Double-sided Readout Strip for ScECAL

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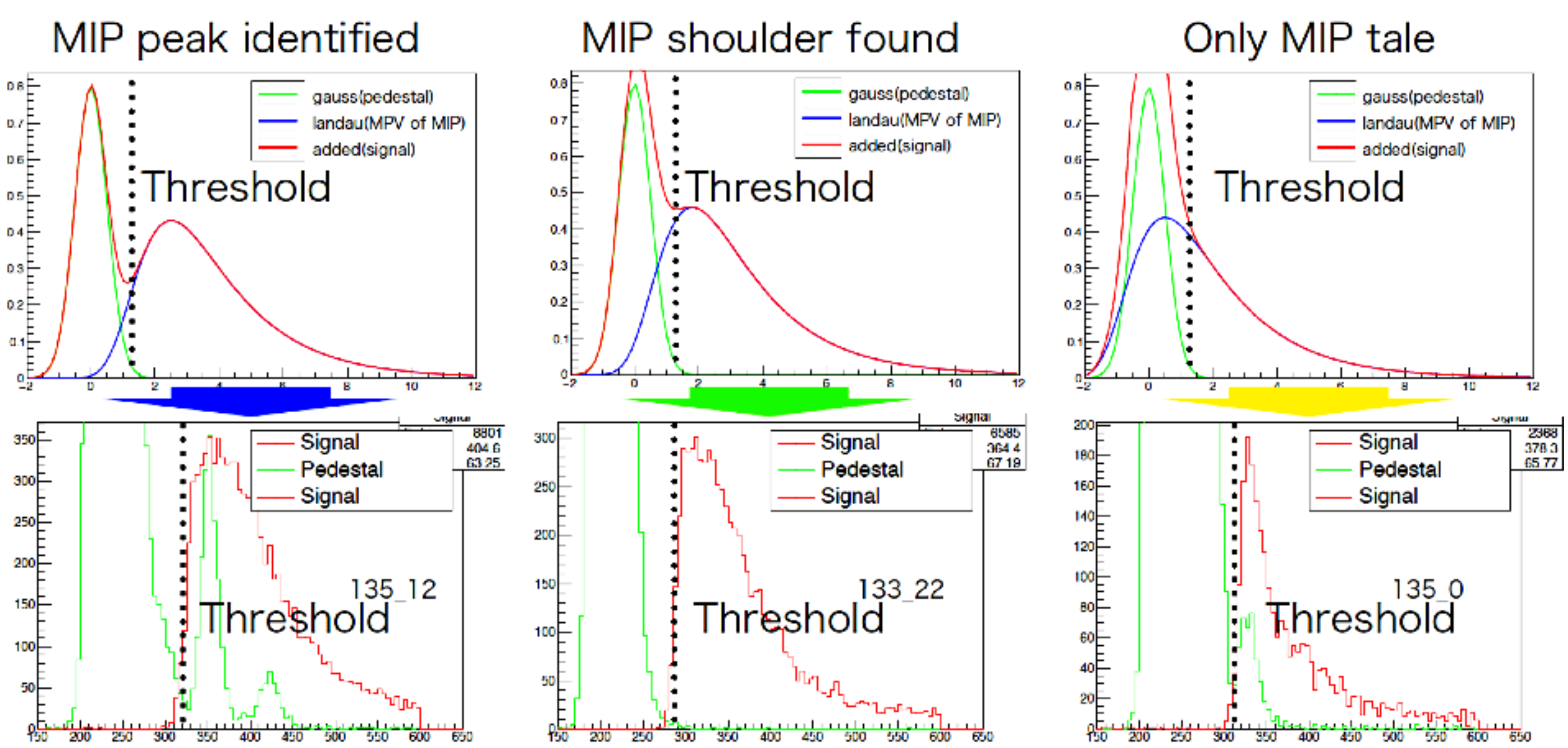
Small-Cell Photosensor for ScECAL

- **SiPM with small pixel pitch (~10μm) is required for ScECAL to improve dynamic range.**
- **Issues on SiPM with small cell**
  - Lower gain → **poor single p.e. resolution**
  - Lower PDE → **lower MIP yield**
  - S/N of EBU analog front-end is not good enough for small-cell SiPM

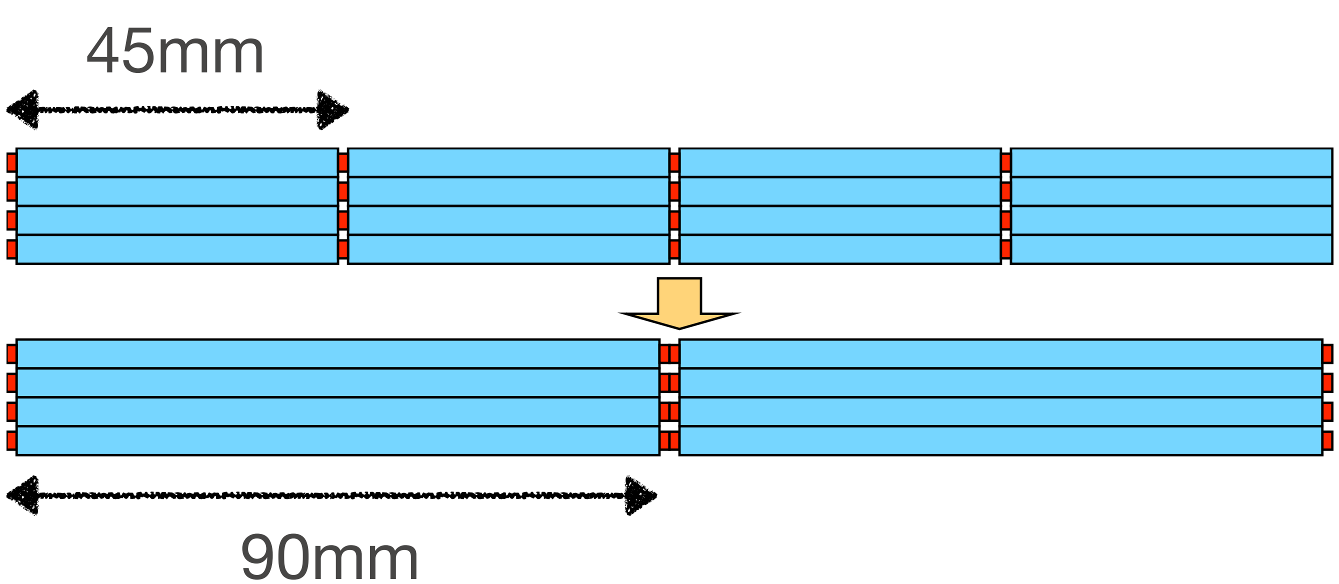


Possible Solutions

- Improve gain/PDE of SiPM
- Increase photon yield
- Increase sensor area
- Improve S/N at EBU readout
- A little larger pixel pitch (15μm?)
- Double SiPM readout

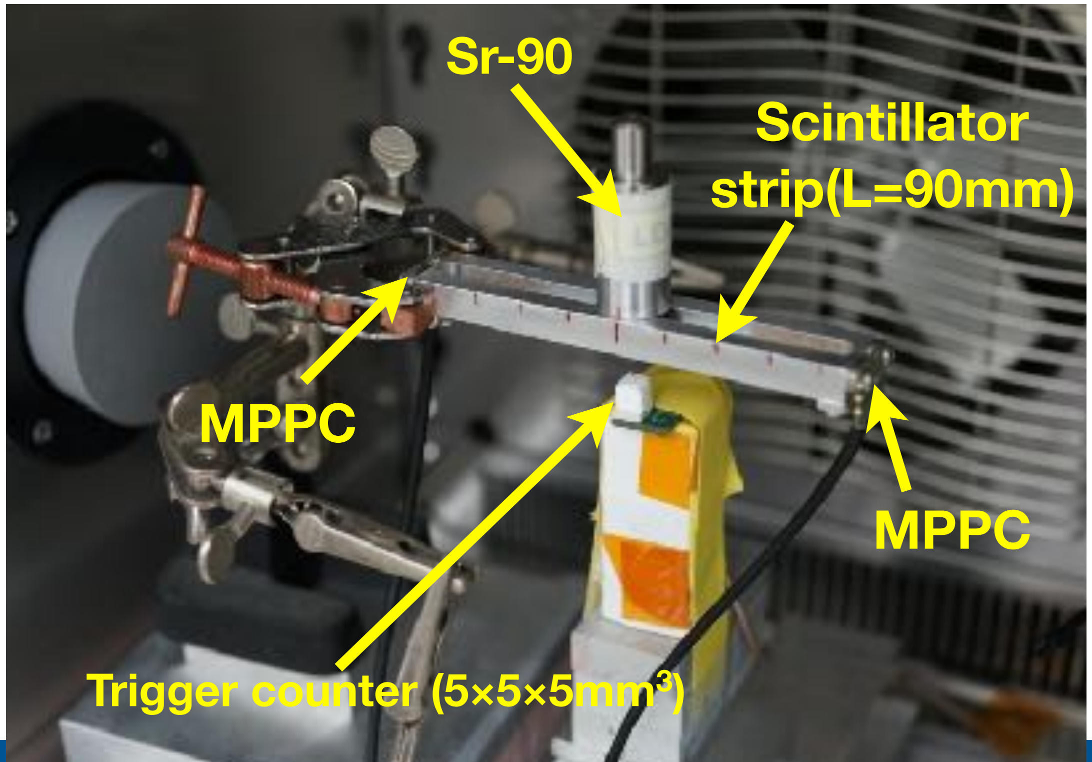
Double-sided Readout Strip

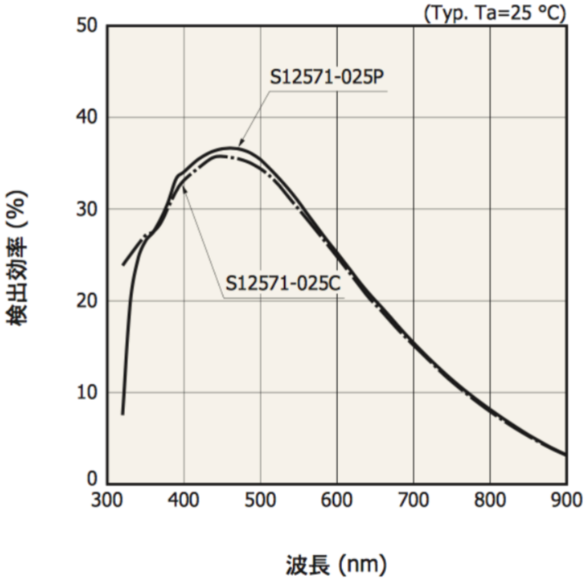
- **Double SiPM readout at both strip ends**
- **Possible advantages**
  - Suppress random hit by taking coincidence → Lowering MIP threshold
  - More uniform response
  - Higher light yield
  - Scintillation photons shared by two SiPMs → Mitigation of saturation
  - Position reconstruction → Remove ghost hits
- **Issues**
  - Need longer strip to keep # of SiPMs (90mm instead of 45mm)
  - More saturation with longer strip?

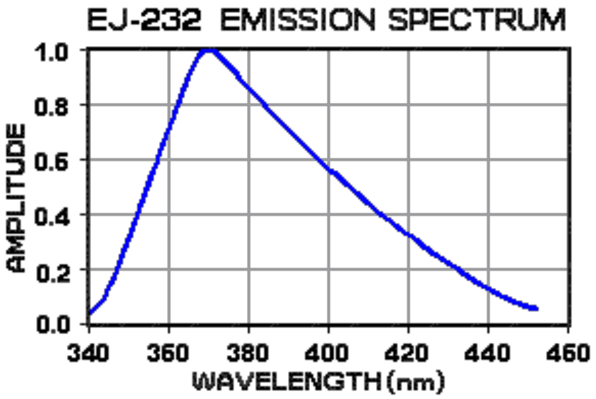


Prototype Test of Double-sided Readout

- **Preliminary test of double-sided readout**
  - Double sided readout with 90mm strip (2×5×90mm^3)
  - **Scintillator: EJ-232** wrapped with ESR film
  - **SiPM:** 8585 (1×1mm^2, **25μm-pixel)**
  - **Setup was not optimal.**
    - Modest light yield of EJ-232
    - Emission spectrum of EJ-232 doesn't match SiPM response
    - Short attenuation length (~8cm) of EJ-232
    - Better to test with SiPM with 10μm-pixel
- Further test with optimal scintillator and SiPM is ongoing as shown later

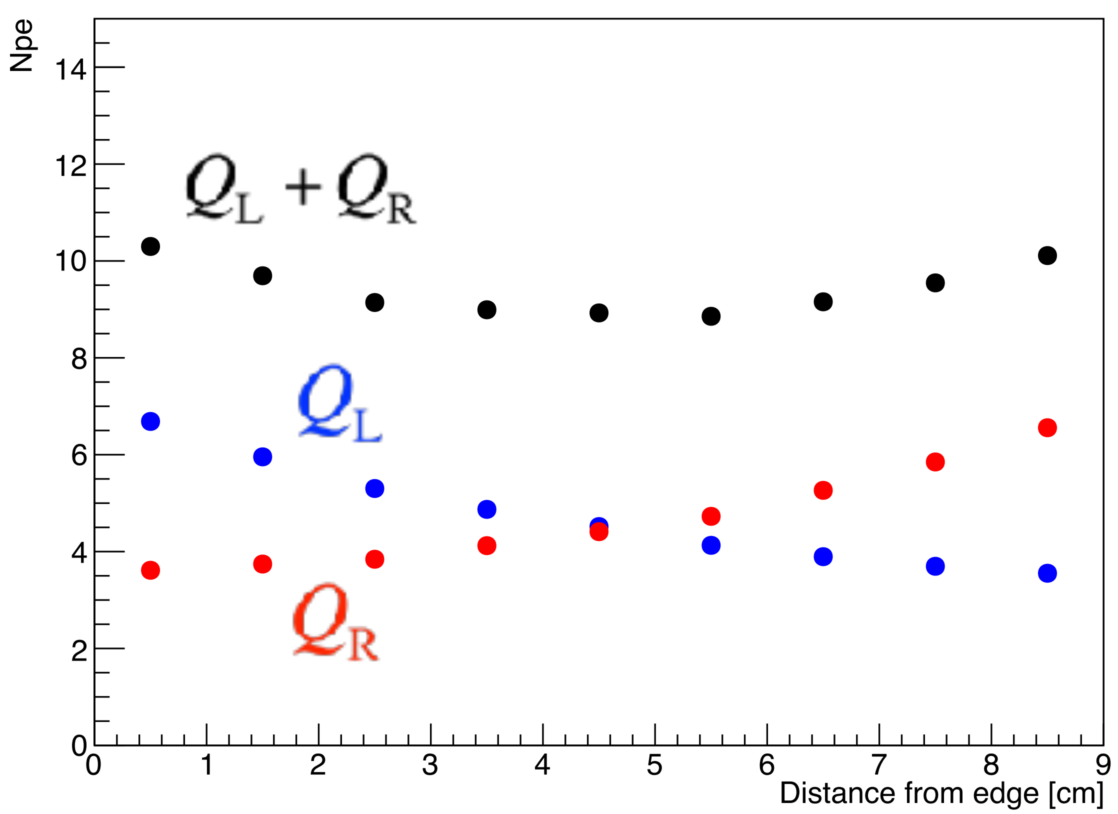


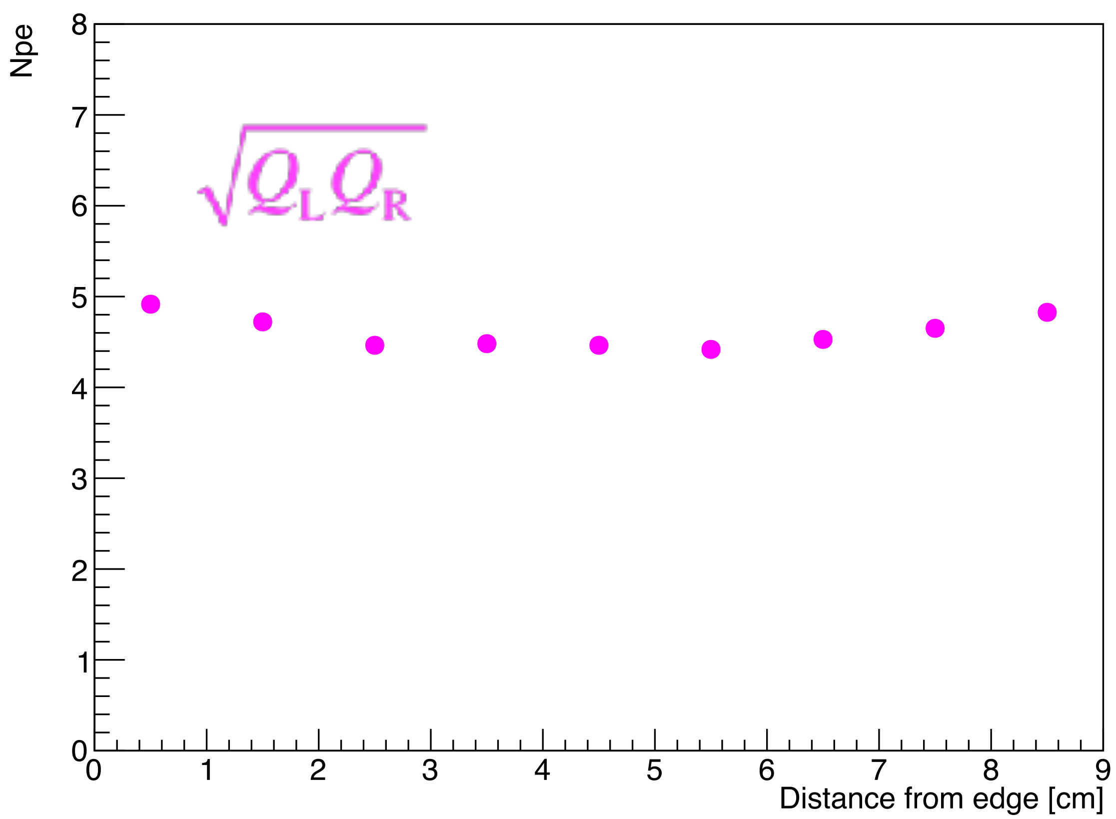




Response of Long Strip

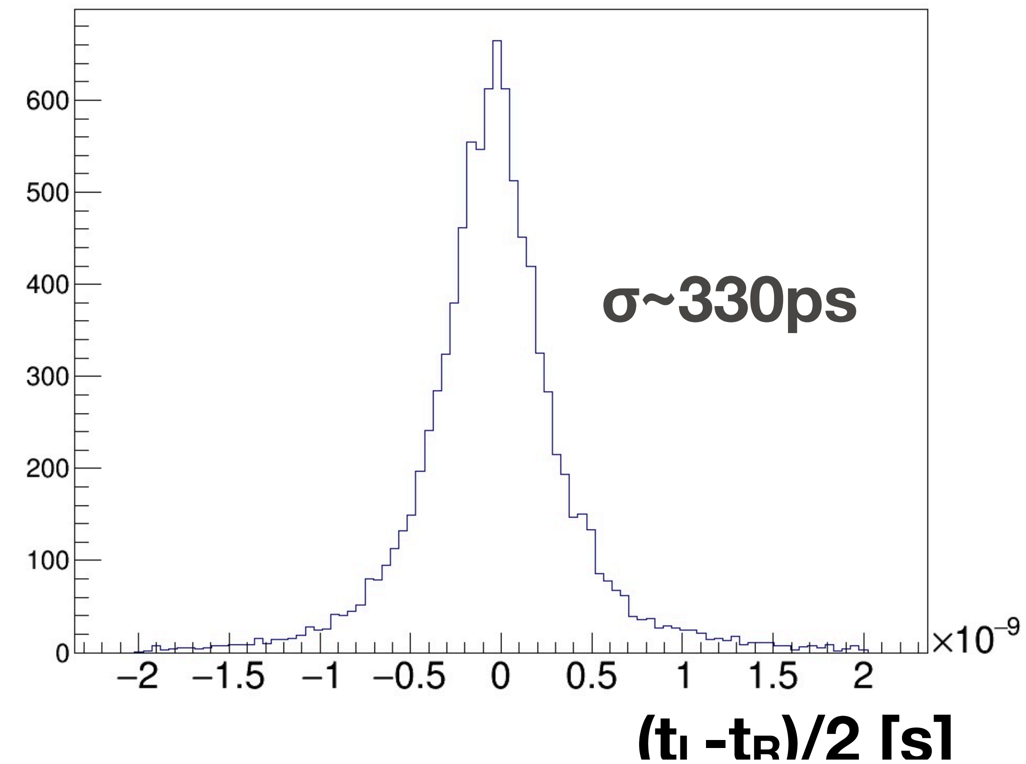
- **Good performance even with this preliminary setup**
  - **Reasonably high light yield**
  - **Good uniformity**
- **N.B.** preliminary results from improved setup will be shown later

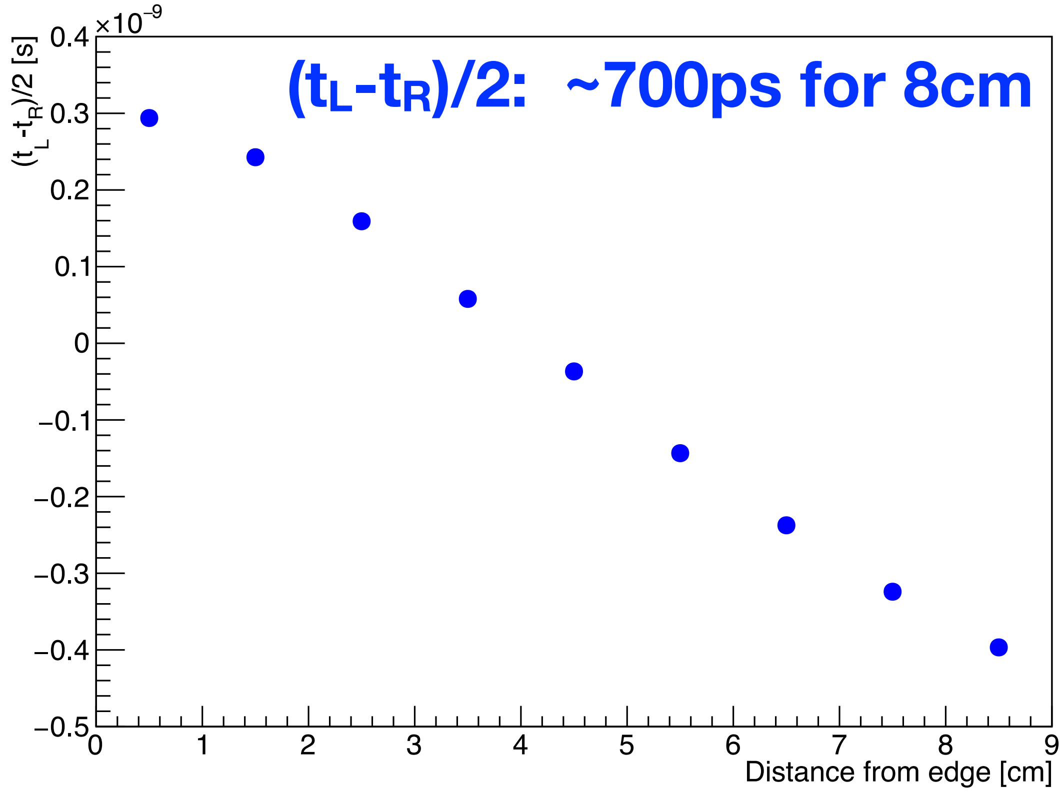




Position Reconstruction

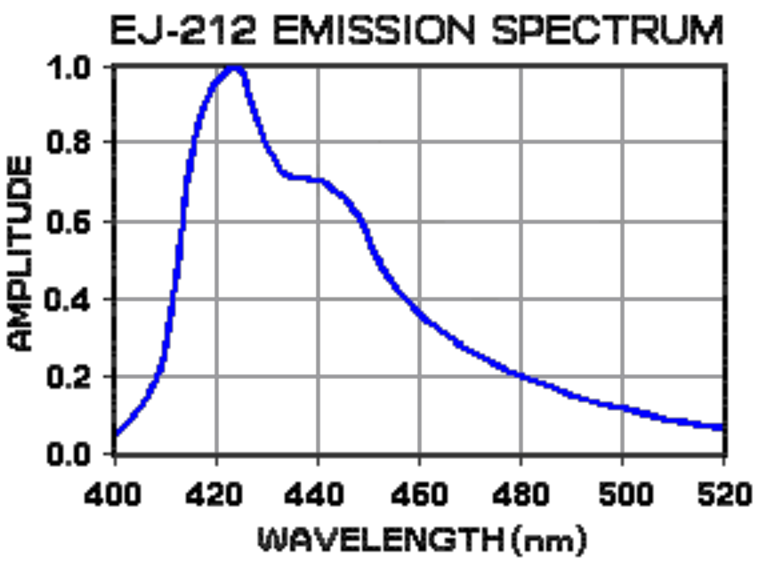
- **Two possibilities**
  - Charge ratio
    - Difficult due to
      - Low N_{pe} statistics
      - Large fluctuation of MIP energy deposit
  - Time difference
    - **σ~4cm** measured with preliminary setup
    - Not promising but still to be improved with larger N_{pe} statistics with optimal scintillator/SiPM

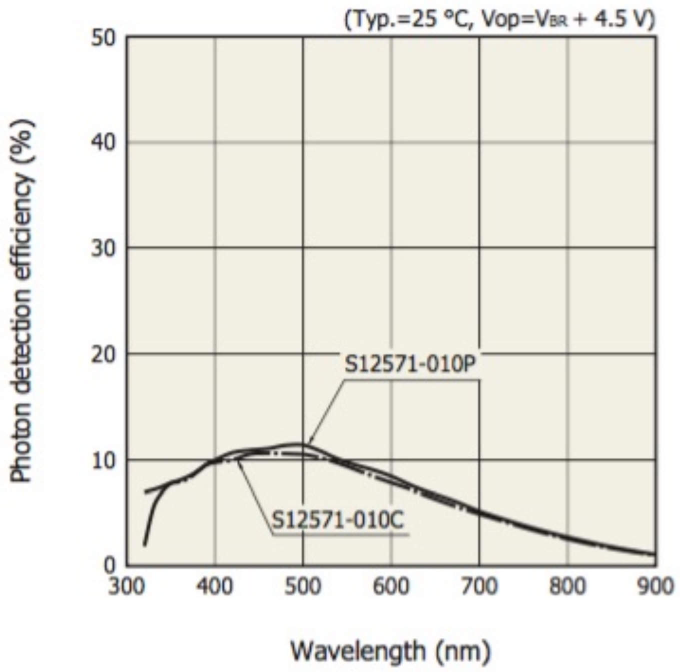




Prototype Test with Improved Setup

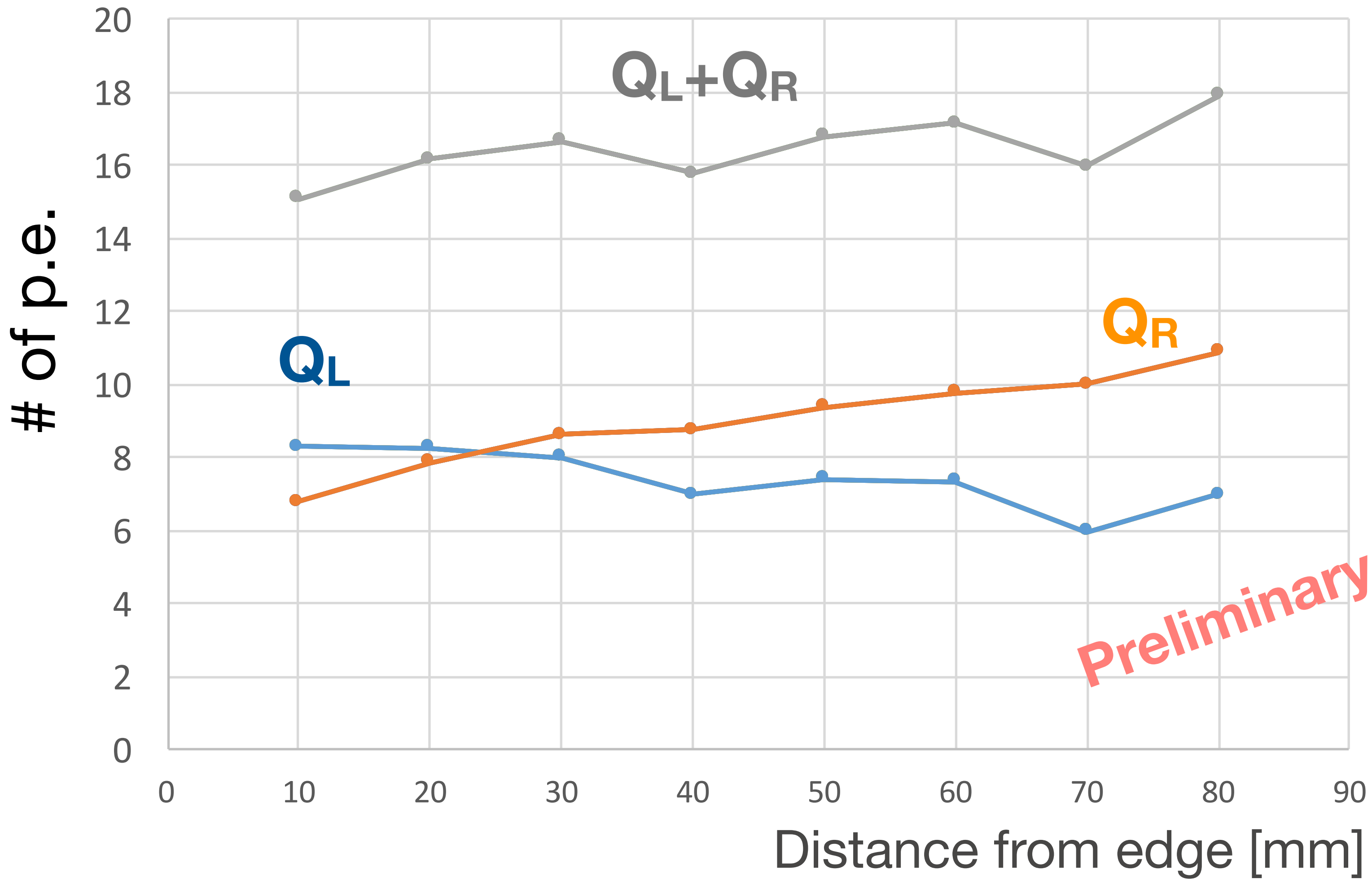
- **Improved setup**
  - Scintillator
    - EJ-212 (~BC400)
    - General purpose
    - Higher light yield
    - Longer attenuation length (~160cm)
    - Emission peak: 423nm → better matches SiPM response
  - SiPM
    - MPPC S12571-010P (1×1mm^2 10μm-pixel)
    - Lower PDE
- **Setup is still being optimised.**
  - Results shown here are preliminary.





Results

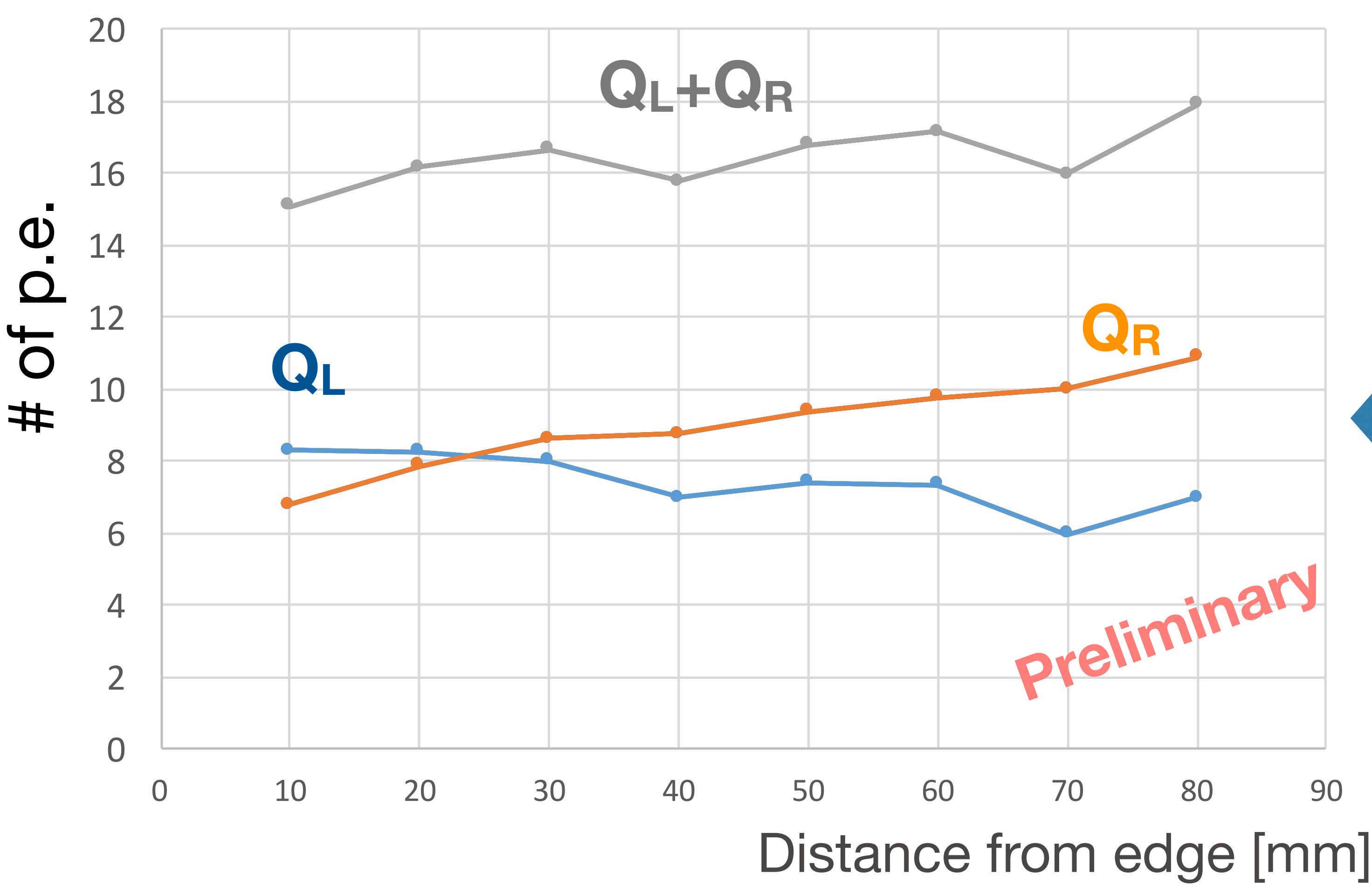
- **Improved performance w.r.t. previous test**
  - Higher light yield by ~50%
  - Better uniformity thanks to longer attenuation length
- **N.B.** measurements are a little unstable for some technical reasons, to be improved



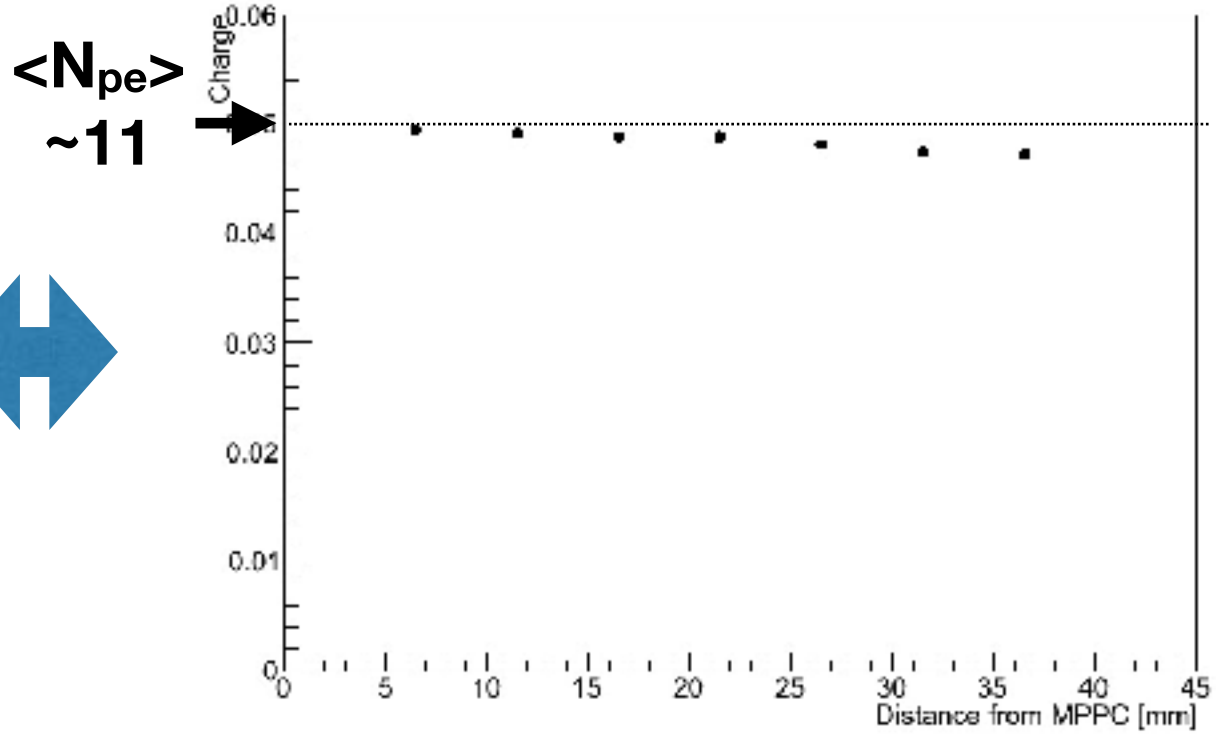
Results

- **Comparison with 45mm strip with single-side readout**
  - Total N_{pe} is increased by ~45% → Better N_{pe}-statistics
  - N_{pe} for each SiPM is slightly decreased → Slightly less saturation

90mm strip with double-side readout



45mm strip with single-side readout



Other Issues for Longer Strip

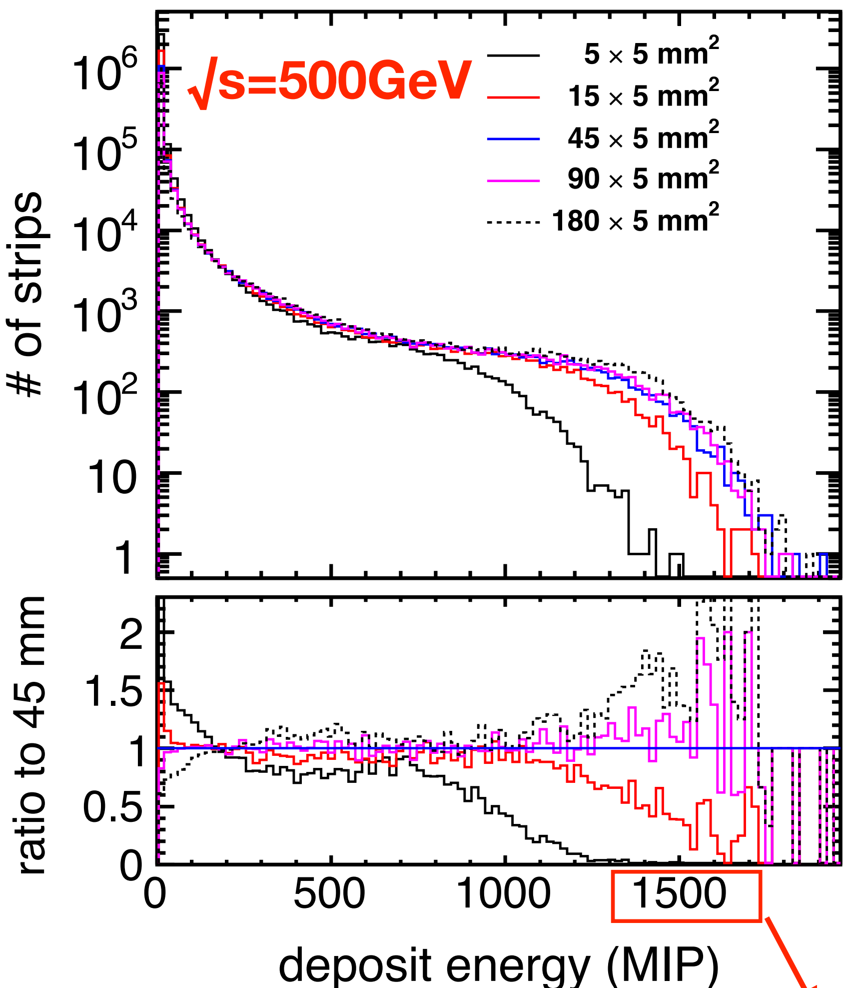
- **Possible issues**
  - Larger energy deposit per strip for Bhabha event? → more saturation
  - More ghost hits?
- **Effects of strip length studied by MC simulation**
  - Studied by Kotera-san
  - $\sqrt{s}$ = 500GeV, 1TeV
  - Bhabha events @θ~90°
  - No digitisation simulated. Compared energy deposits only.

Energy Deposit per Strip

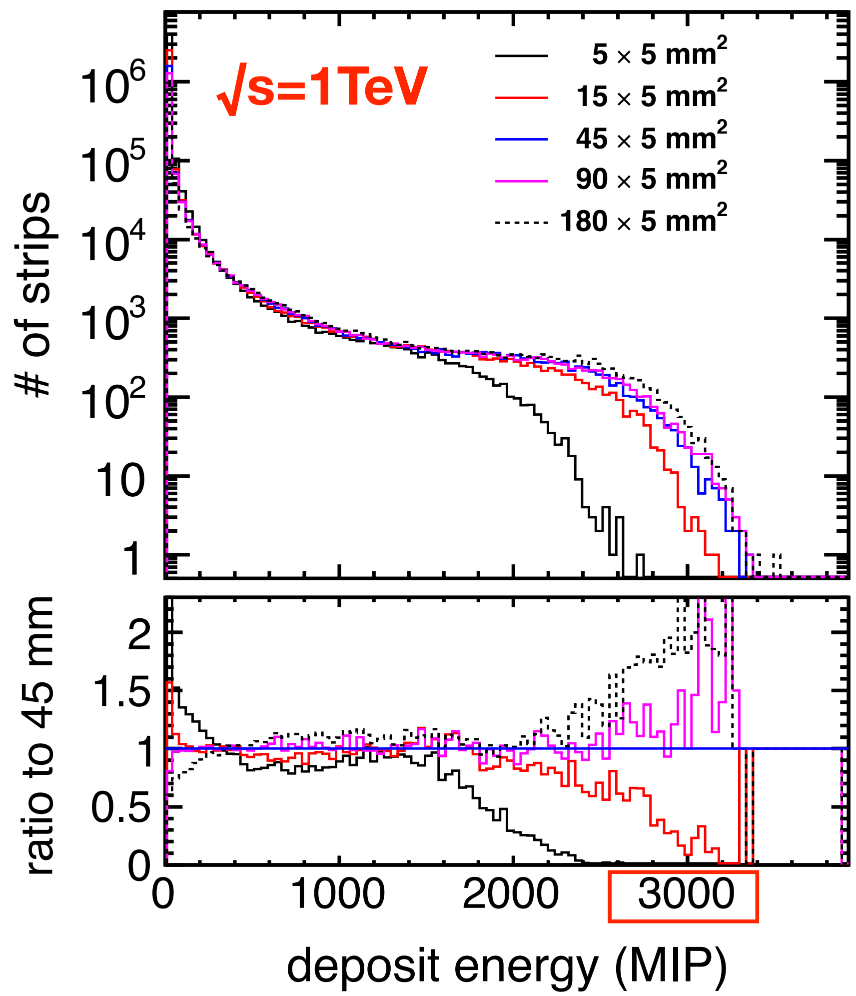
Considering Bhabha events at √s = 500 GeV, 1 TeV

K. Kotera

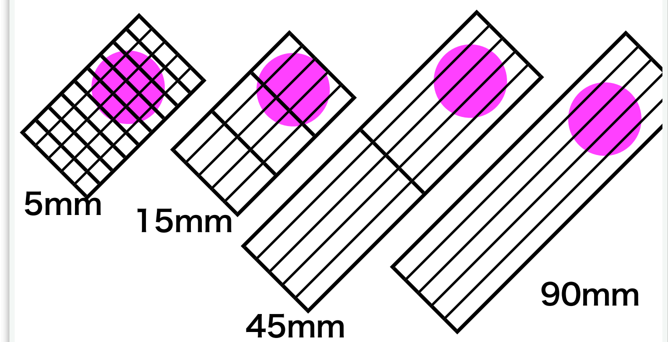
no MPPC saturation



no MPPC saturation



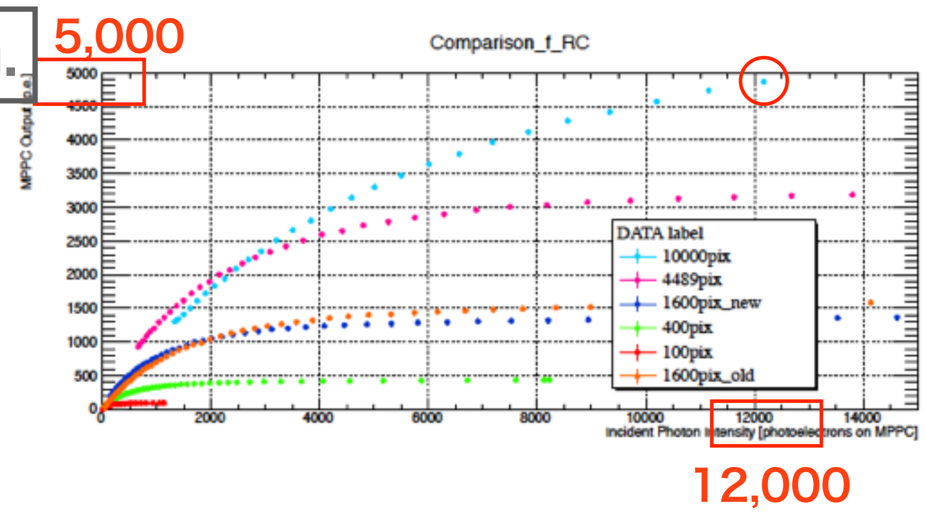
- 45, 90mm no serious difference.



- core sizes of clusters are smaller than 45mm

1500MIP → N_{pe} ~10k for nominal strip config.

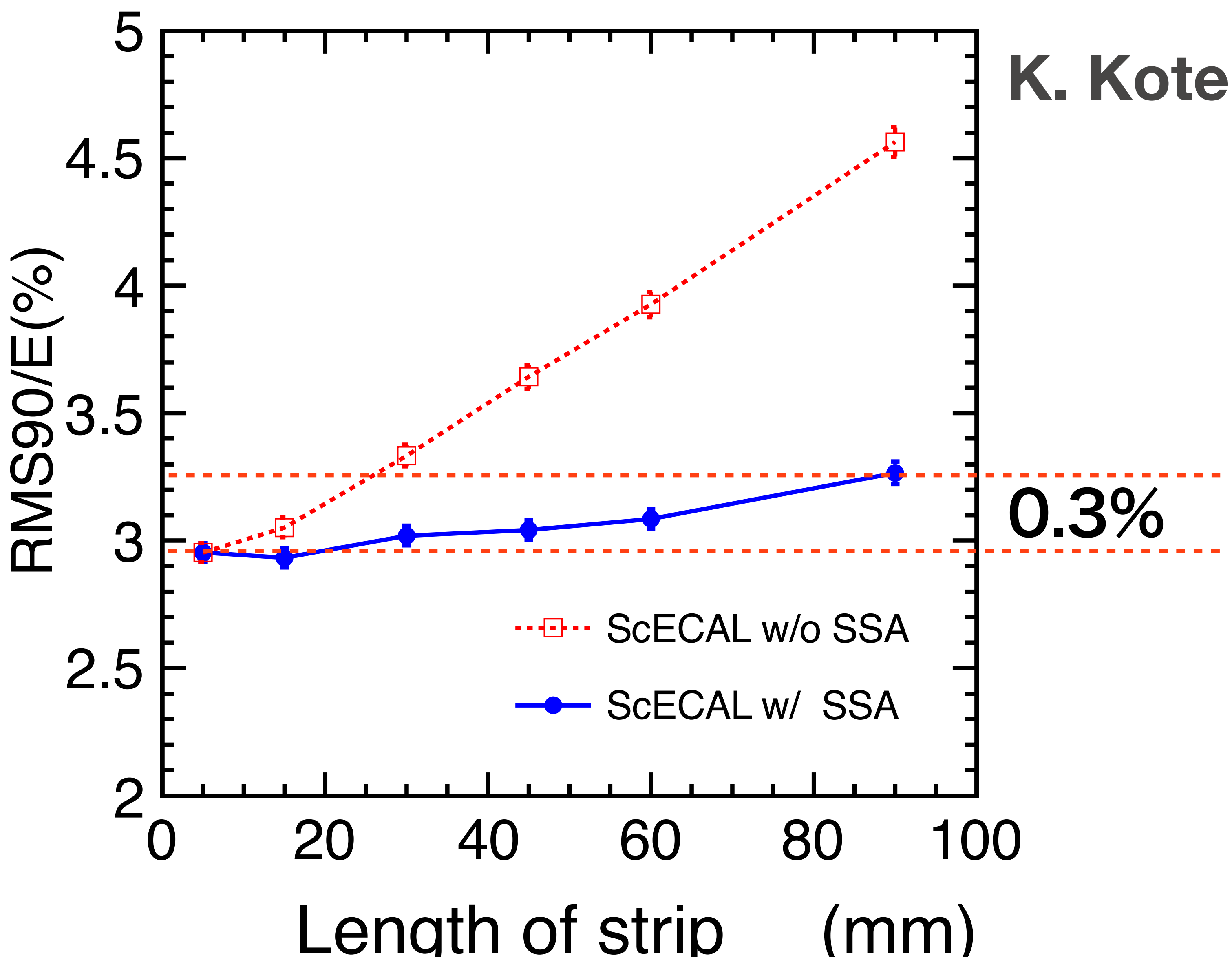
Response of 10μm-cell SiPM



- **No significant difference at longer strip**
  - Cluster size smaller than strip length
- **Saturation not worsened with longer strip**

Jet Energy Resolution

- **JER slightly worsened for longer strip due to ghost hits**
- **Can be improved by**
  - Additional tile layers
  - Position reconstruction with double-sided readout (?)



Summary

- **Double-sided SiPM-readout under study to improve performance of strip with small-cell (10μm) SiPM**
- **Looks promising, although results are still preliminary**
  - Higher light yield
  - Good uniformity
  - Possibility of position reconstruction with double-sided readout
  - Found in MC simulation that calorimeter performance is not worsened with longer strip in terms of highest energy deposit and JER.
- **To do**
  - Further performance studies with improved setup
    - Improve systematics of measurements
- Test of position reconstruction
- Test of coincidence at both ends
- Double-sided readout with SMD SiPMs