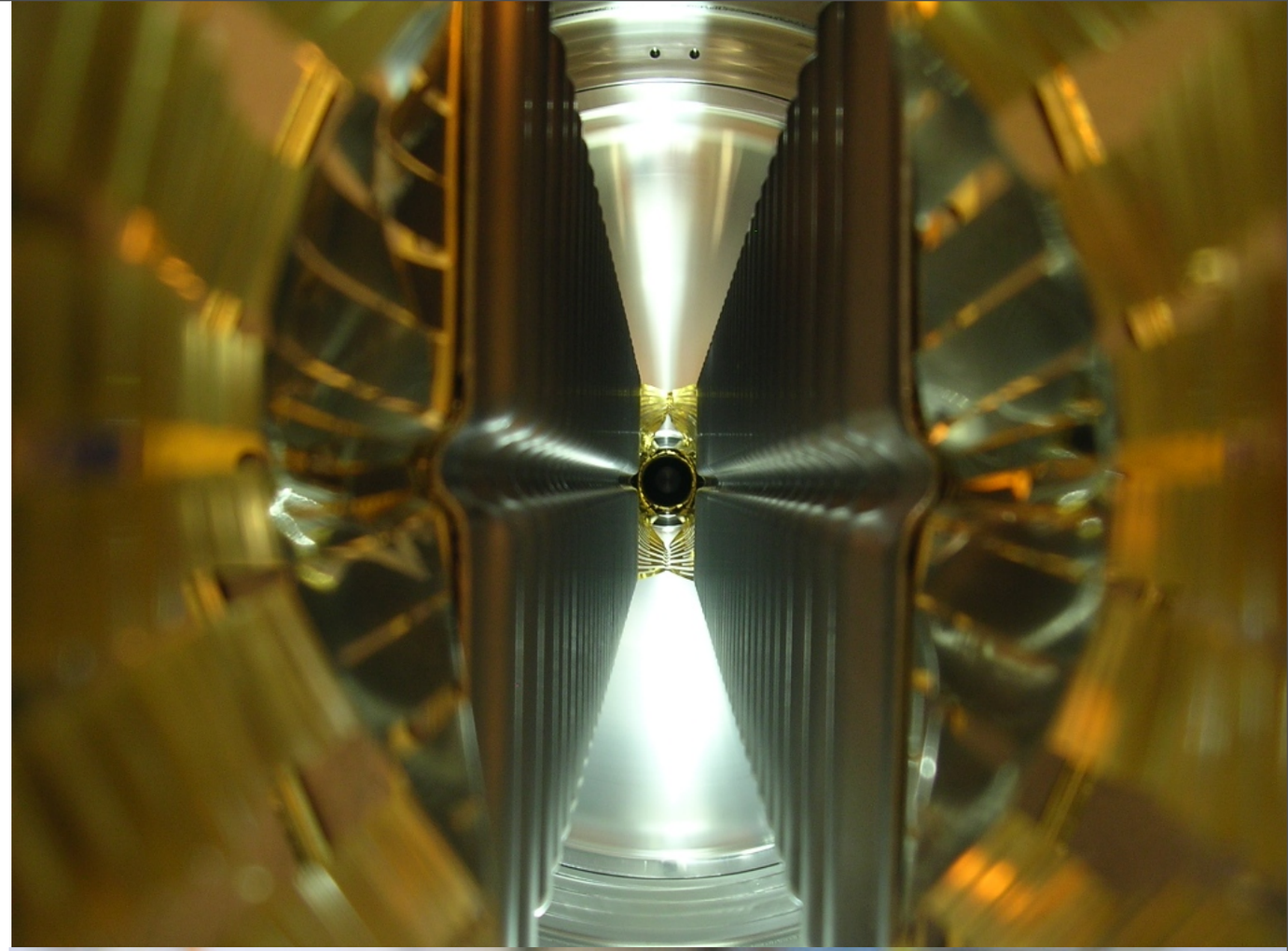
MANCHESTER 1824

Second metal layer charge loss in the LHCb VELO

Jon Harrison for the LHCb VELO group

Inter-Experiment Workshop on Radiation Damage in Silicon Detectors, CERN, 7th March 2012



Cluster Finding Efficiency

- A key aspect of the VELO physics performance is the ability to efficiently find and reconstruct **clusters**.

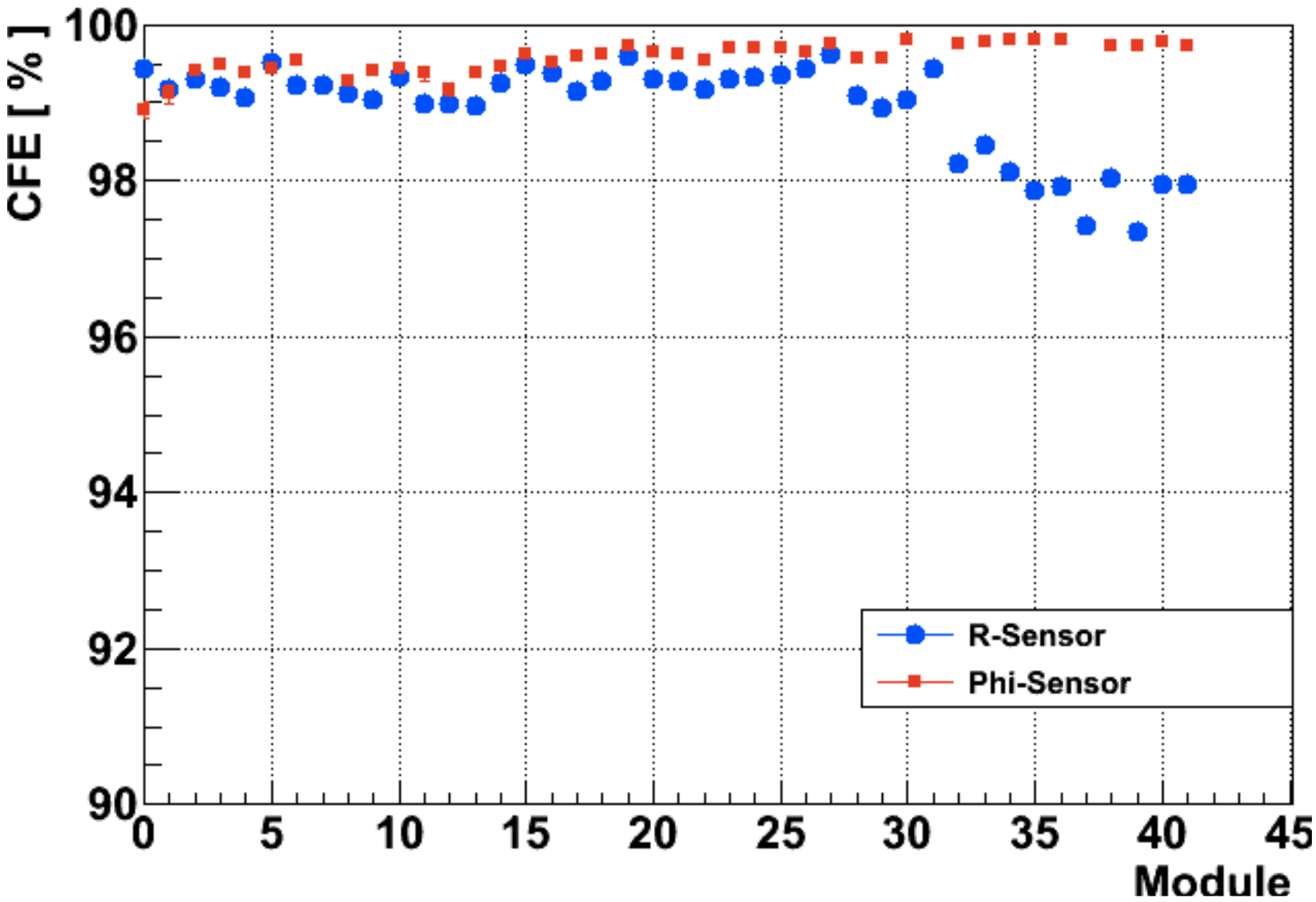
- A cluster is defined as one or more adjacent silicon strips with charge above a particular threshold.

- **Cluster Finding Efficiency** (CFE) is therefore the percentage of tracks at a particular position in the sensor where a cluster is obtained at the track extrapolation point.

- Typically measured using regular dedicated scans, but can also be derived from physics data.

Drop in CFE

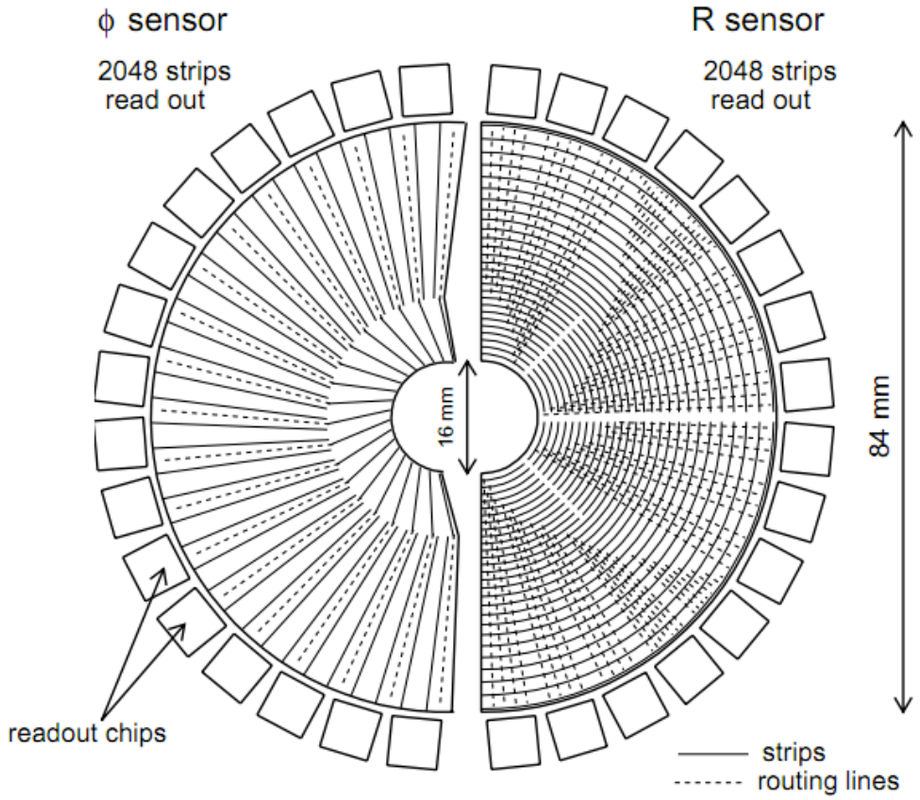
- With irradiation a significant decrease in CFE is observed, specifically in the outer radius regions of **downstream R-sensors**:



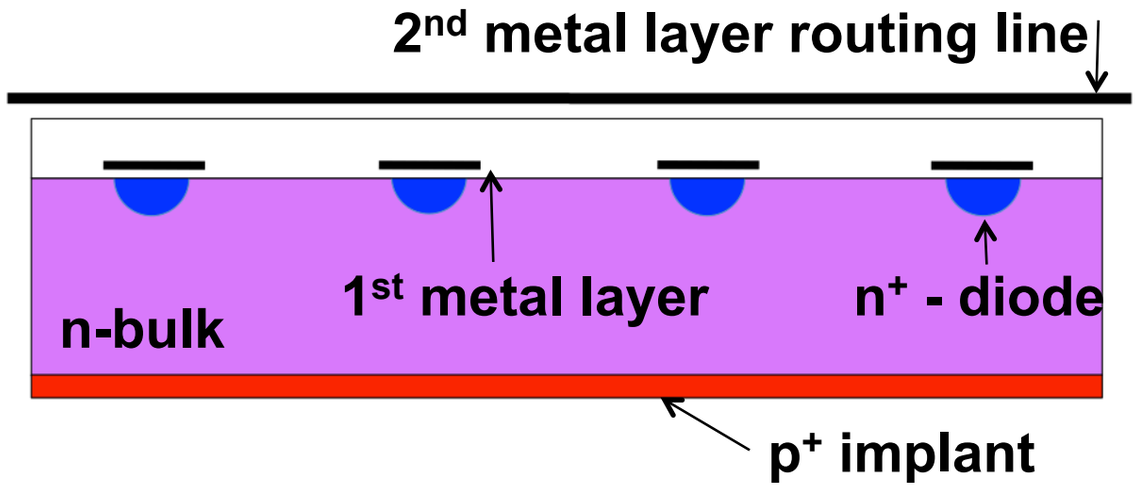
All sensors after 1.220 fb^{-1}

R and phi sensors

- VELO sensors require both **routing lines** to carry the collected charge to the amplifier and a **first metal layer** to couple to the sensor strips

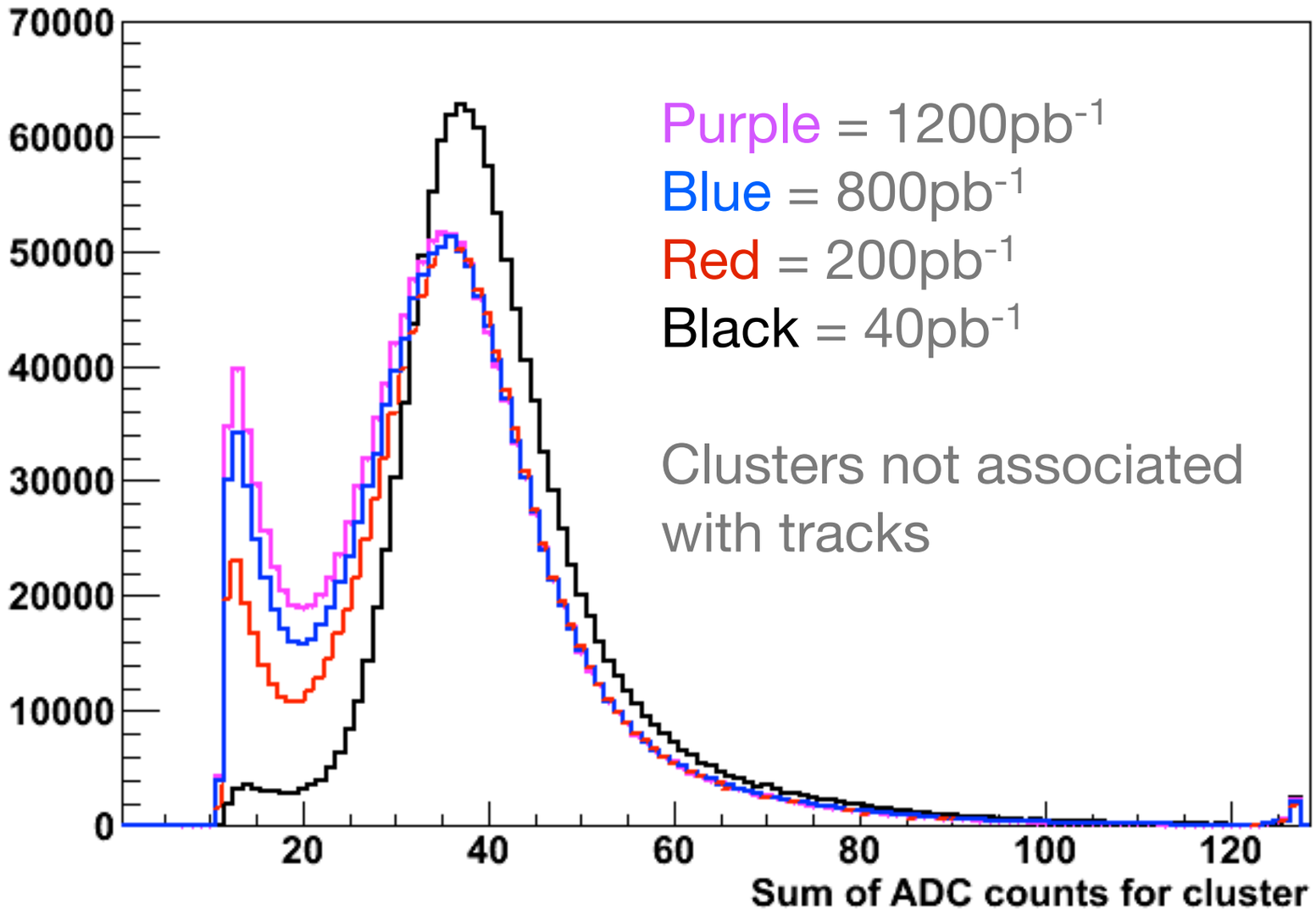


- R and phi sensors are read out differently with routing lines **perpendicular** and **parallel** to the strips respectively



Charge coupling in R sensors

- No measurable effect before irradiation

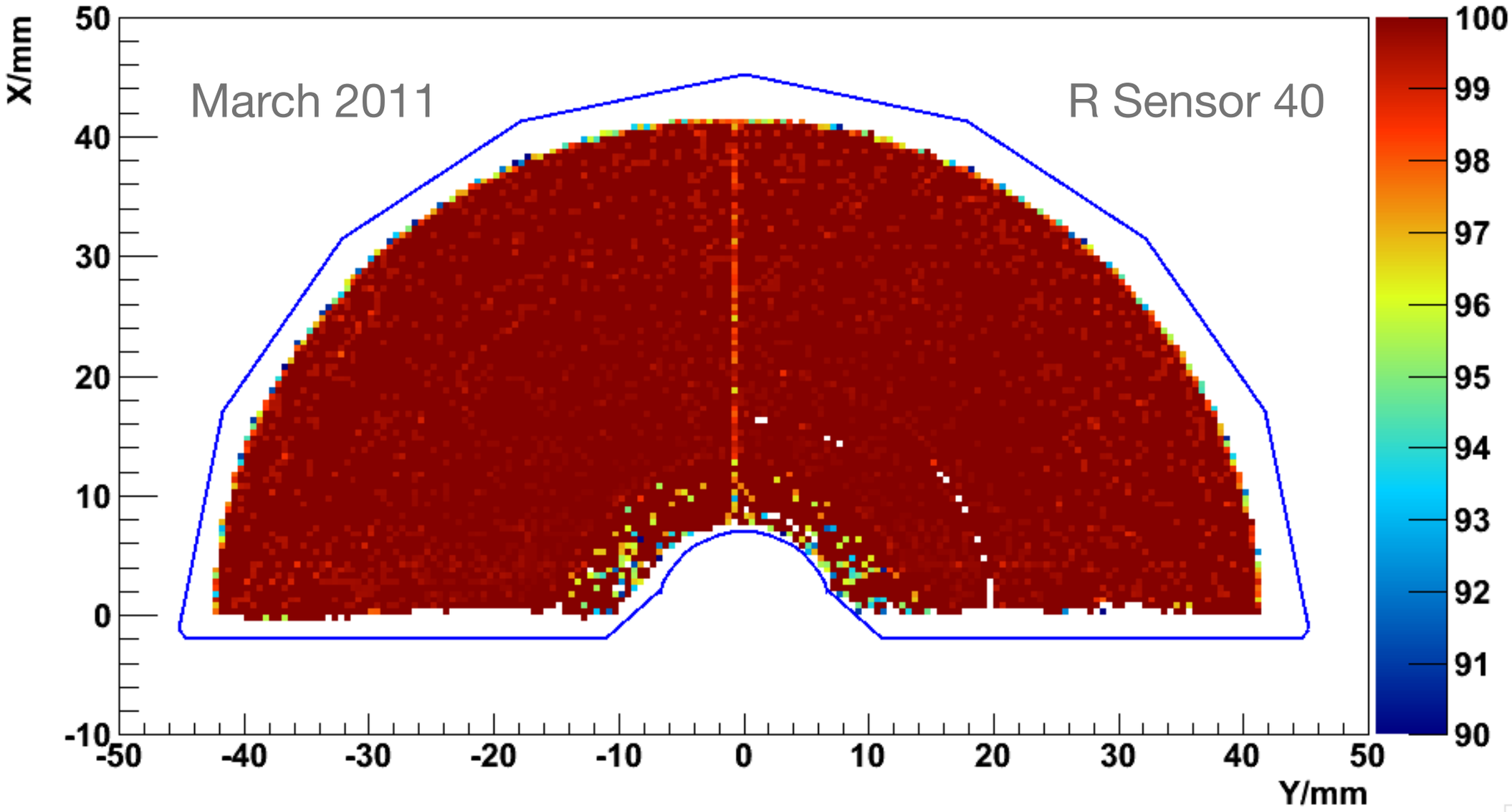


- With irradiation **Gauss-Landau** ADC distribution develops a secondary peak at low values

- Signal **induced** in routing lines positioned above outer strips in R sensors

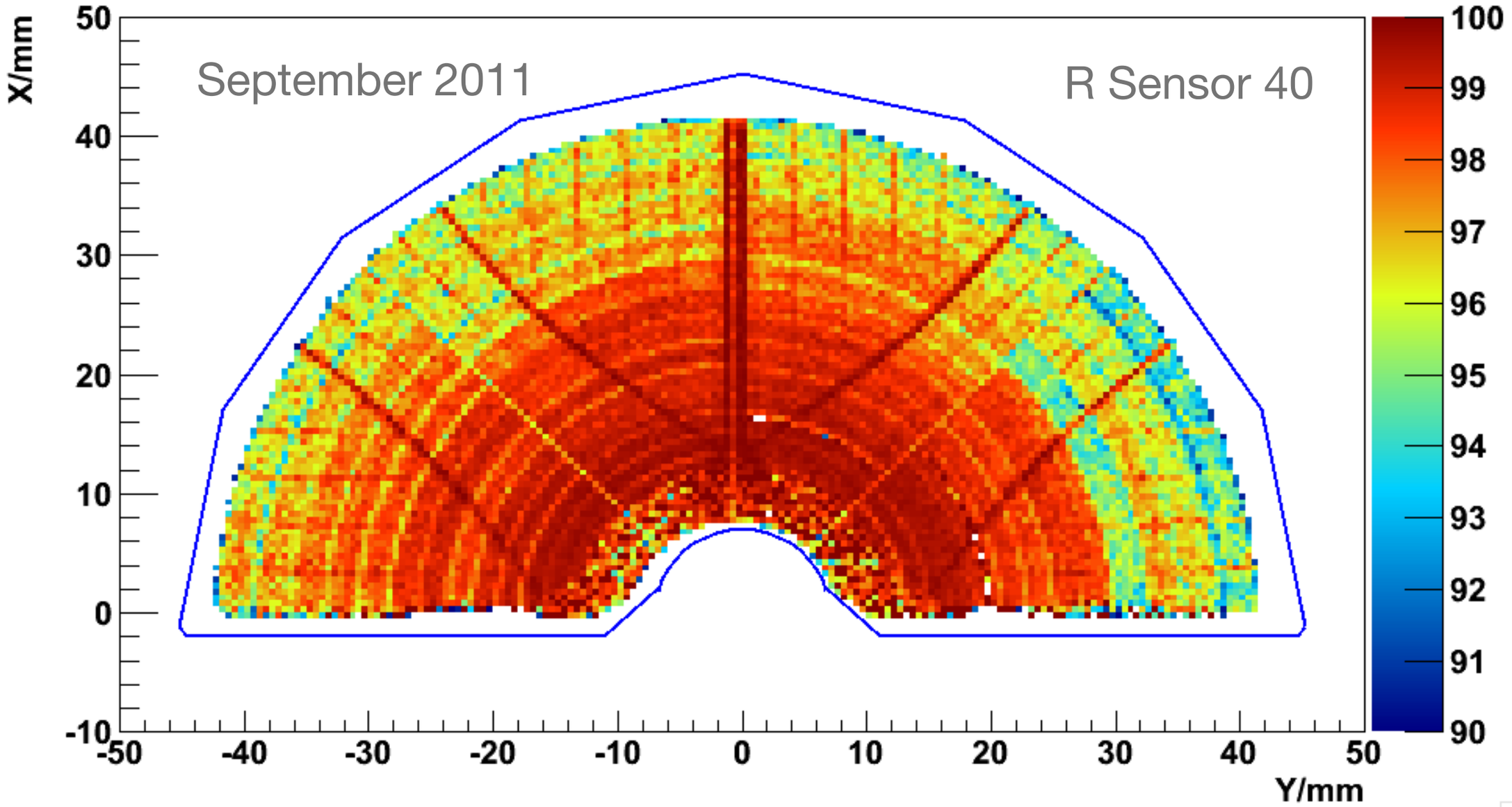
2D CFE map **before** irradiation

- Plot CFE vs *x* and *y* sensor position at **40 pb^{-1}**:



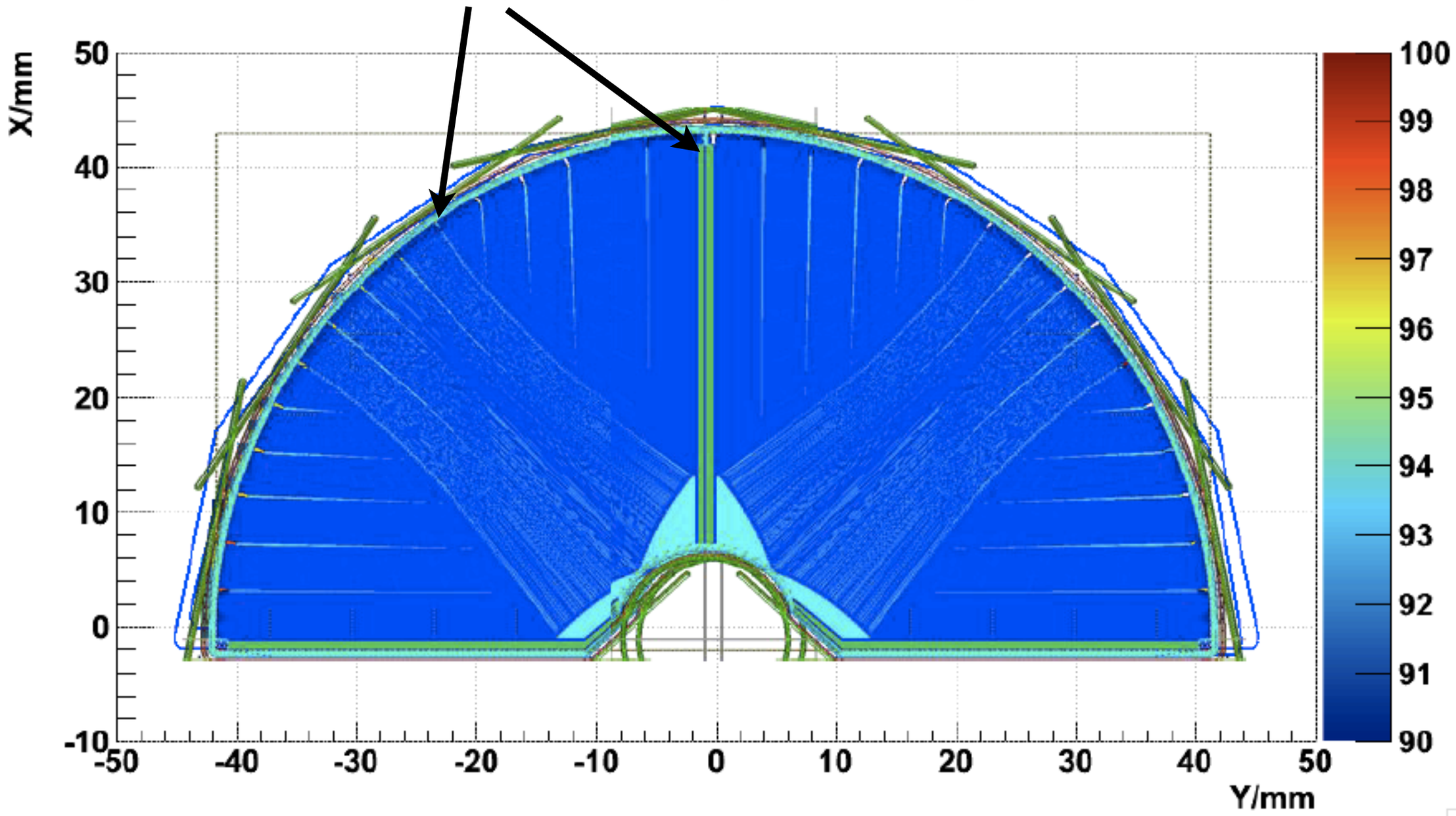
2D CFE map **after** irradiation

- Repeat at **600 pb^{-1}**:



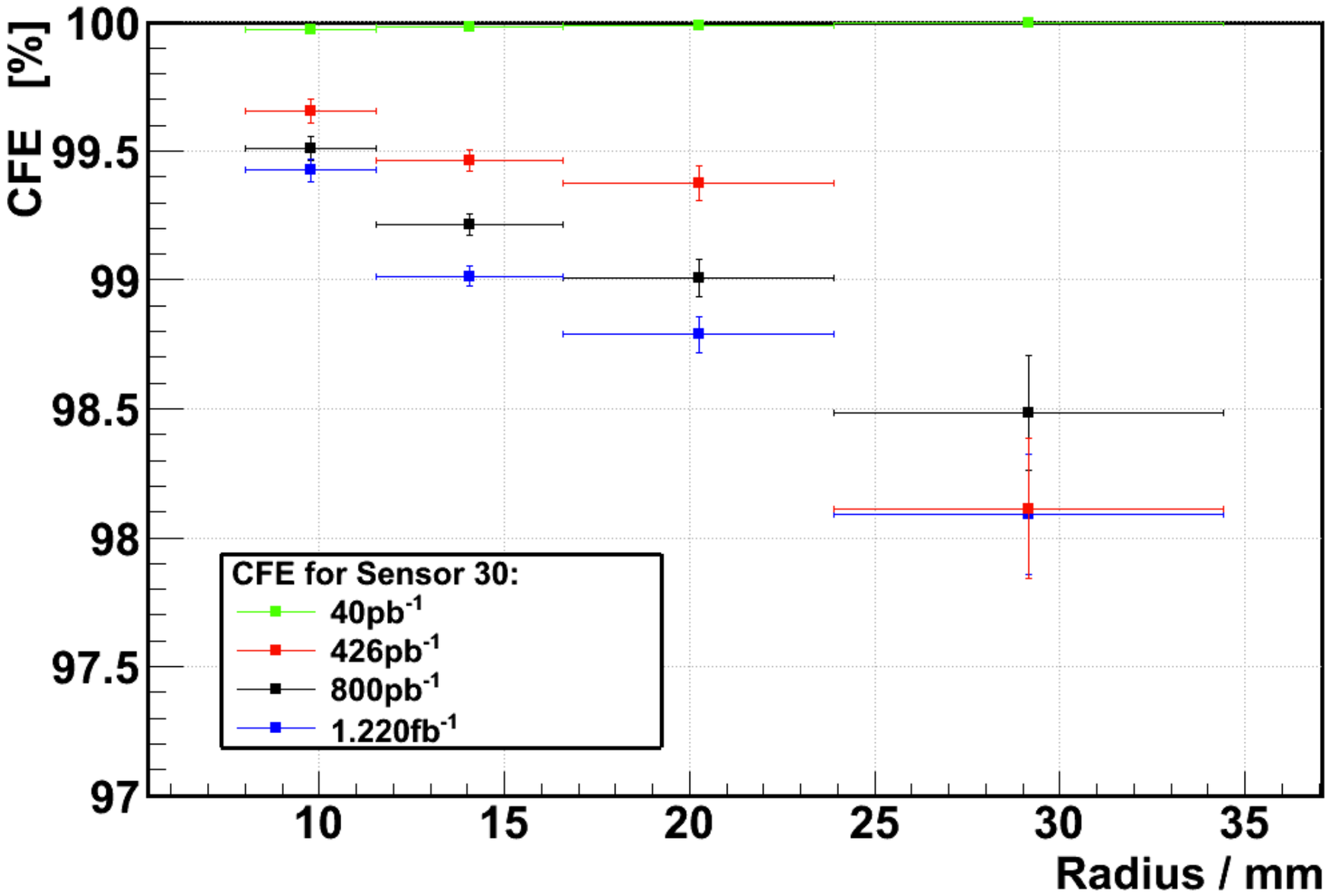
Routing line coverage

- **Higher CFE** located at gaps in routing line coverage:



Radial dependence

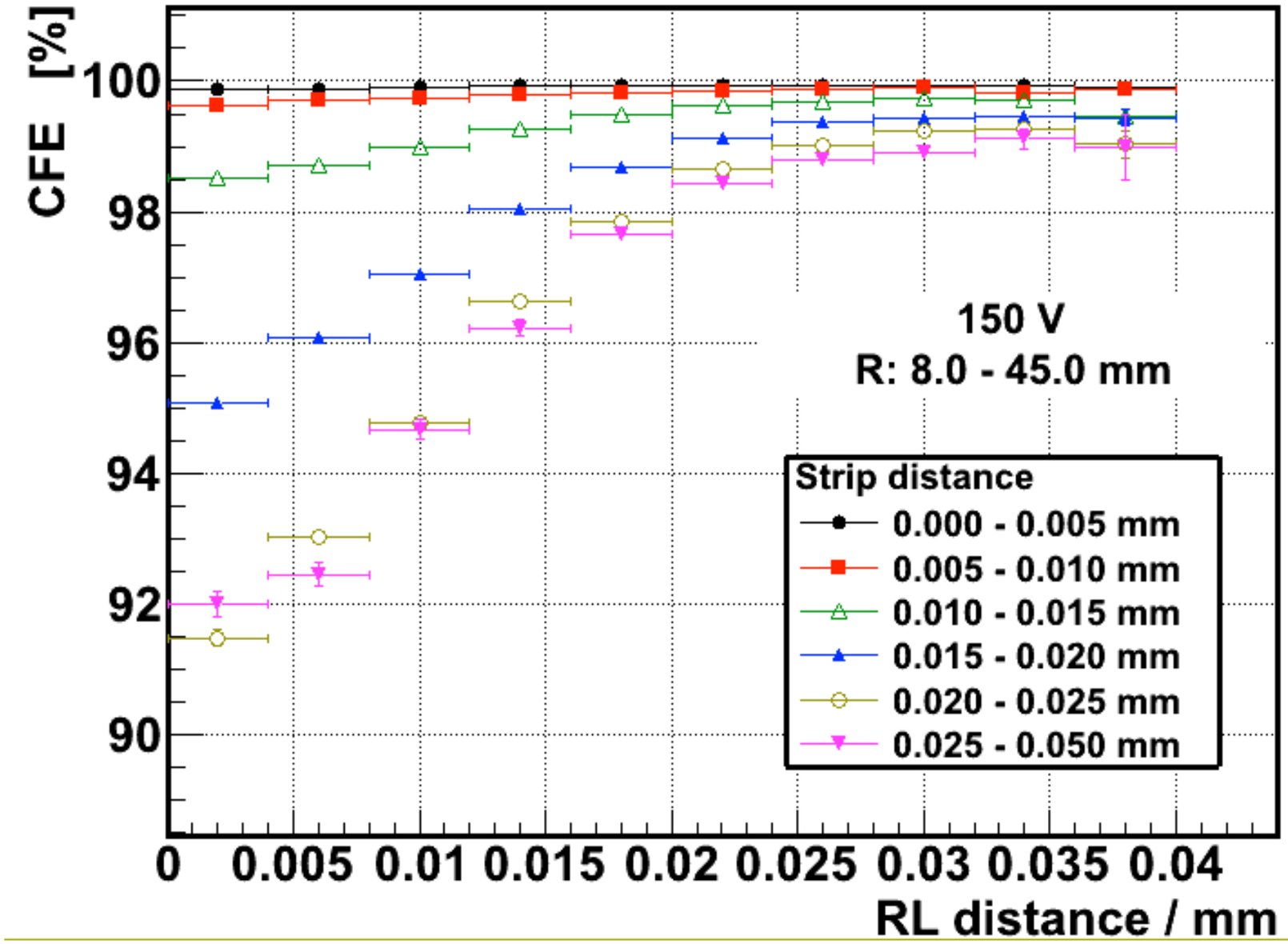
- CFE drop appears to depend on **radius**:



CFE vs radius for a single R sensor (30) colour coded by fluence

Radial dependence

- However more important is **distance to routing line** and **distance to strip:**

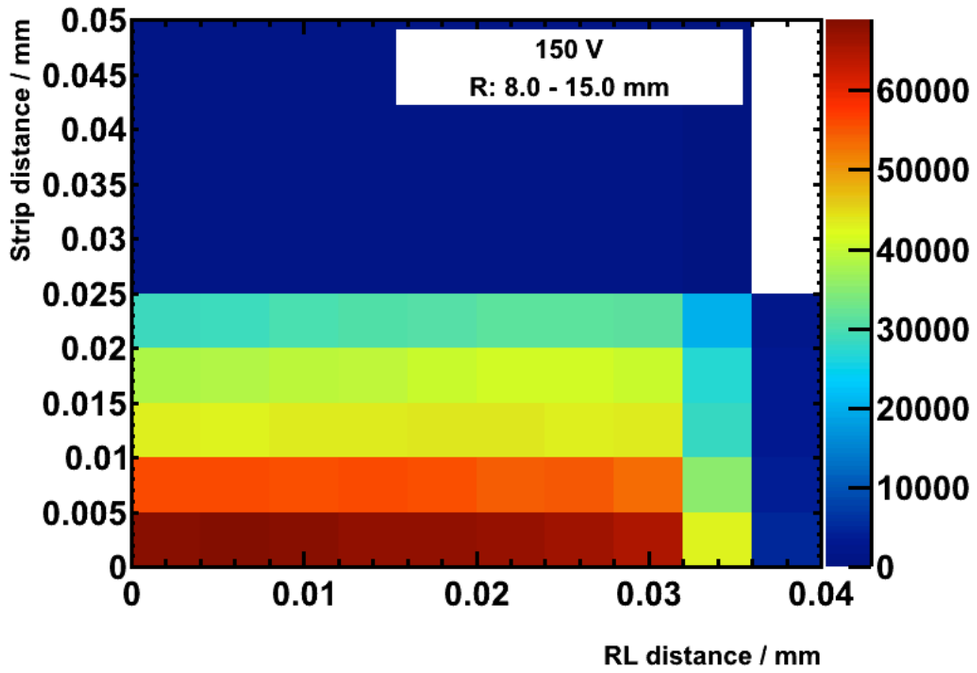


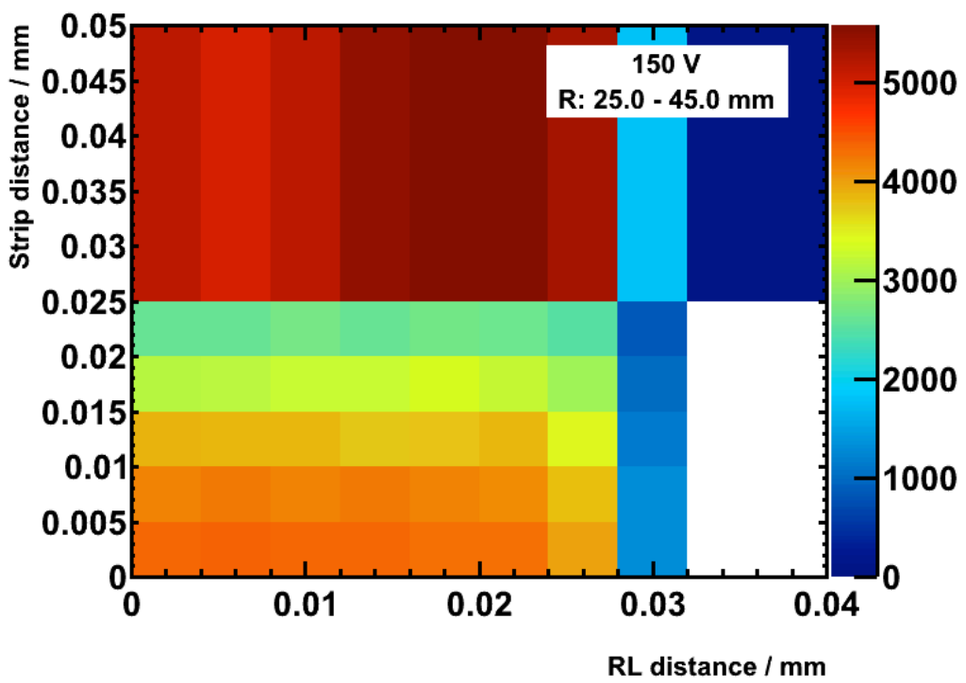
CFE vs routing line distance for a single R sensor (30) colour coded by strip distance after 1.220 fb^{-1}

Radial dependence

- CFE is lowest when **close to a routing line and far from a strip**

- At large R this is more likely to occur due to sensor geometry:

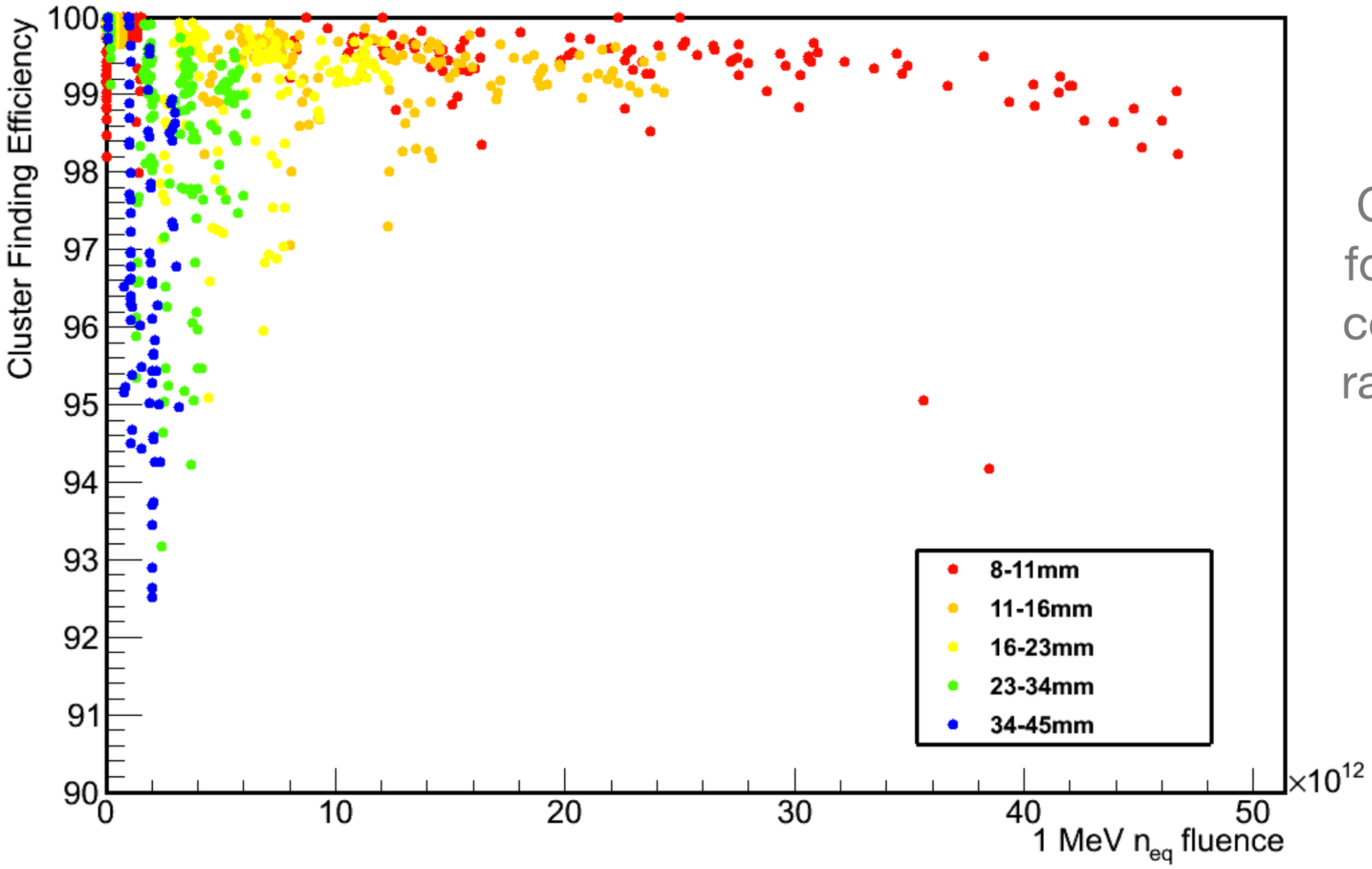




Bin yields for CFE as a function of routing line distance and strip distance for a single R sensor (30) for different radius regions

Fluence dependence

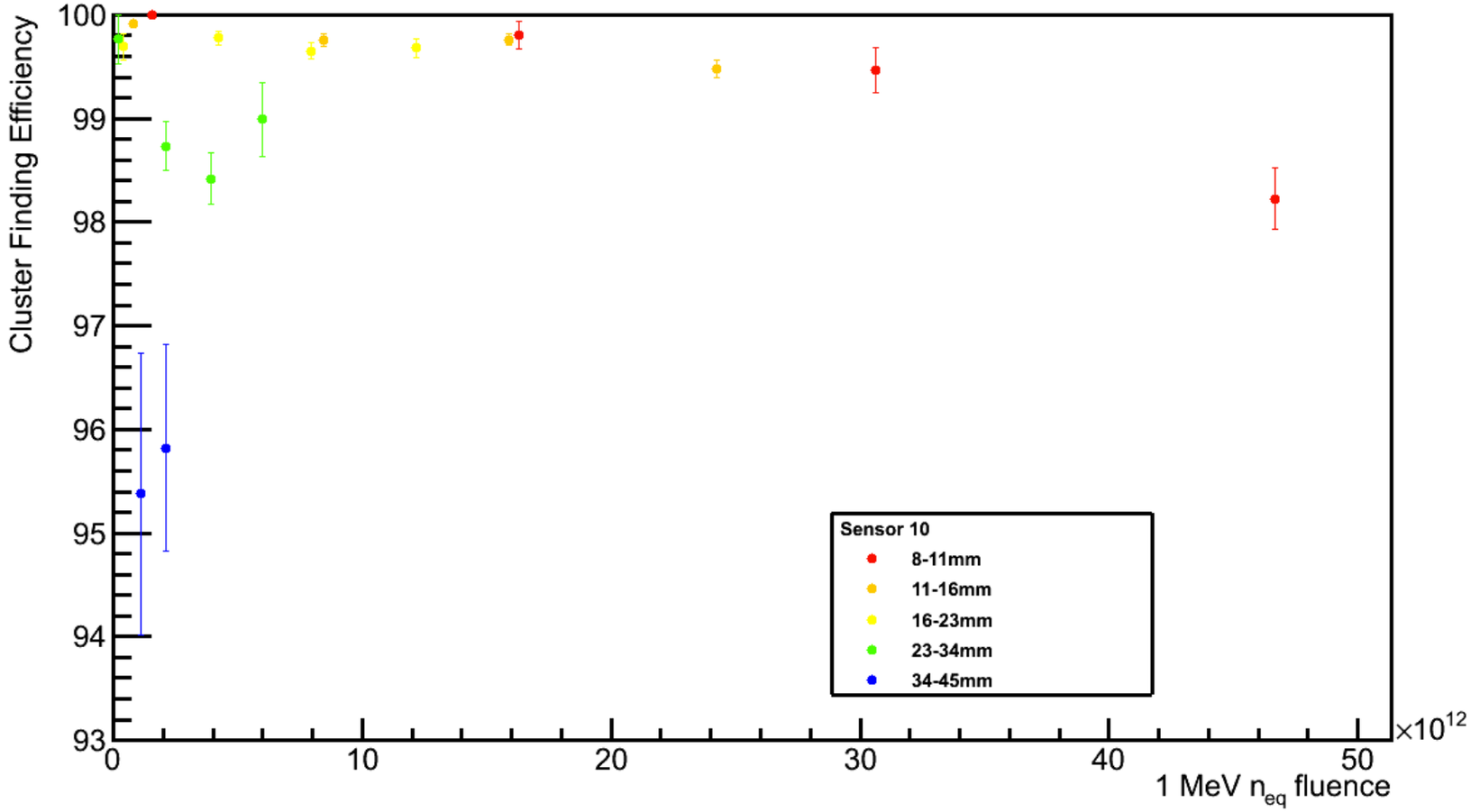
- With fluence all regions of the sensors are experiencing a gradual drop in CFE



CFE vs fluence for all R sensors colour coded by radial position in the sensor

Fluence predictions

- With further fluence **expect CFE drop to continue**
- Extrapolate based on current trend

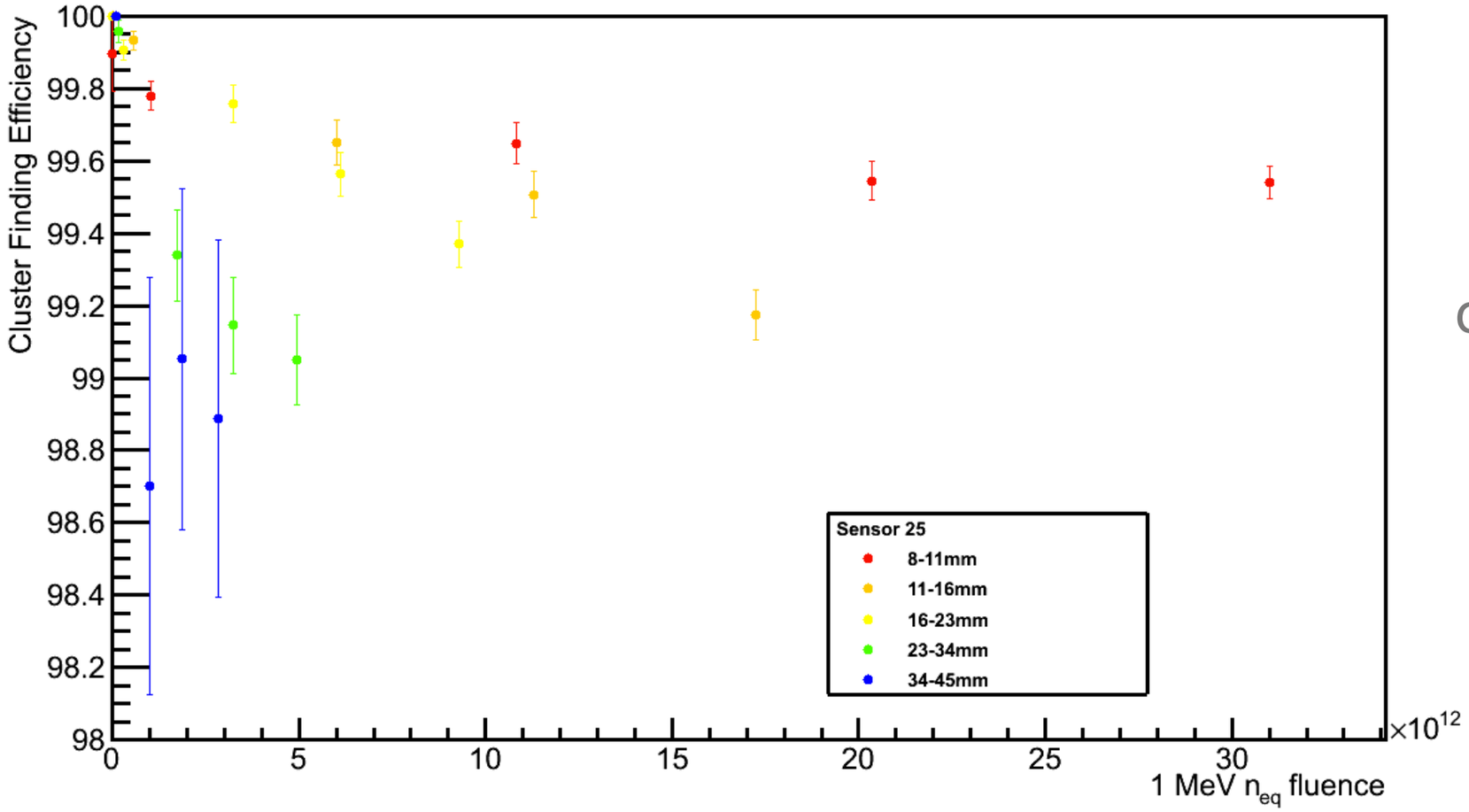


CFE vs fluence for a single R sensor (10) colour coded by radial position in the sensor

Fluence predictions

- Each sensor experiences **different fluences** in different regions due to *z* position in the VELO

- Expected magnitude of effect varies between 96% - 98% at 2.4fb^{-1}

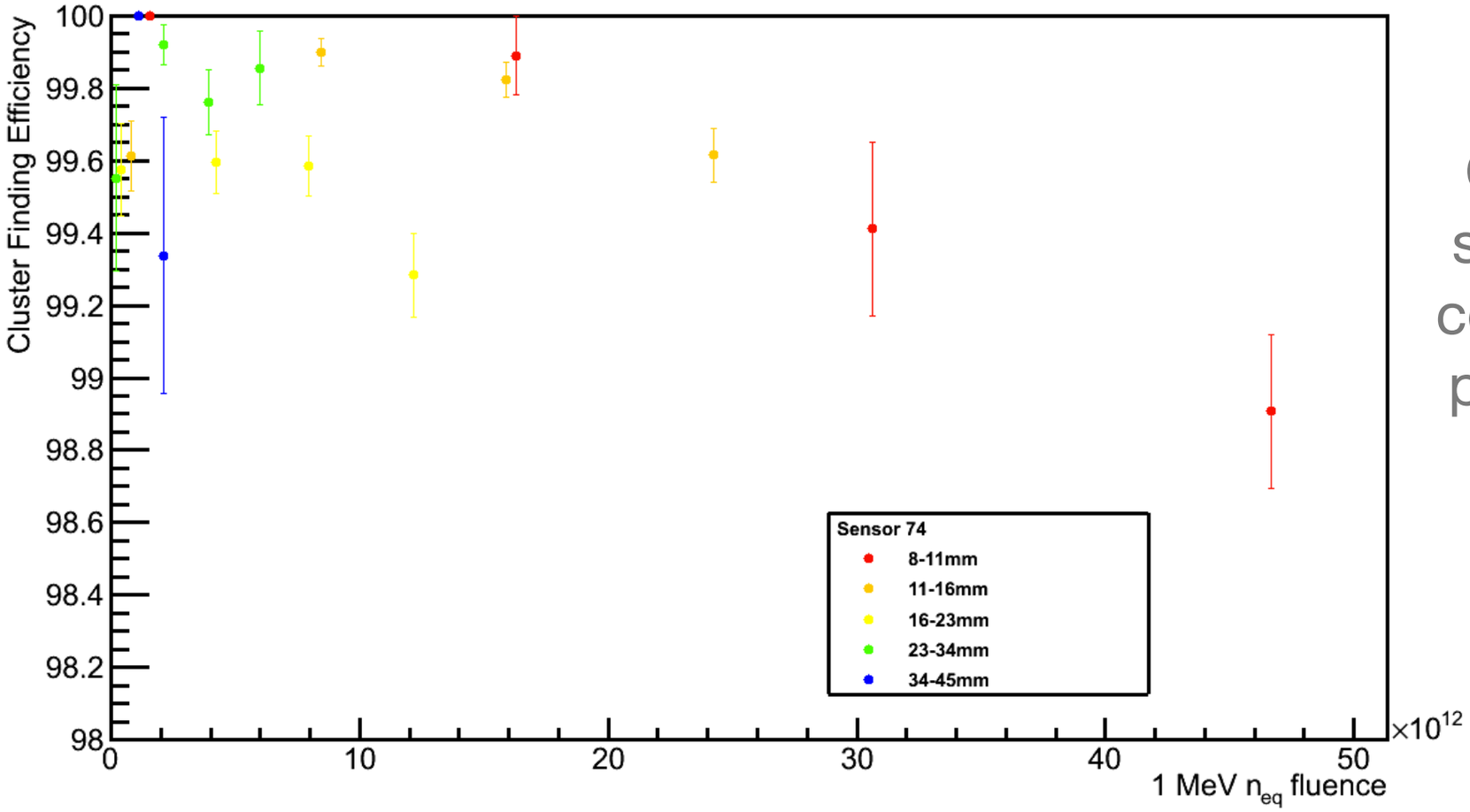


CFE vs fluence for a single R sensor (25) colour coded by radial position in the sensor

Fluence predictions

- However this effect is also seen in **phi sensors**

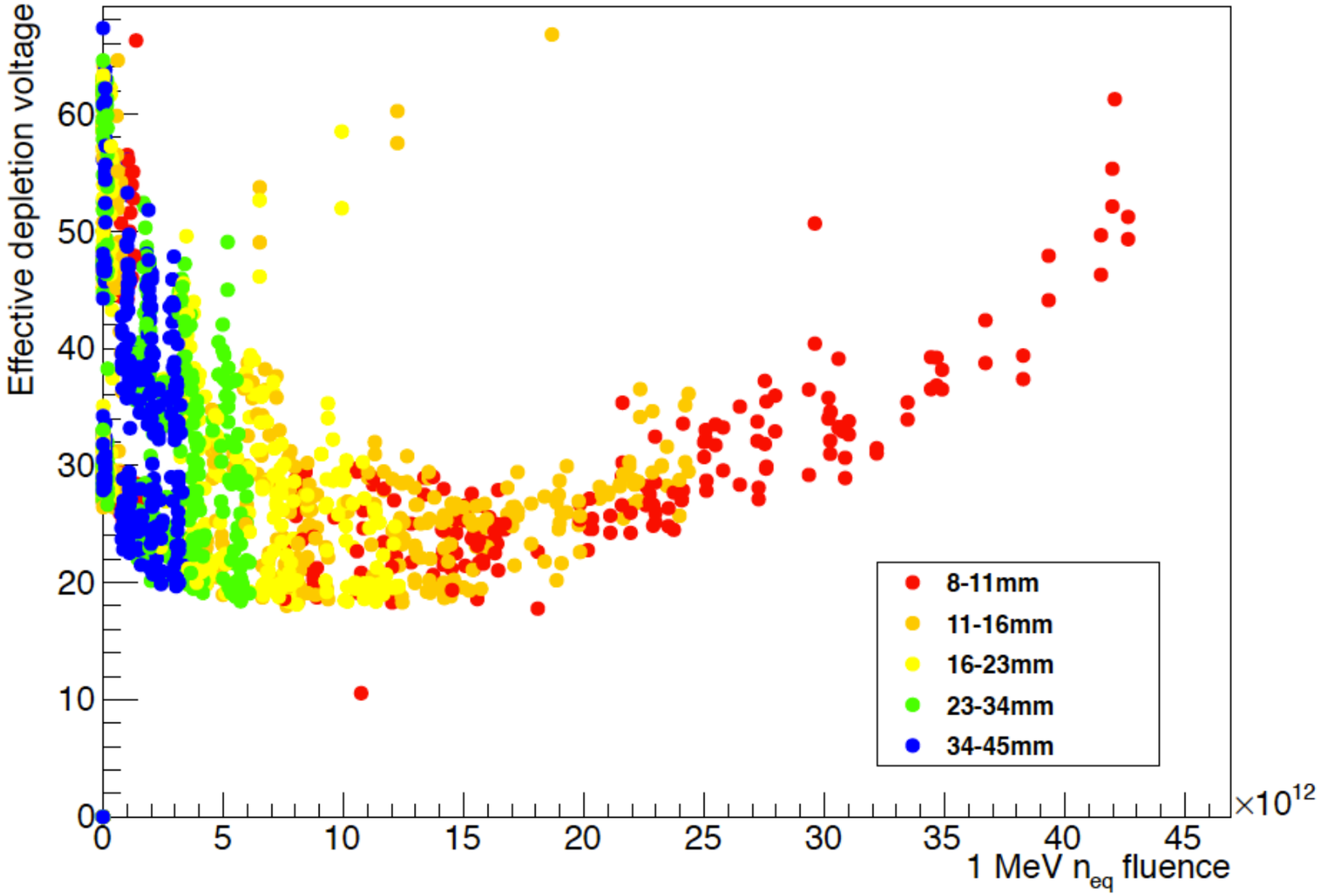
- Effect **not attributed** to charge coupling with routing lines, possibly due to sensor not being fully depleted



CFE vs fluence for a single phi sensor (74) colour coded by radial position in the sensor

Voltage dependence

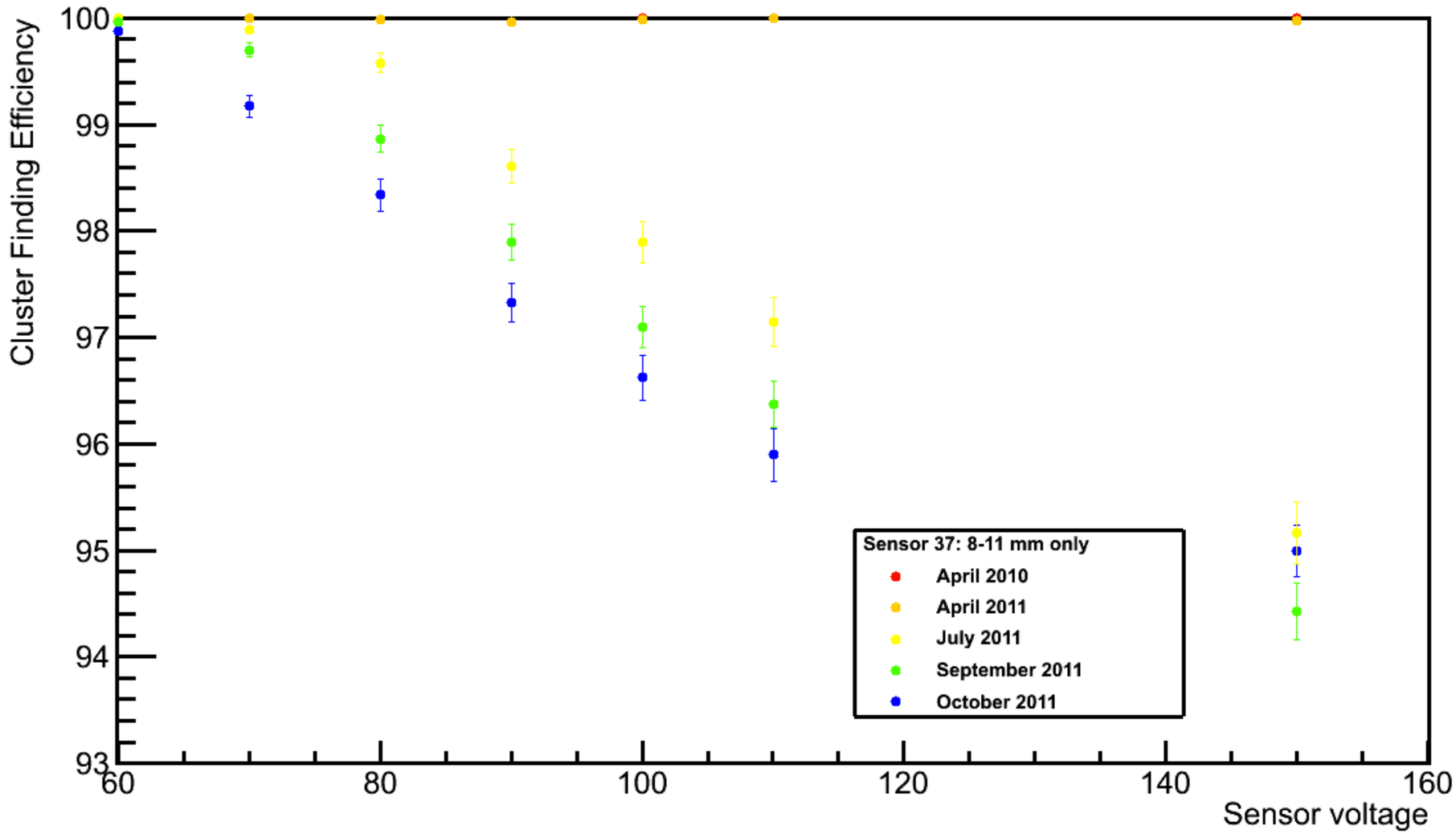
- With irradiation inner regions of sensors are **type inverting** and require a larger voltage to become fully depleted



Effective depletion voltage vs fluence for all sensors colour coded by radial position in the sensor

Voltage predictions

- In 2011 all sensors were at 150 V. Some sensors expected to require > 200 V in 2012 based on EDV extrapolations



CFE vs fluence for the inner region of a R sensor (37) colour coded by fluence

Voltage predictions

- Extrapolate based on current trend
- If CFE varies with voltage as expected, it may drop to as low as 90% in the inner regions of the sensors which are crucial for tracking performance
- Sensor operation voltages in 2012 need to be carefully considered to minimise this effect
- Further study with an upcoming dedicated scan

Outlook

- **Clear evidence** of charge loss to the routing lines in VELO R sensors
- Currently physics performance is unaffected (< 0.5%)
- Expected CFE to drop with further fluence and increased operation voltage
- Continue to investigate effect to best determine 2012 sensor voltages
- Also possible to change **clustering thresholds**

Backup

- Others are also studying double metal effects:

Novel Punch Through Protection (PTP)

PTP structures protect the AC coupling capacitors from large induced current caused by beam splash by routing the current to the bias ring.

measurement

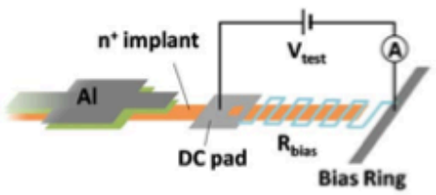
measure resistance between bias ring and DC pad by applying Vtest up to -150 V

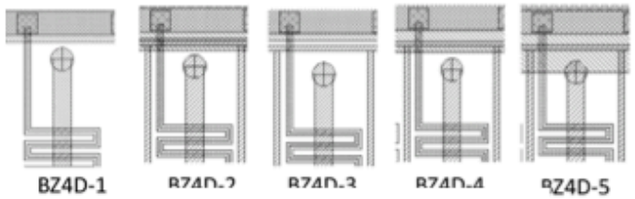
PTP structure

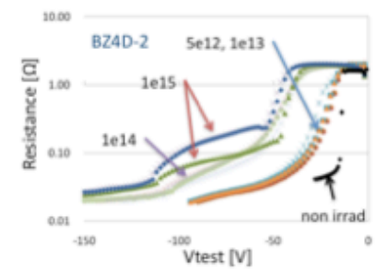
p-bulk, 320µm thick test sensor

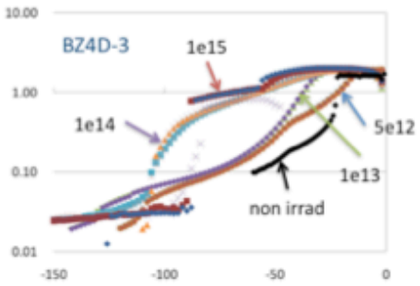
Bias ring Al width extension:

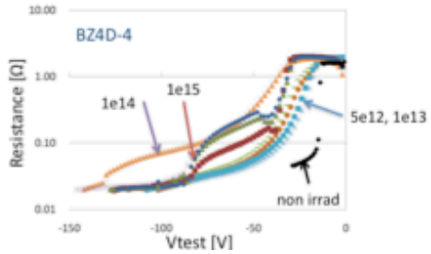
1 : No extension, No p-stop
2 : Up to p-stop
3 : No extension
4 : Over p-stop
5 : Full extension

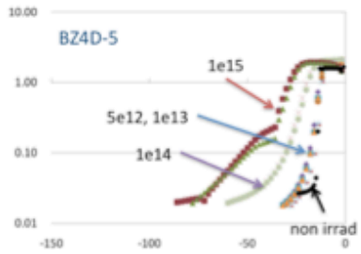












- Work done by: S. Mitsui, Y. Unno (Sokendai/KEK), Y. Ikegami, Y. Takubo, S. Terada (KEK), K. Hara, Y. Takahashi (Univ. Tsukuba), O. Jinnouchi, R. Nagai, T. Kishida (Tokyo Inst. Tech.), K. Yorita (Waseda Univ.), K. Hanagaki (Osaka Univ.), R. Takashima (Kyoto Univ. Edu.), S. Kamada, K. Yamamura (Hamamatsu Photonics K.K.)

- Potential input to future VELO simulation - work in progress