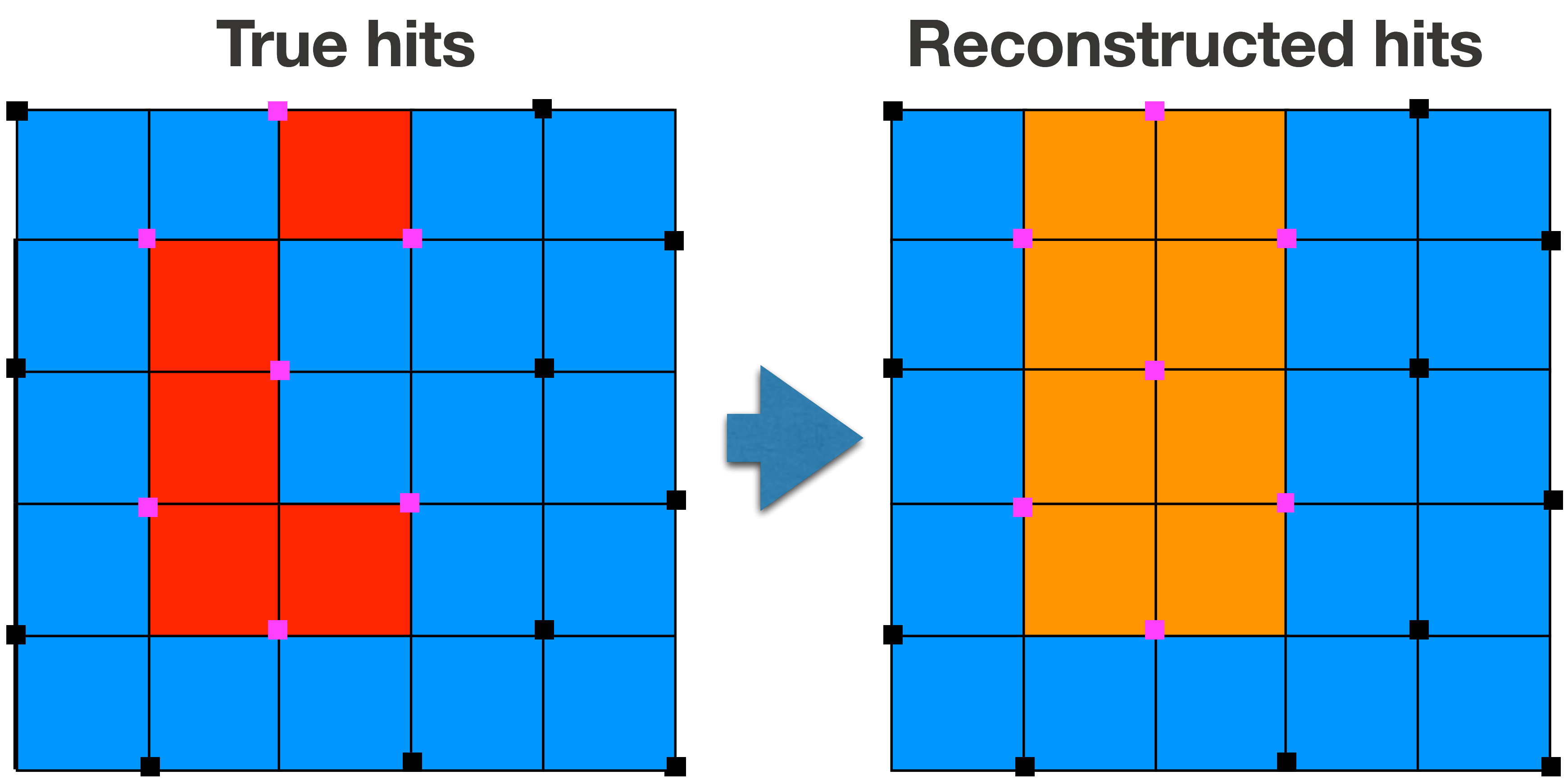

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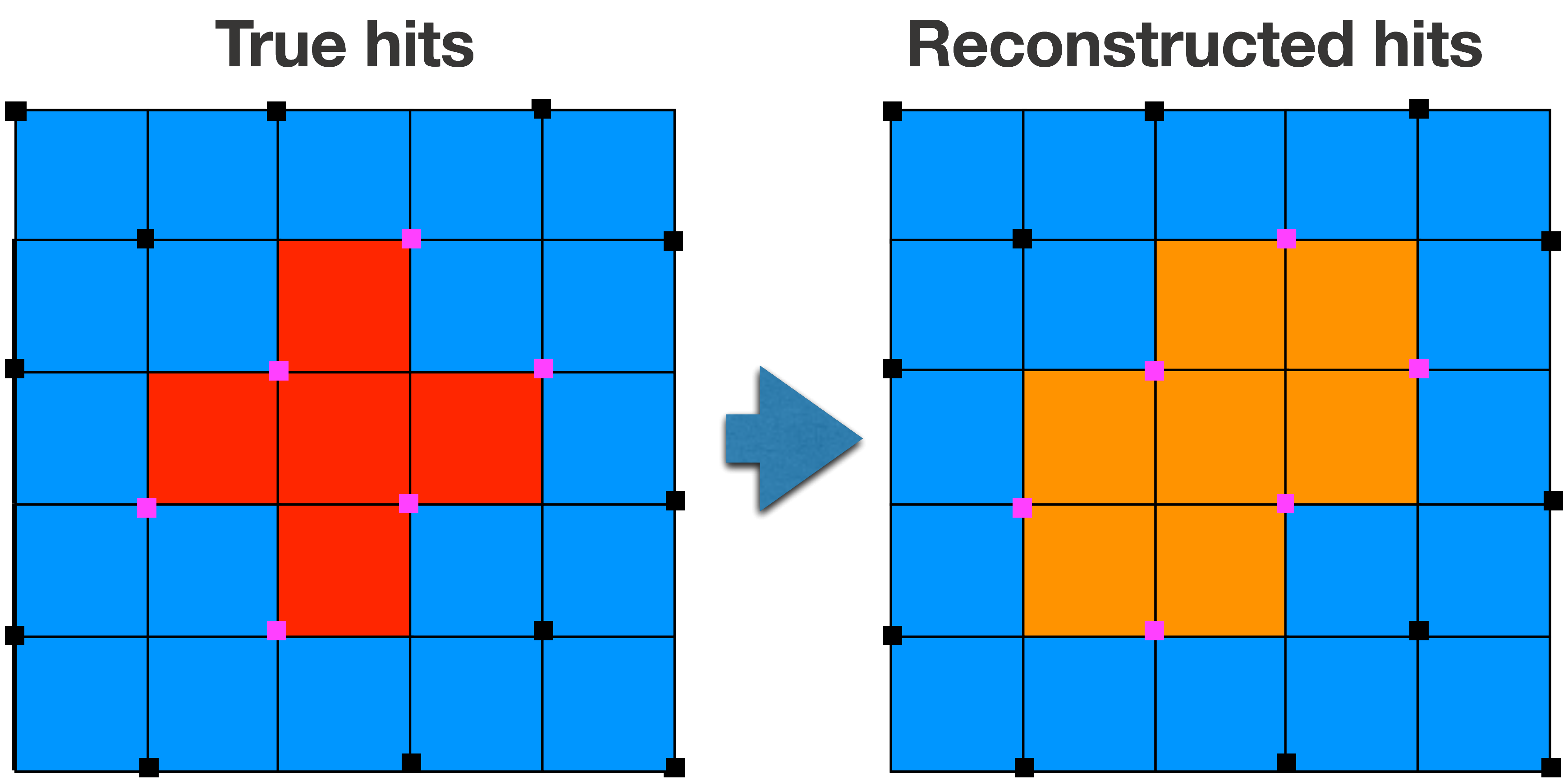

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Summary and Prospects

- We've joined development of AHCAL starting with
  - Scintillator material study
  - Optimisation of optical readout scheme
  - Study on radiation hardness of SiPM and scintillator material
- Next steps
  - Optimisation of scintillator material, especially for PS/MS-based scintillator
  - "Four-corners readout"
    - Further optimisation of optical coupling to
      - Improve light yield
      - Reduce light leakage to neighbouring cell
    - Simulation study on effect of cluster smearing on the calorimeter performance
    - To be tested on surface-mount type HBU (already provided by DESY group)
  - Study on radiation hardness of SiPM and scintillator materials.
    - Radiation hardness test for MPPC is in progress in collaboration with Hamamatsu especially for recent version of MPPC.
    - Radiation hardness test for PVT, PS and MS.