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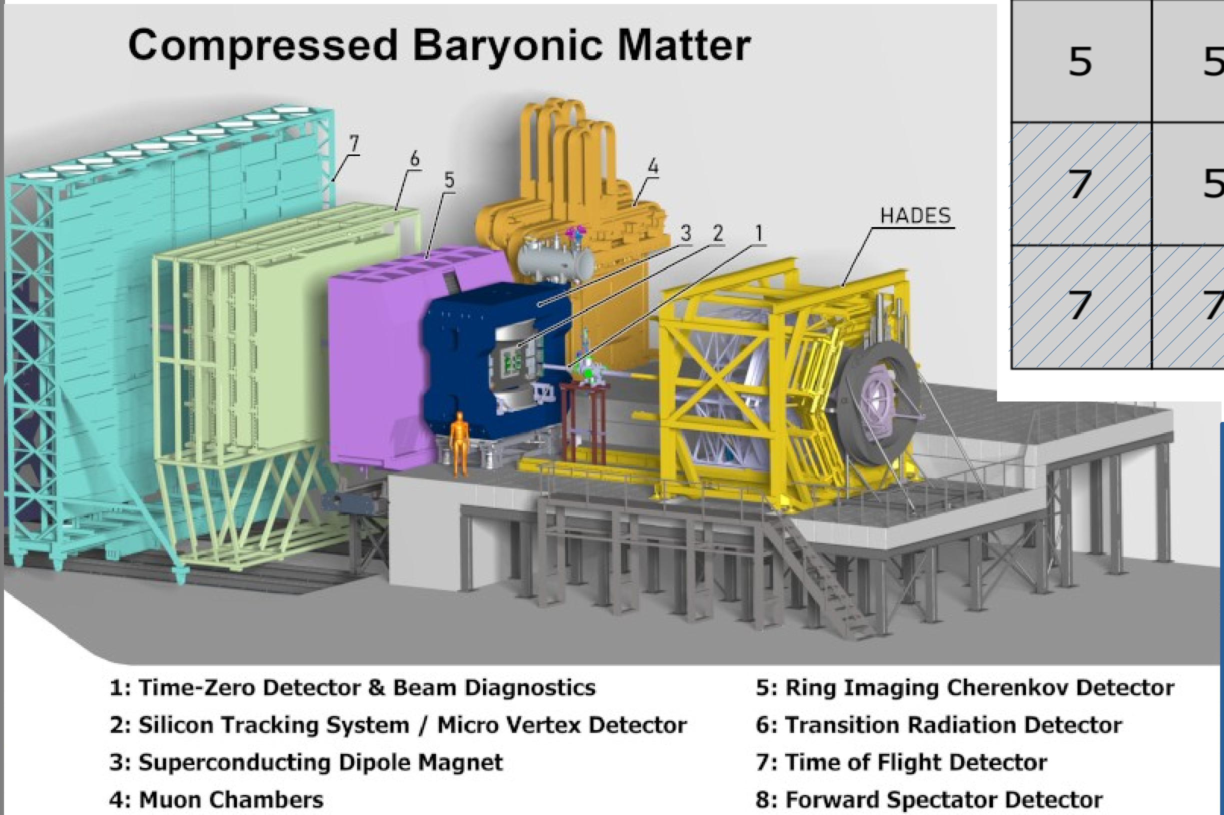
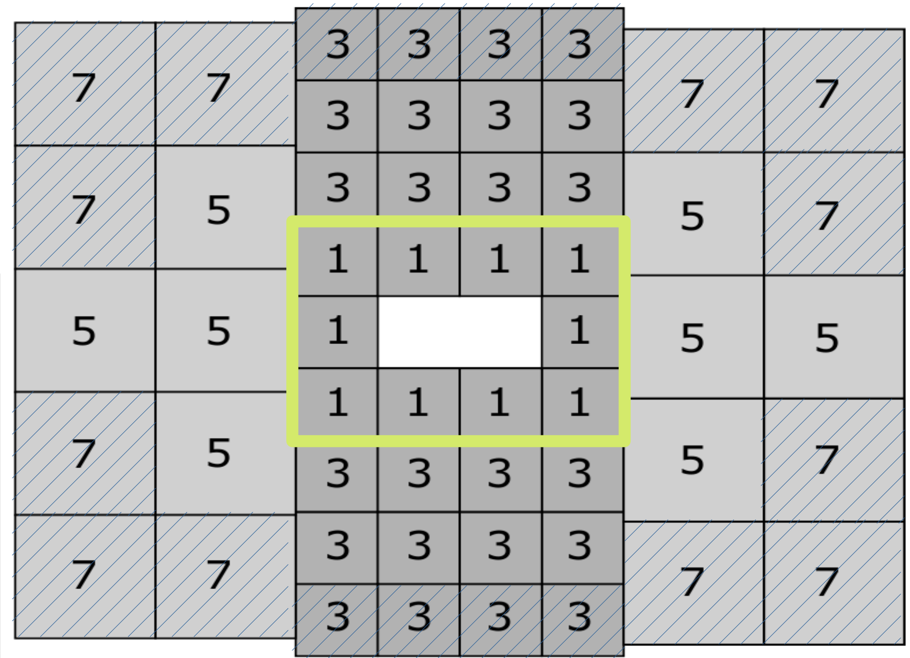
TRD2D status

Alex Bercuci

46th Collaboration Meeting
22nd October 2025
Lanzhou, China

The TRD2D @ CBM



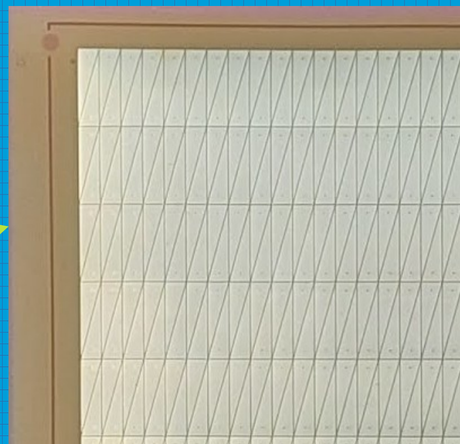


- **11.5 m²** read-out area (11.66)
- > **10⁵** read-out channels (115200)
- ≈ **3k** channels/detector (2880)
- 10 detectors x 4 layers

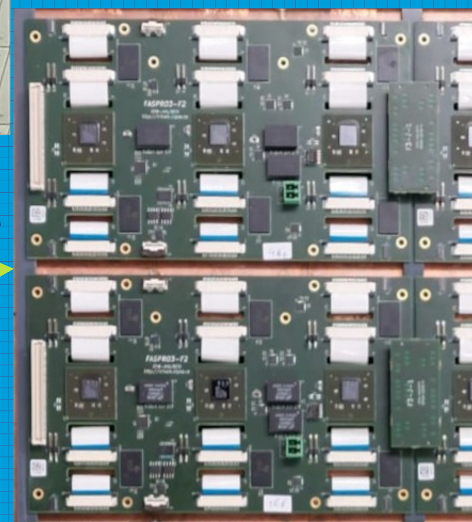
10^5 particles/cm²/s
≈ 100 µm x resolution
≈ 800 µm y resolution
e/π separation

Overview

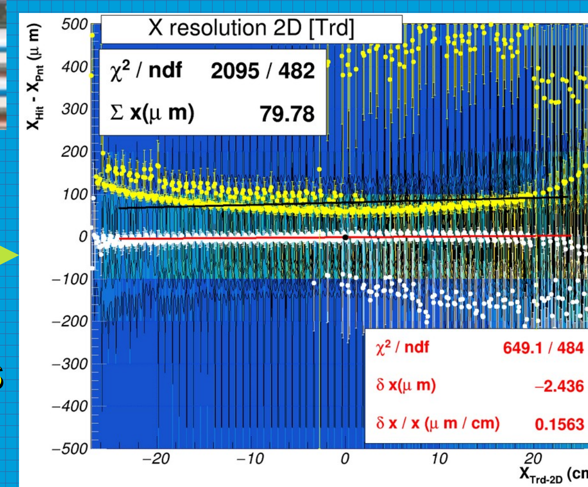
1. Chamber construction



2. FEE update



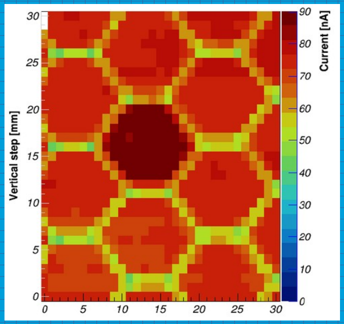
3. Data analysis

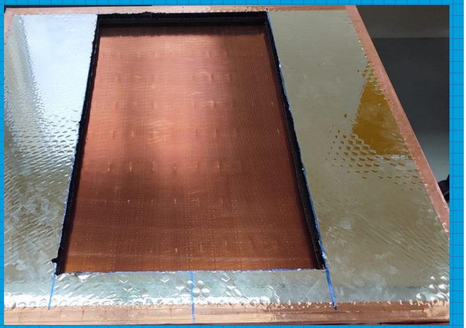


- 10 detectors x 4 layers
- > **10^5** read-out channels
- ≈ 100 µm x resolution
- ≈ 800 µm y resolution

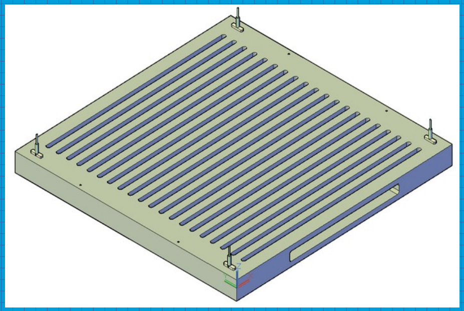
I. Chamber construction

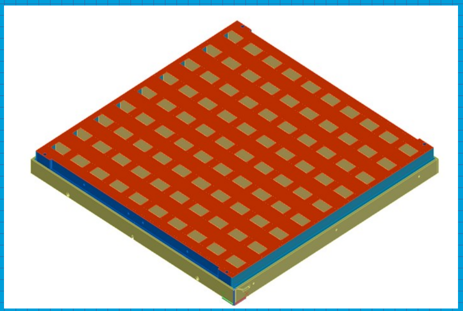
Prototype lessons

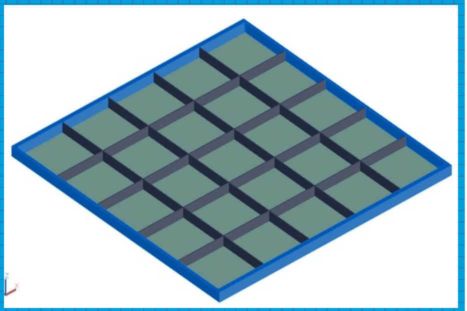




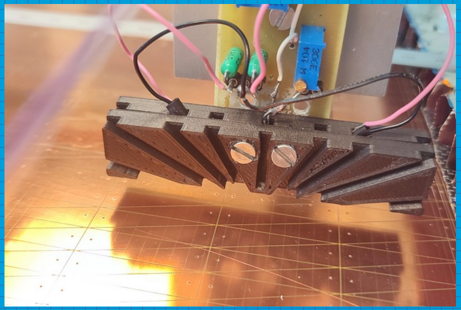
New designs

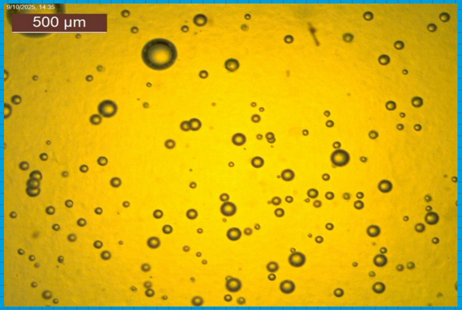


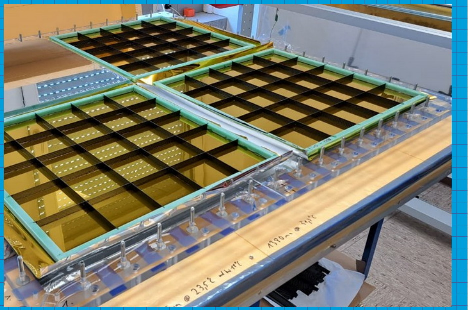




QA tools & procedures







Production

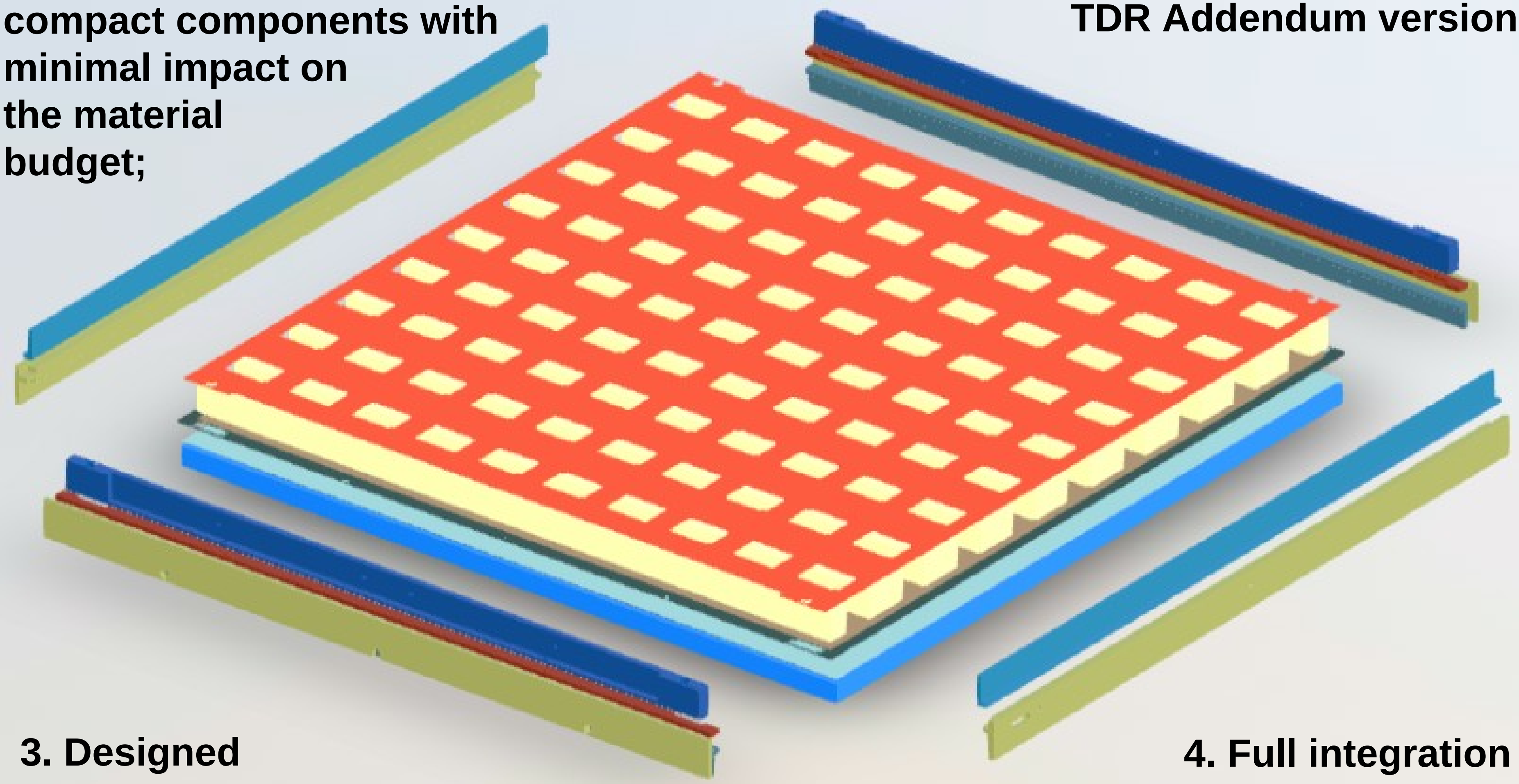
PRR / FoS

In progress Q2/26

Chamber design updates

1. Stronger, fewer & more compact components with minimal impact on the material budget;

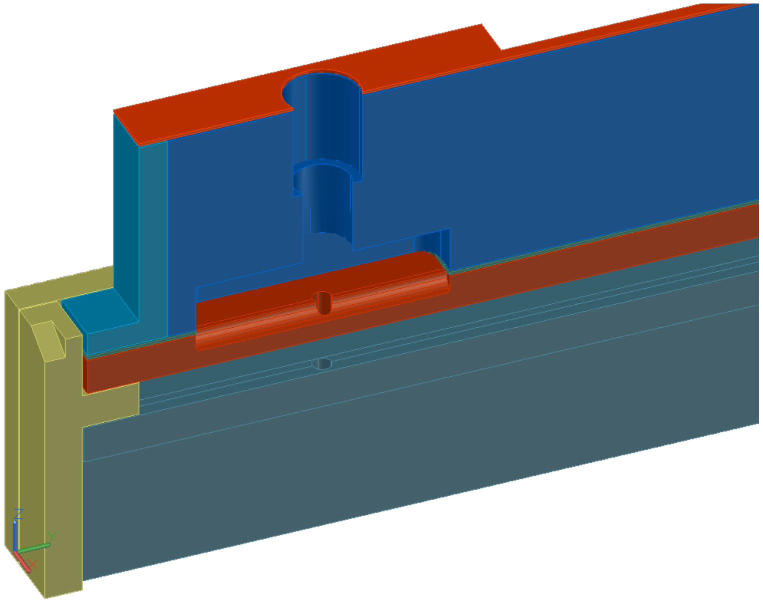
2. No critical modifications wrt. the TDR Addendum version;



3. Designed around the technology of assembly (devices, gluing, QA) for production;

4. Full integration with TRD-STD wrt. gas services (same flow resistivity) and TR detection.

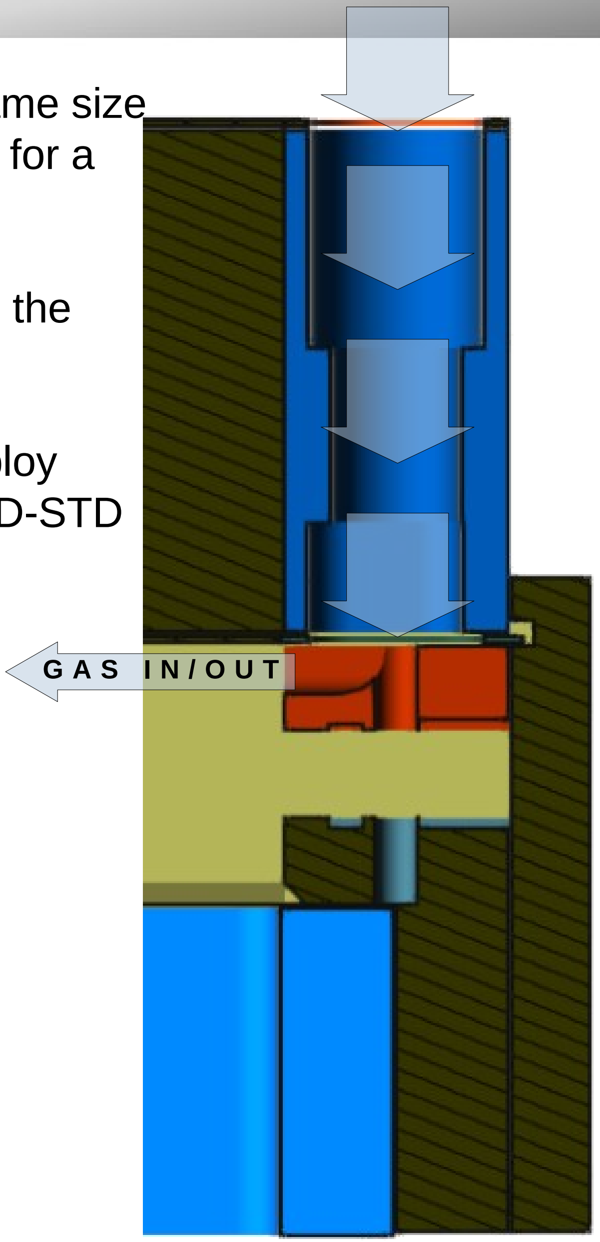
Chamber design updates



1. Gas inlets are of the same size as the TRD-STD, to allow for a unique gas system.

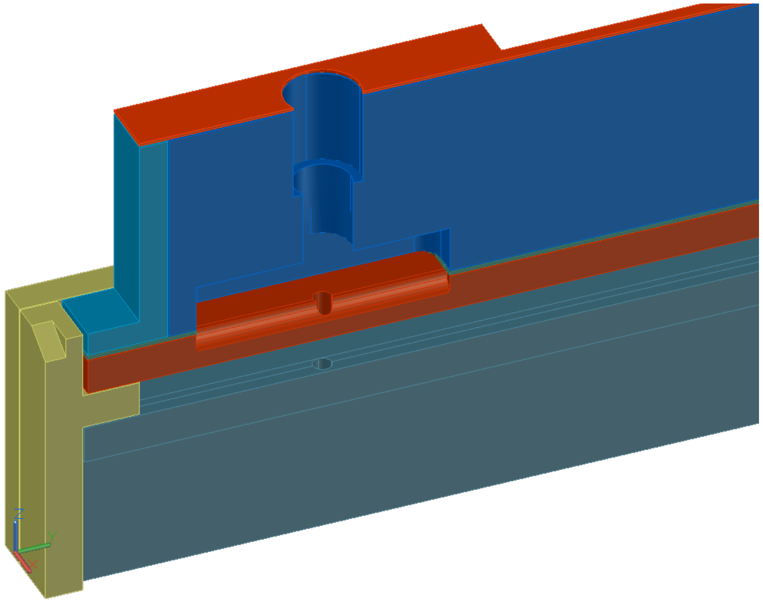
2. Avoid gas feed through the Pad-plane

3. Entrance windows employ the same structure as TRD-STD to provide same gas flow resistivity



https://indico.gsi.de/event/23197/#5-trd-2d-chamber-design-update

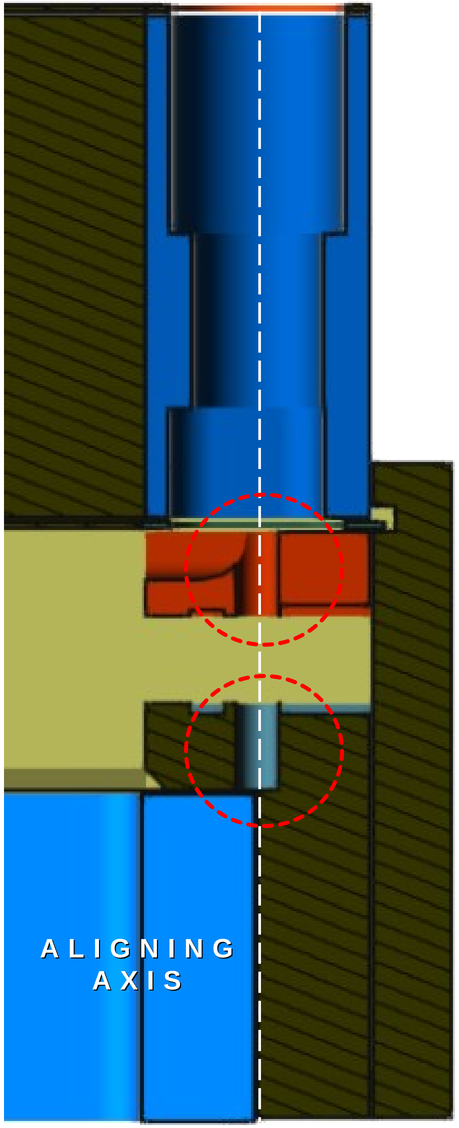
Chamber design updates



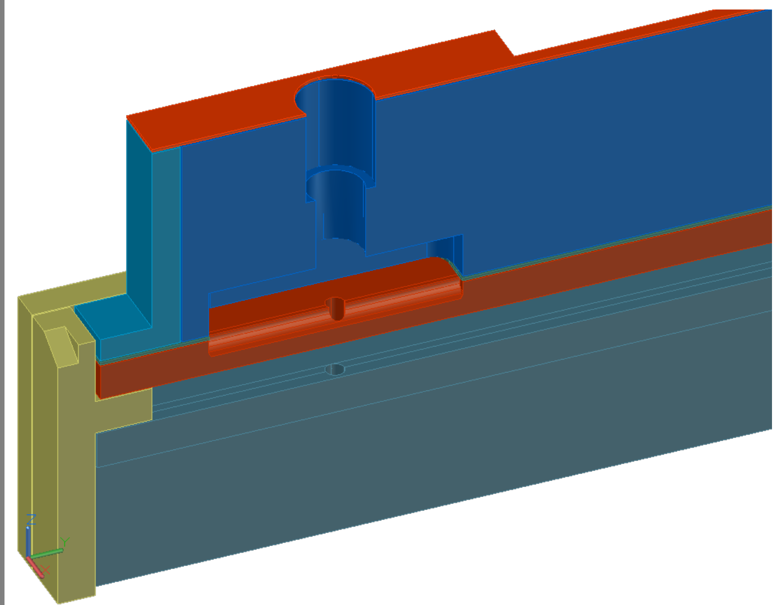
https://indico.gsi.de/event/23197/#5-trd-2d-chamber-design-update

1. A system of pin holes, aligned with the gas inlets are used together with a special device to align all components.

2. See S9 for its use during Assembly.



Chamber design updates

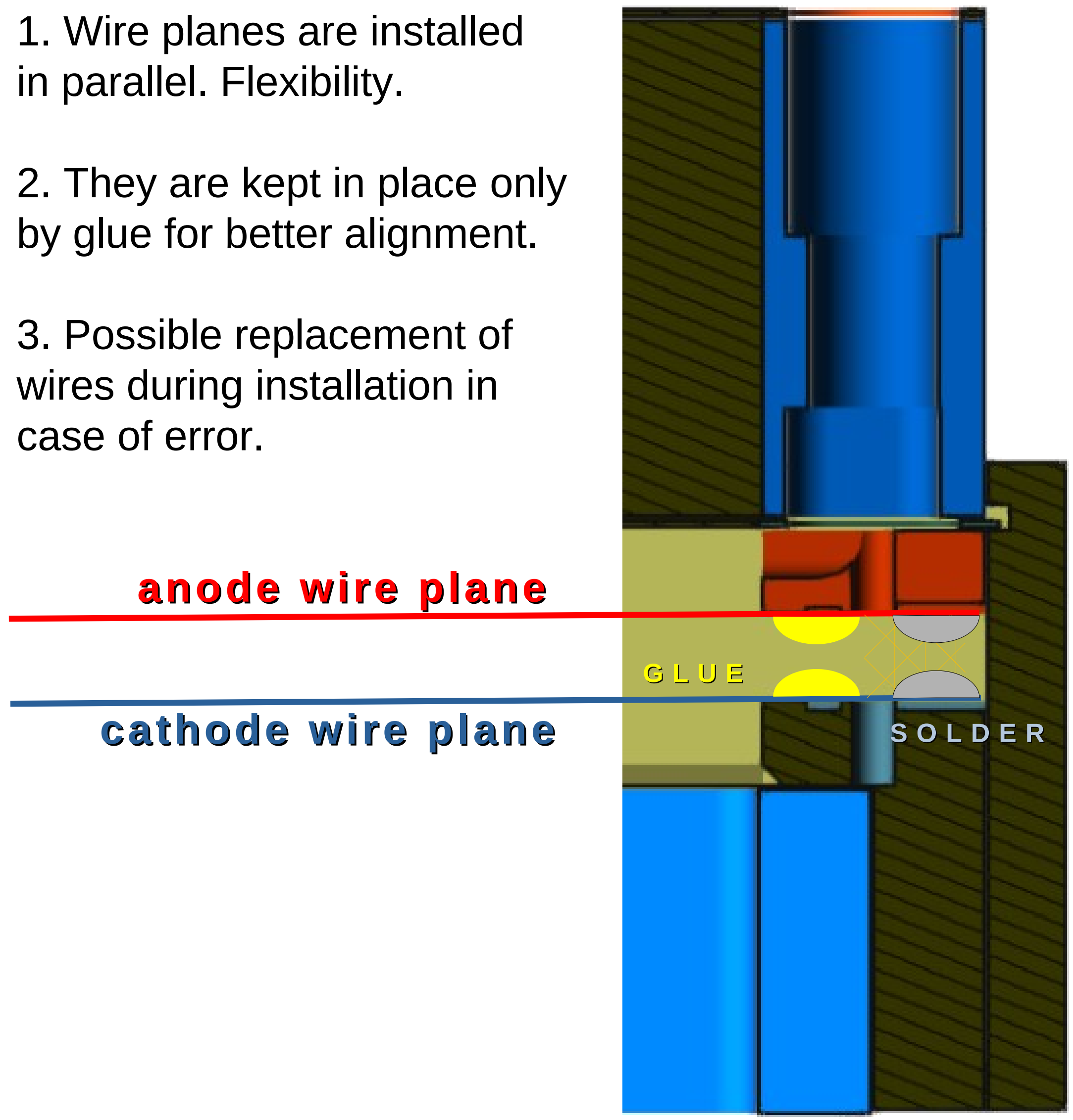


https://indico.gsi.de/event/23197/#5-trd-2d-chamber-design-update

1. Wire planes are installed in parallel. Flexibility.

2. They are kept in place only by glue for better alignment.

3. Possible replacement of wires during installation in case of error.



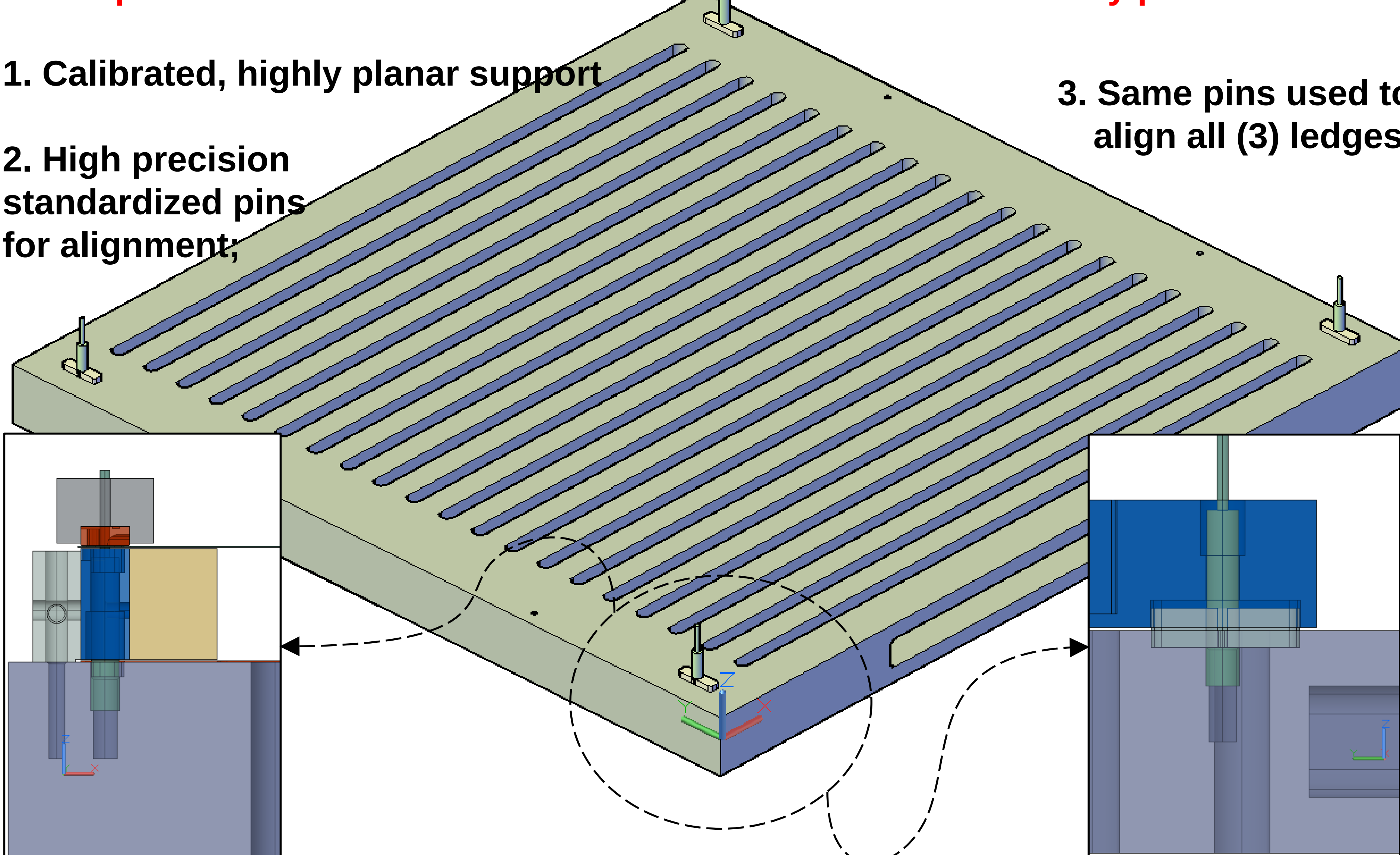
Assembly device

Adapted from the similar device used in the TRD-STD assembly procedure

1. Calibrated, highly planar support

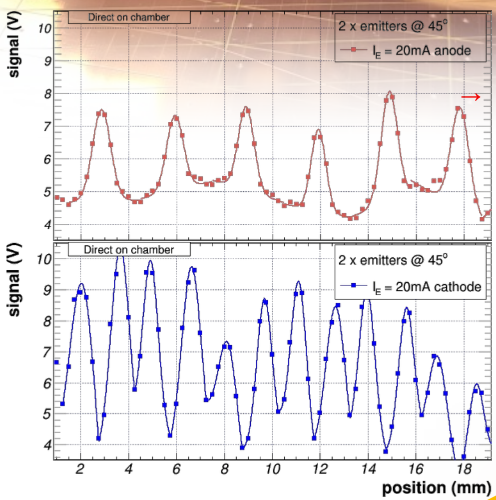
2. High precision standardized pins for alignment;

3. Same pins used to align all (3) ledges.



Tools and procedures

→ The Uni Muenster efforts to build a new, reliable were joined by the Buch team.
→ A prototype for the analog stage was developed and successfully tested in real conditions.
→ Positions and wire tensions for both anode and cathode electrodes were measured.

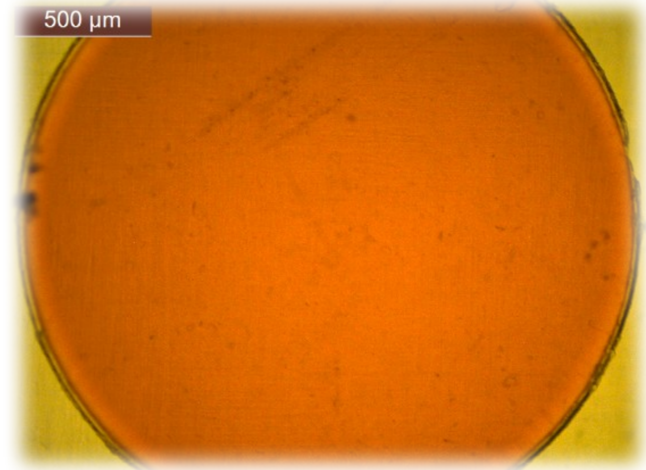


https://indico.gsi.de/event/23101/#2-electronic-integration

wire QA device

Gluing technology

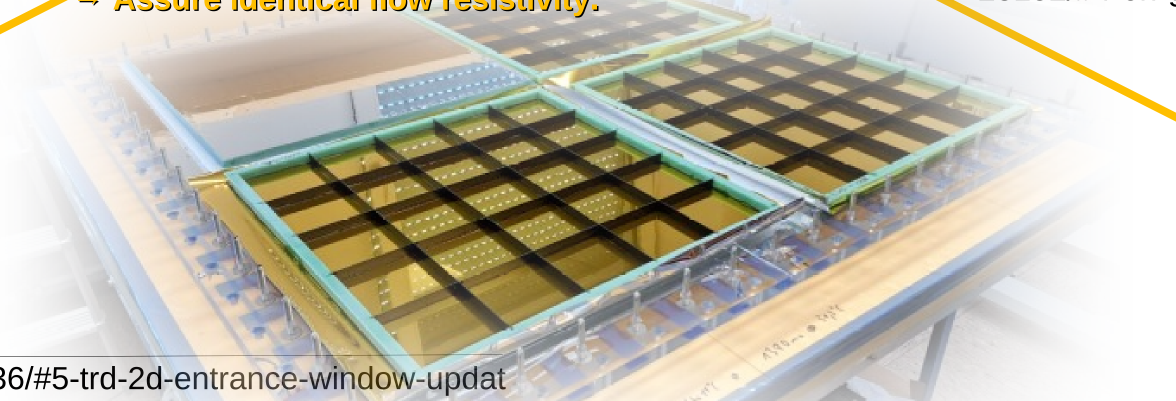
entrance window assembly



→ The spacers are borrowed from the RPC where they are used for spacing the glass planes.
→ Diameter 2mm x Height 170µm
→ Self adhesion layer for easy installation on the support.

https://indico.gsi.de/event/23152/#4-on-glueing-processes-in-cham

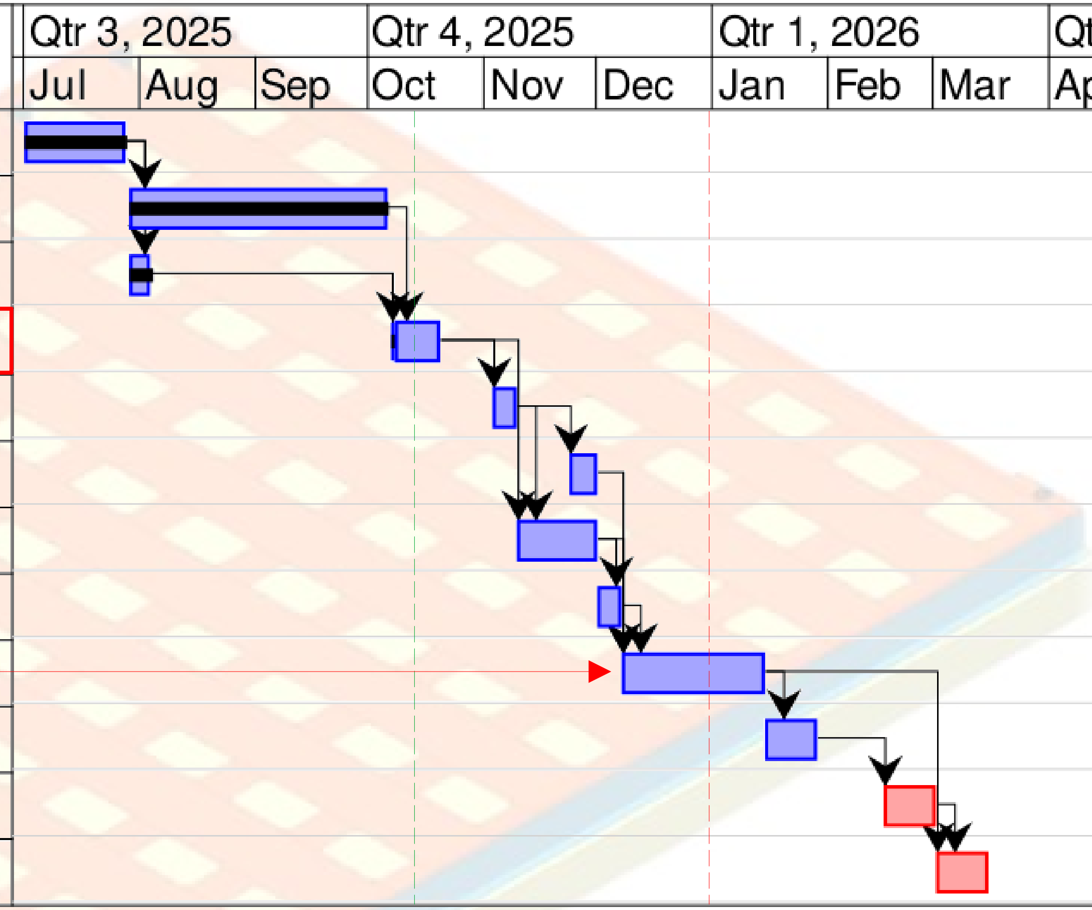
→ foil gluing on the same stretcher (Uni Muenster) as for the TRD-STD detectors.
→ Assure identical flow resistivity.



https://indico.gsi.de/event/23236/#5-trd-2d-entrance-window-updat

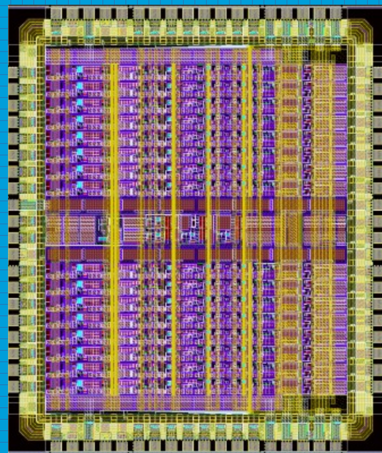
Chamber production milestones

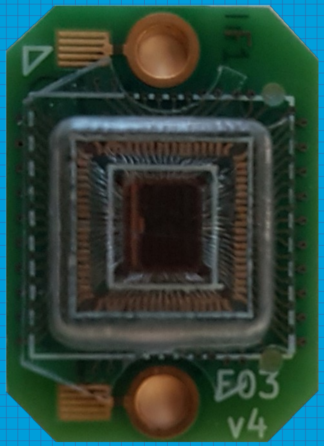
	Name
1	Internal evaluation of design
2	Design update
3	Company contacts / offers
4	Secure financial
5	Produce entrance window
6	Glue foil Uni Muenster
7	Produce device assembly
8	Produce TRD2D components
9	TRD2D assembly
10	TRD2D QA Bucharest
11	TRD2D QA Muenster
12	TRD2D QA GSI

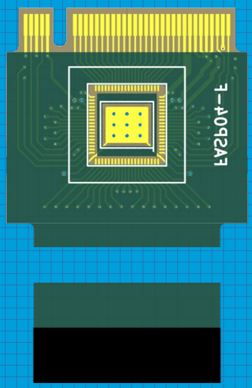


II. FEE updates

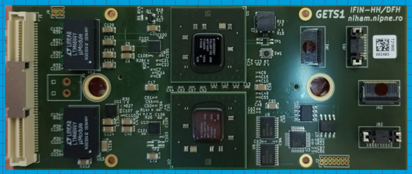
FASP ASIC Production & Bonding



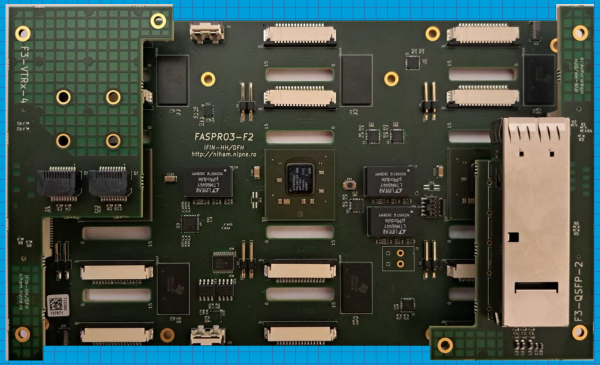




FEB designs



6xFASP @ mCBM 21&22



12xFASP @ mCBM 25

To be continued

QA tools & procedures

In progress

Production

In progress

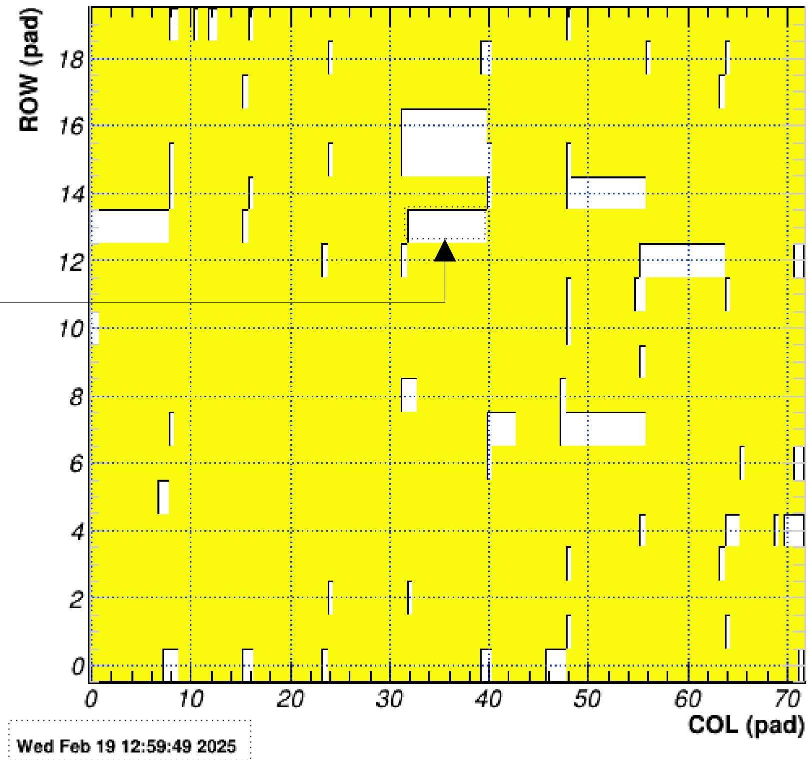
FEB

1. ASIC – FASP Production

→ Test production (0.2k) / *wire bonding* > 90% dice (+bonding) efficiency (mCBM 21-24)

→ Test production (0.5k) / *flip-chip bonding* (mCBM 25)

- → ~ 80% bonding efficiency (first batch)
- → ~ 50% bonding efficiency (second batch) !!
- → further problems when bonded to FEB

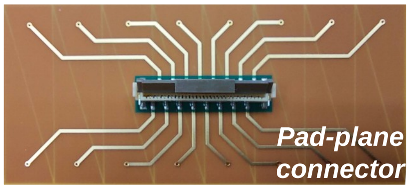


2. ASIC Engineering run

- → ~ 200% (17k) of the CBM demand

3. New concept ASIC bonding

→ New substrate + wire bonding (correlated with changes in the pad-plane)



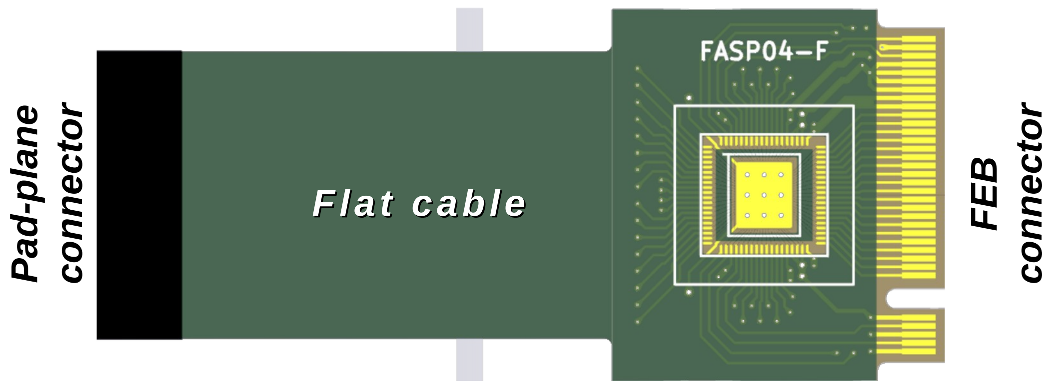
- → design ready
- → engineering in progress (Hybrid Swiss)
- → production and testing Q1/26

4. FEB updates

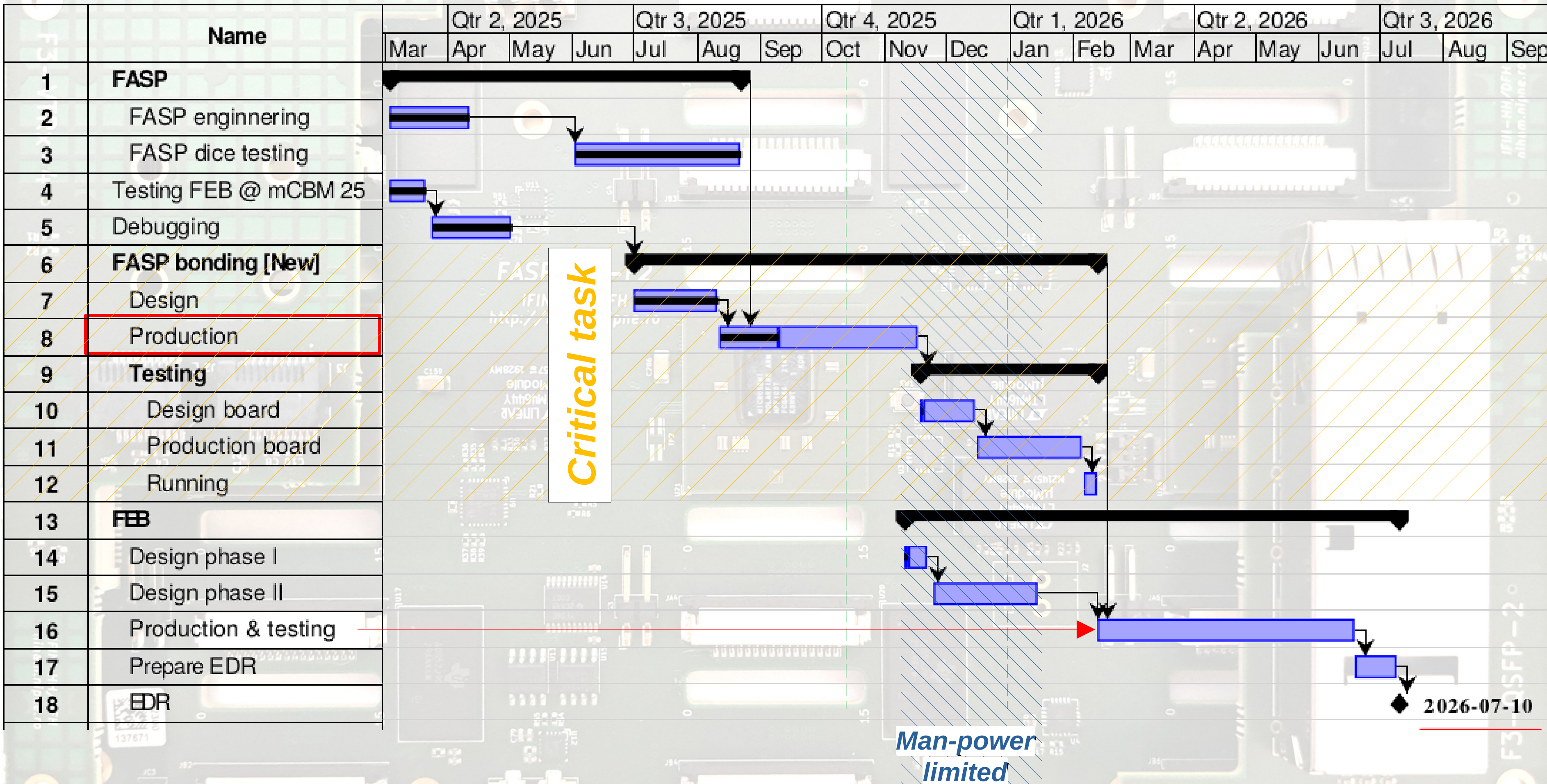
→ reduced component cluttering

→ increased redundancy

→ improvements in DAQ (CDR)

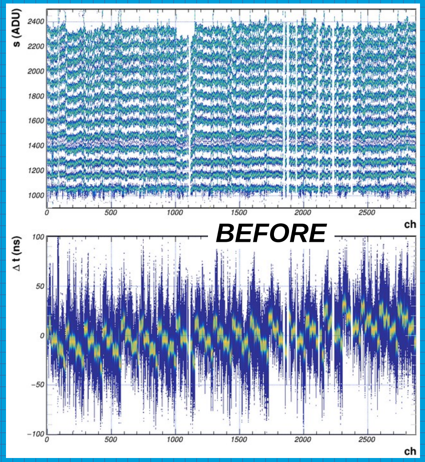


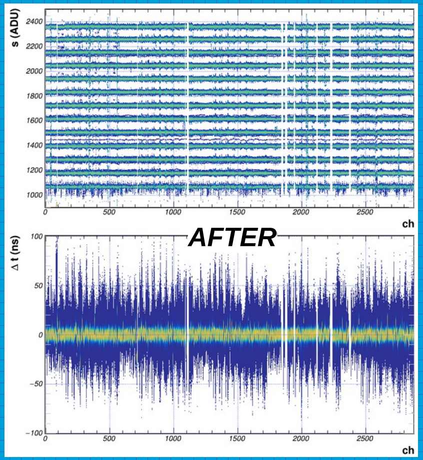
FEE production milestones

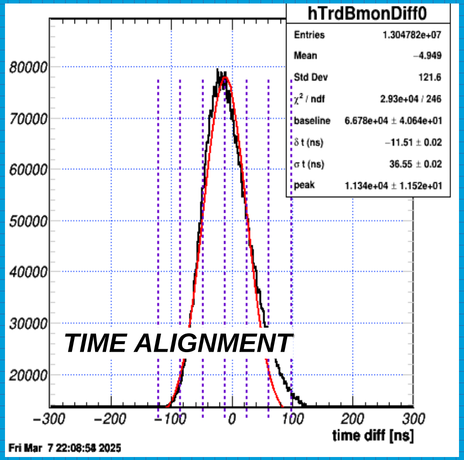


III. Data analysis

FEB calibration

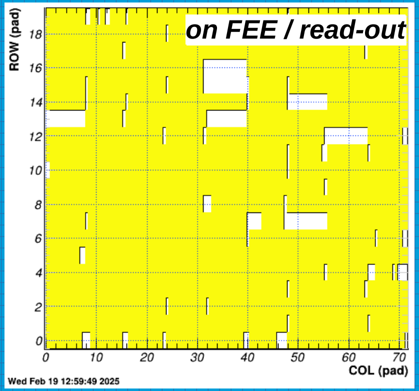


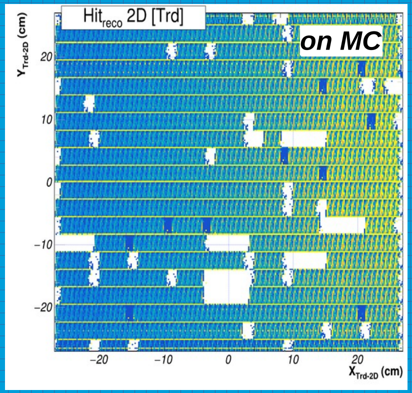


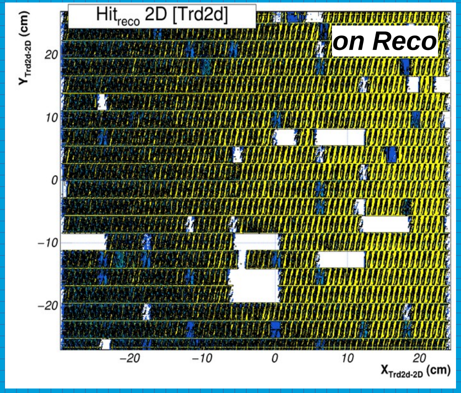


DONE

Read-out and Channel masking







DONE

Position Reco & Resolution

Position reference → [alignment]
Systematic effects (Cl. Size) → [realistic MC]
Error parametrization (Pulls) → [STS + MC]

CM 46 → milestone Q2/26

Energy Reco & Resolution

PID reference → [ToF tracking]
→ [secondary vertices]

in progress
milestone Q2/26

Position reference definitions
alignment

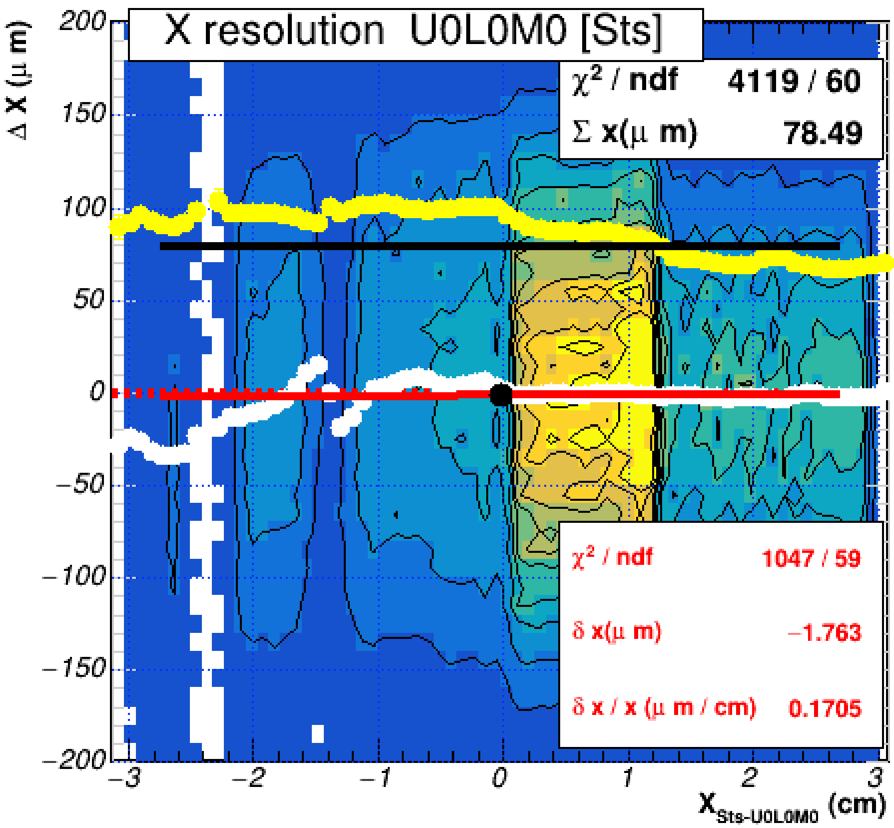
*Basic plots used for this detector alignment ("open box" approach)**

→ *ΔX = X_{Hit} – X_{Trk} ;*

→ *mean of ΔX(X_{Hit}) ; alignment;* ***systematics (white/red)*****

→ *sigma of ΔX(X_{Hit}) ; error parametrization;* ***uncertainty (yellow/black)*****

Au-Au
Beam 1.23A GeV
Interaction mbias
mCBM
Run 3604



Info encrypted in such figure

→ describe **only #real_objects**

→ reference : anchor **position from geometry**

→ residual misalignment

→ x direction δx = -1.76 μm

→ z direction 17.97 cm x 0.17 μm/cm → δz = 3.06 μm

→ linearity of the systematics

→ for x > 0 system behaves as expected

→ **combined uncertainty (Σx) of track extrapolation (σx_{Trk}) and STS hit (σx_{Hit});** $\Sigma^2 x = \sigma^2 x_{Trk}(p, ...) + \sigma^2 x_{Hit}$

→ **Σx = 78.49 μm dominated by the track**

→ **uncertainty depends on sensors combination and track quality.**

https://indico.gsi.de/event/23052/#4-sts-alignment-with-3-hit-sts

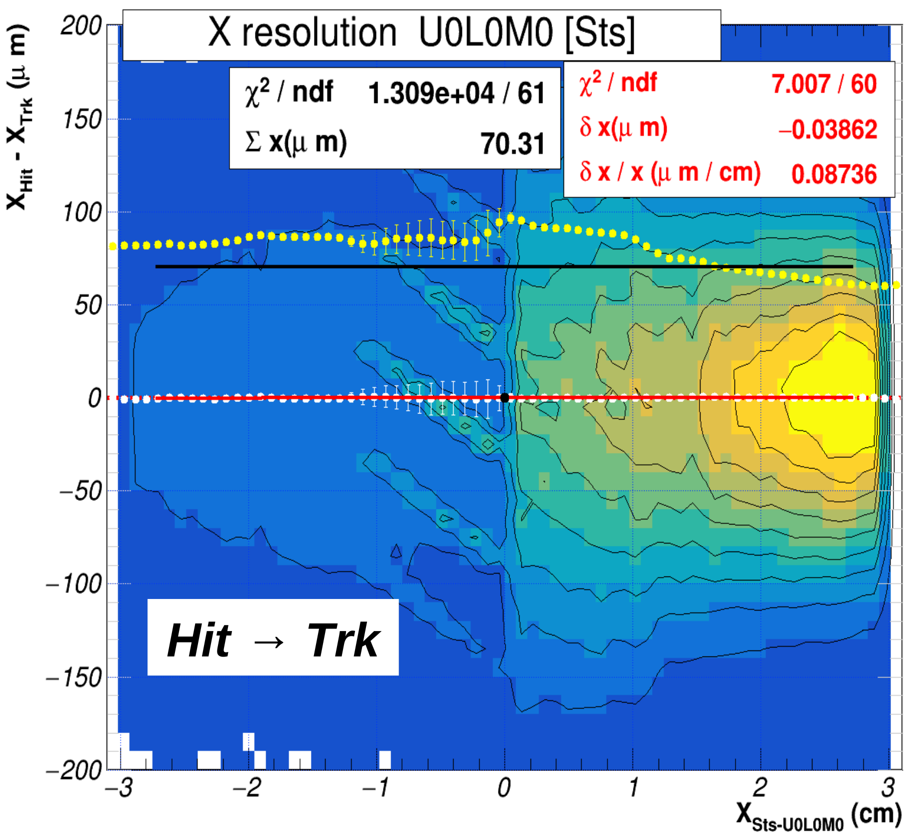
*) More complete and detailed results are presented in the back-up slides at the end of this talk.

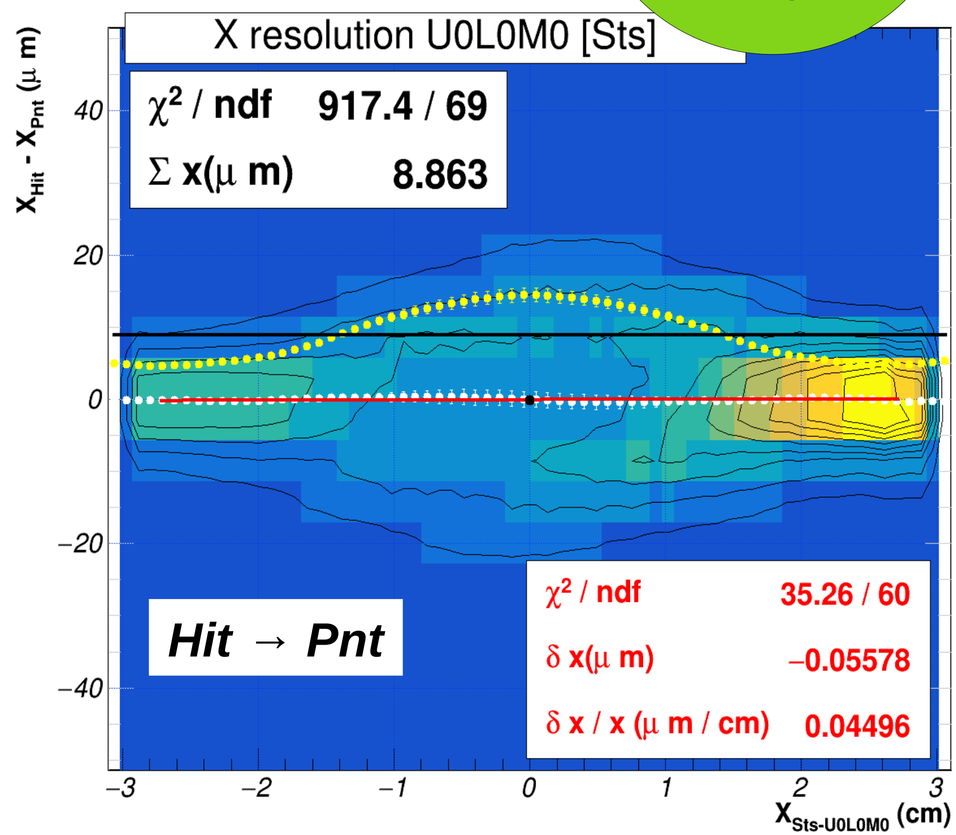
**) The color code is also meant for the back-up slides

Position reference definitions
residual mis-alignment influence

Au-Au
Beam 1.23 AGeV
Interaction mbias
mCBM
MC

Do the same game with perfect alignment
→ indirect access to uncertainty info
- → [3604]**Σx** = **78.49 µm**; [MC]**Σx** = **70.31 µm**; **+11% difference !!**
- → [MC]**Σx** = **8.86 µm** intrinsic average resolution ?!
- → uncertainty dependence on (θ, φ) smeared out by reco/tracking.

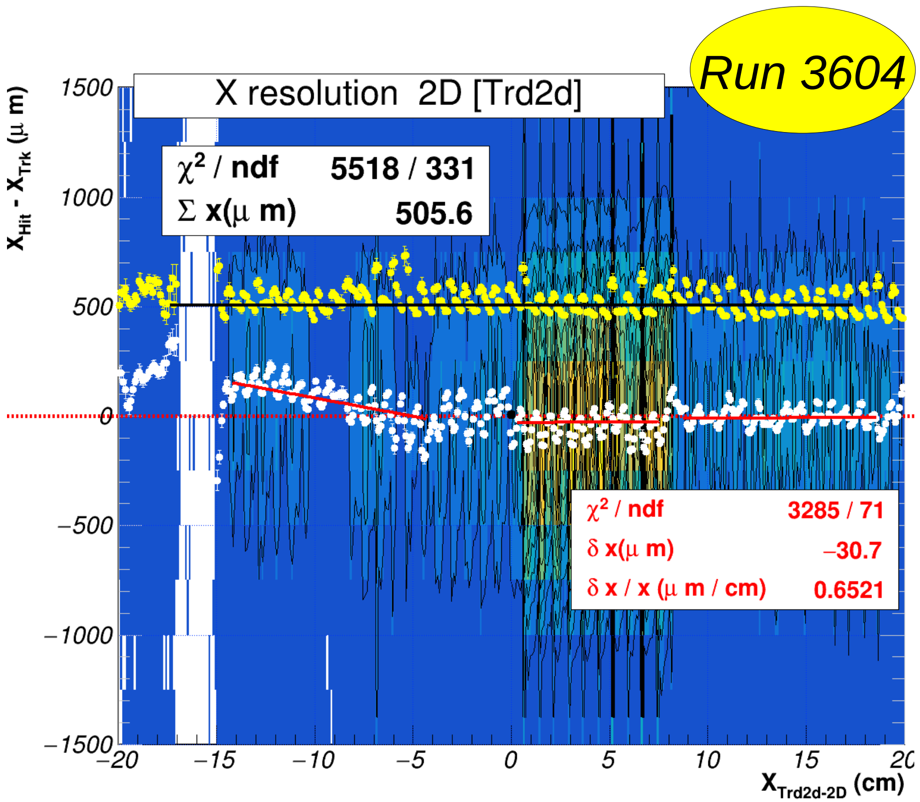


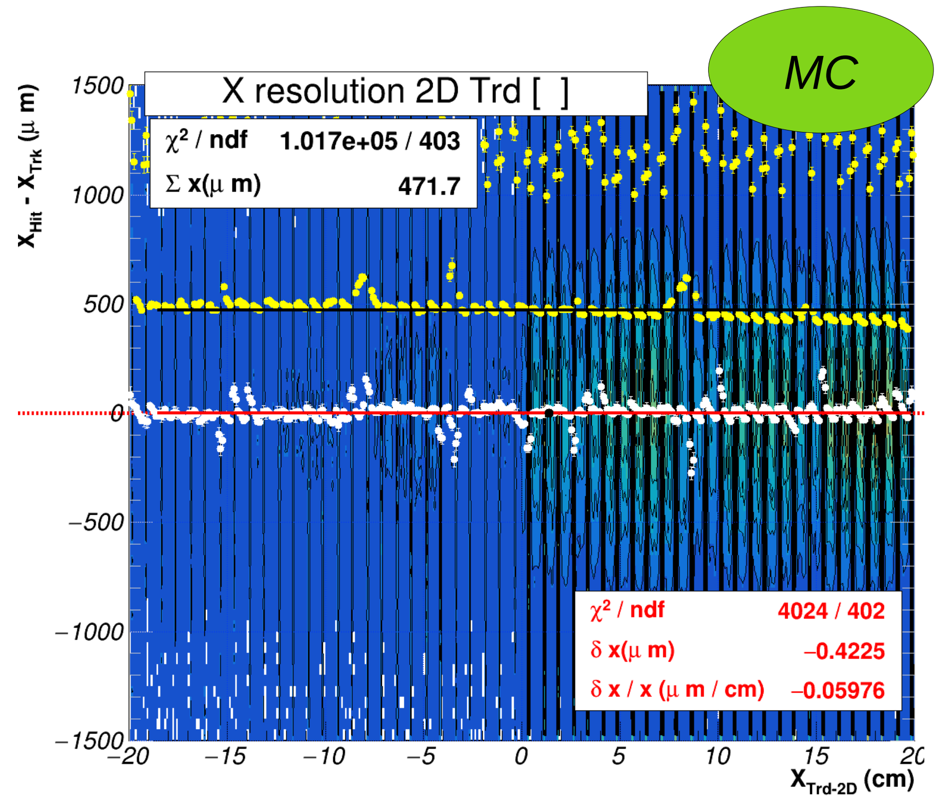


TRD2D residuals

$X_{Hit} - X_{Trk}$

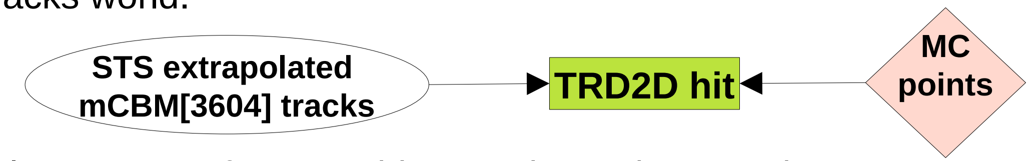
- Use 3 STS hit tracks to generate references
- Study Hit → Trk residuals for measurements and MC
  → residual mis-alignment **δx = - 30.7 µm**
  → [3604]**Σx = 505.6 µm**; [MC]**Σx = 471.7 µm**; **+7% difference !!**
  → systematic effects in the mCBM data reco visible !





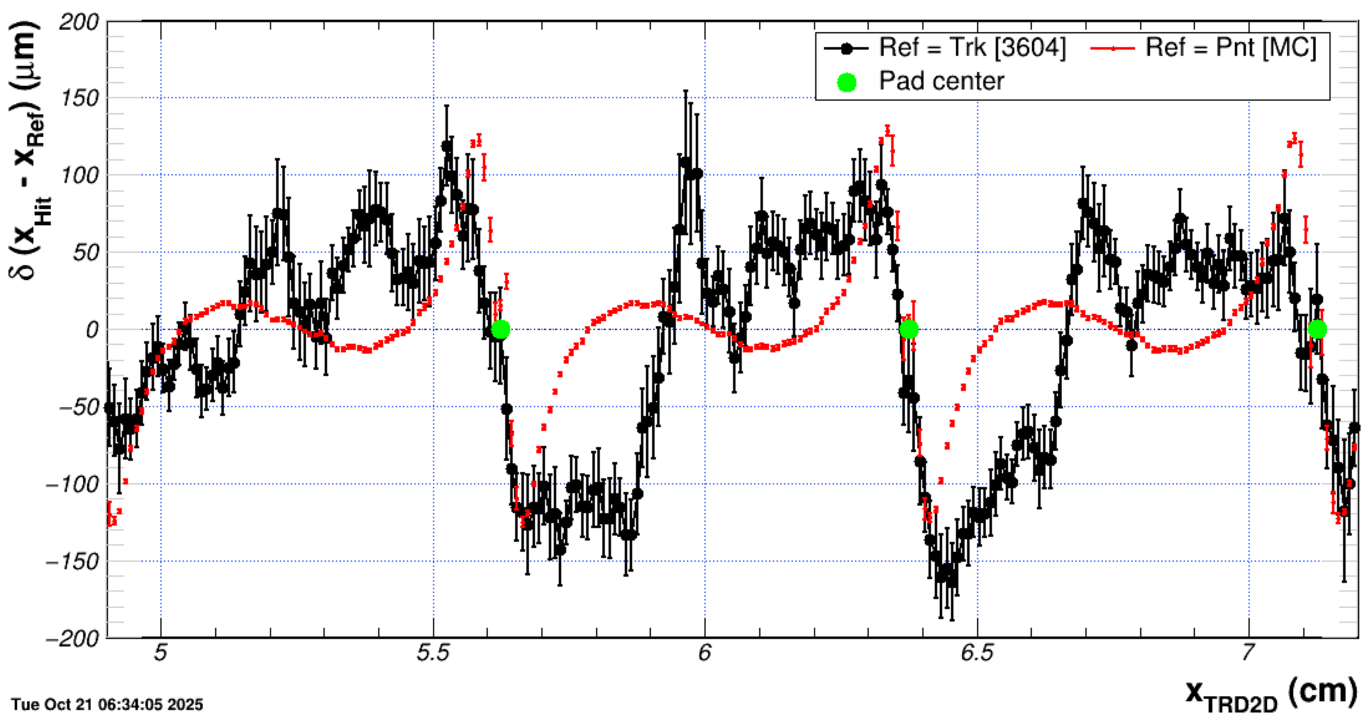
TRD2D systematic
X_{Hit}

- The system is ready to place side-by-side the model world of MC points with the #real_data driven, reconstructed tracks world.



- For clarity, only one type of TRD2D hits are shown (nRC,sz4)

✔ Observed TRD2D systematic effects **range** is described by MC.
✗ The data is richer in “features” !



TRD2D systematic

X_{Hit}

- The system is ready to place side-by-side the model world of MC points with the #real_data driven, reconstructed tracks world.

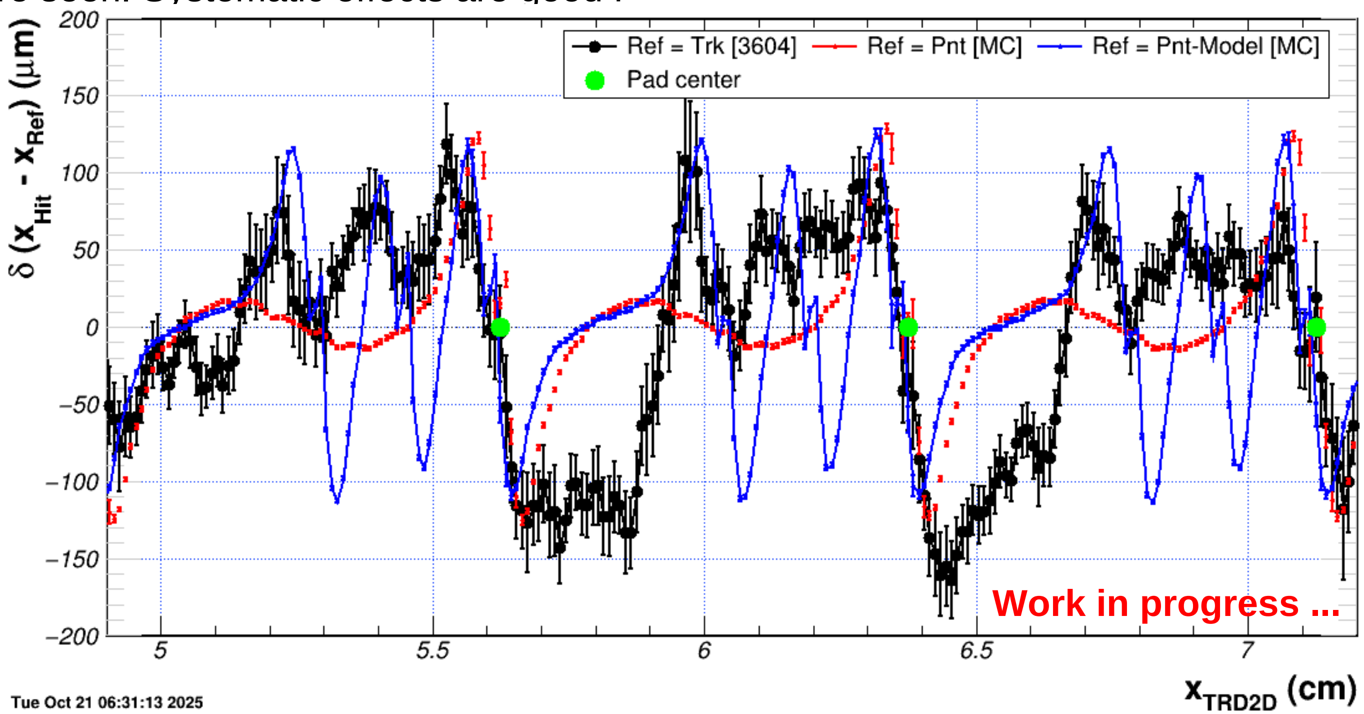
STS extrapolated mCBM[3604] tracks → **TRD2D hit** ← **MC points**

- For clarity, only one type of TRD2D hits are shown (nRC,sz4)

✔ Observed TRD2D systematic effects **range** is described by MC.

✗ ~~The data is richer in "features" !~~

✔ Observed data drive #real_detector reconstruction : Details of the chamber construction (*wire to pads mis-alignment*) are seen. Systematic effects are good !

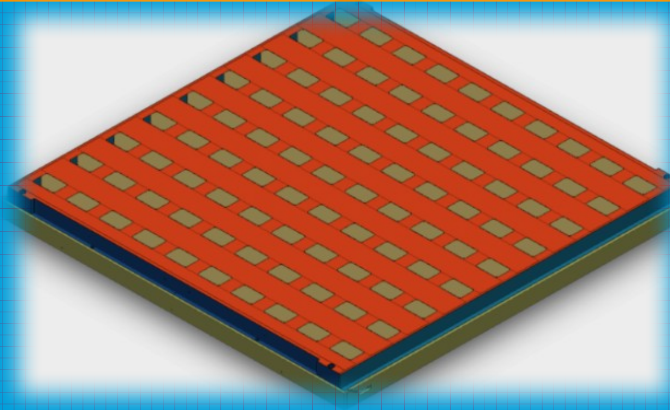


Conclusions

1. The CHAMBER

- A full reboot of the design/assembly was performed on 2025 based on lessons from the previous prototypes.
- Various updates are proposed for better integration in CBM and precise production.
- New prototype construction is starting
- New milestone Q2/26

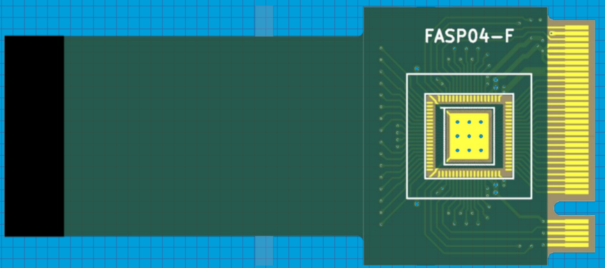
Laura, Philipp & Marian



2. The FEE

- Successful engineering run for the FASP dices for full CBM.
- Flexible bonding technology defined and ready for production.
- Modifications have to be propagated through the FEE/DAQ chain
- New milestone Q3/26

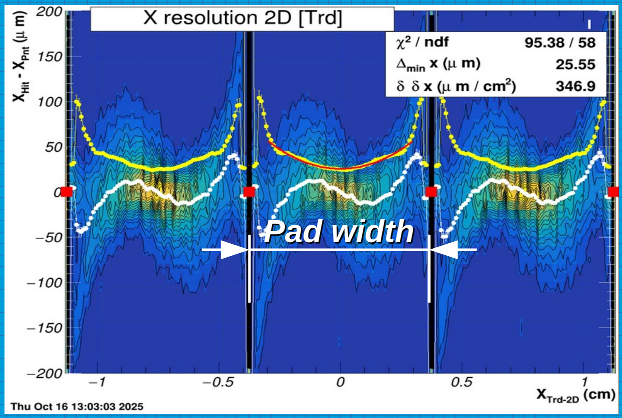
Claudiu



3. The DATA

- mCBM data and MC can be joined to shed light on the detector systematic effects. Sensitivity to construction details reconfirmed.
- Learning curve (calibrations, LUT) for analysis production is steep but populated with very good data.
- Milestone Q2/26 for performance paper.

Alex



Thank you

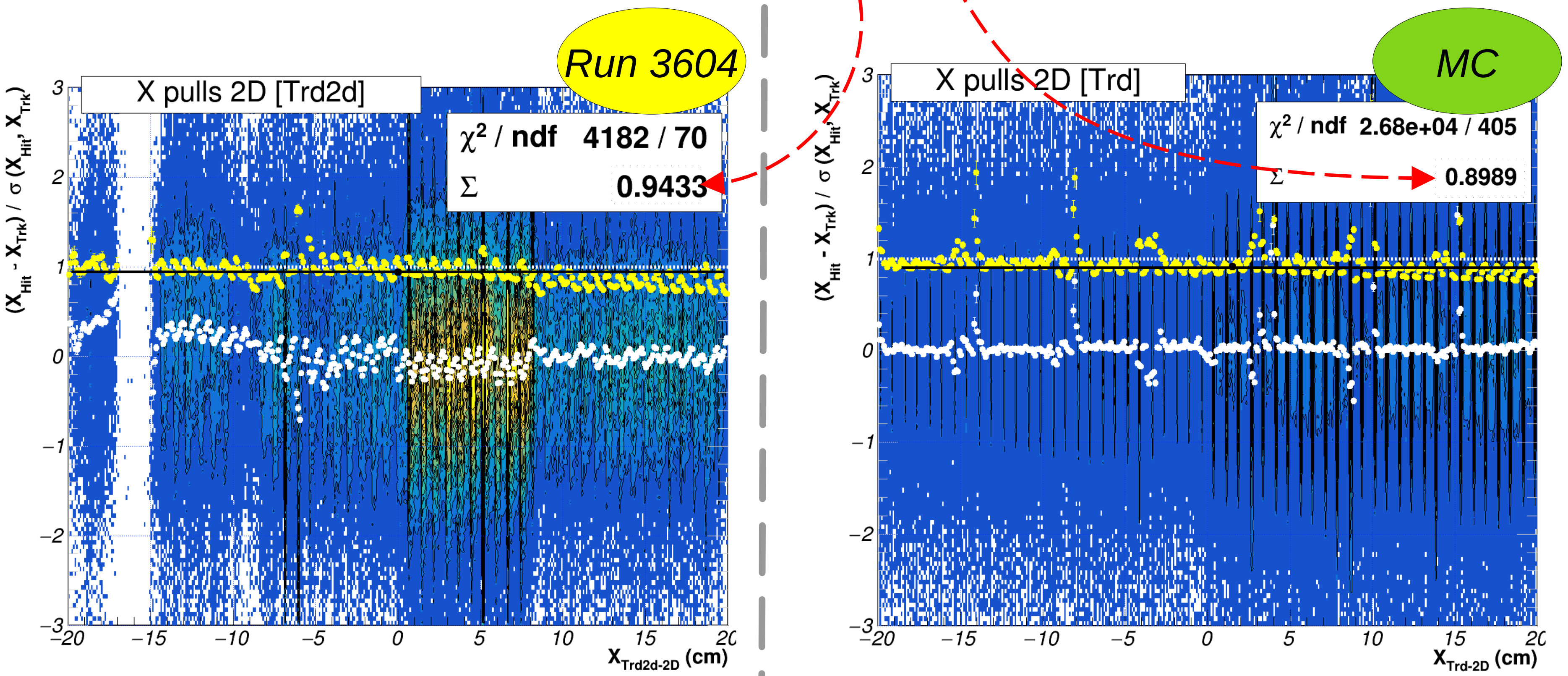
BACKUP

TRD2D pulls

$X_{Hit} - X_{Trk}$

- Uncertainties are systematically over-estimated:
  → [MC] Σx = **-10% difference !!**
  → [3604] Σx **-6% difference !!**

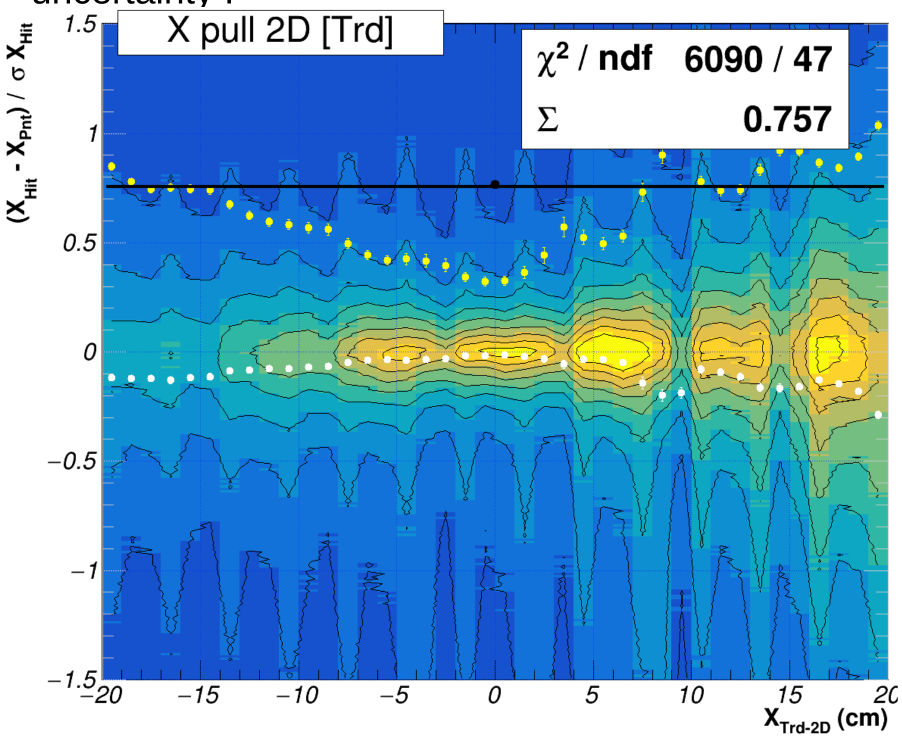
- Try to differentiate between σx_{Trk} σx_{Hit}

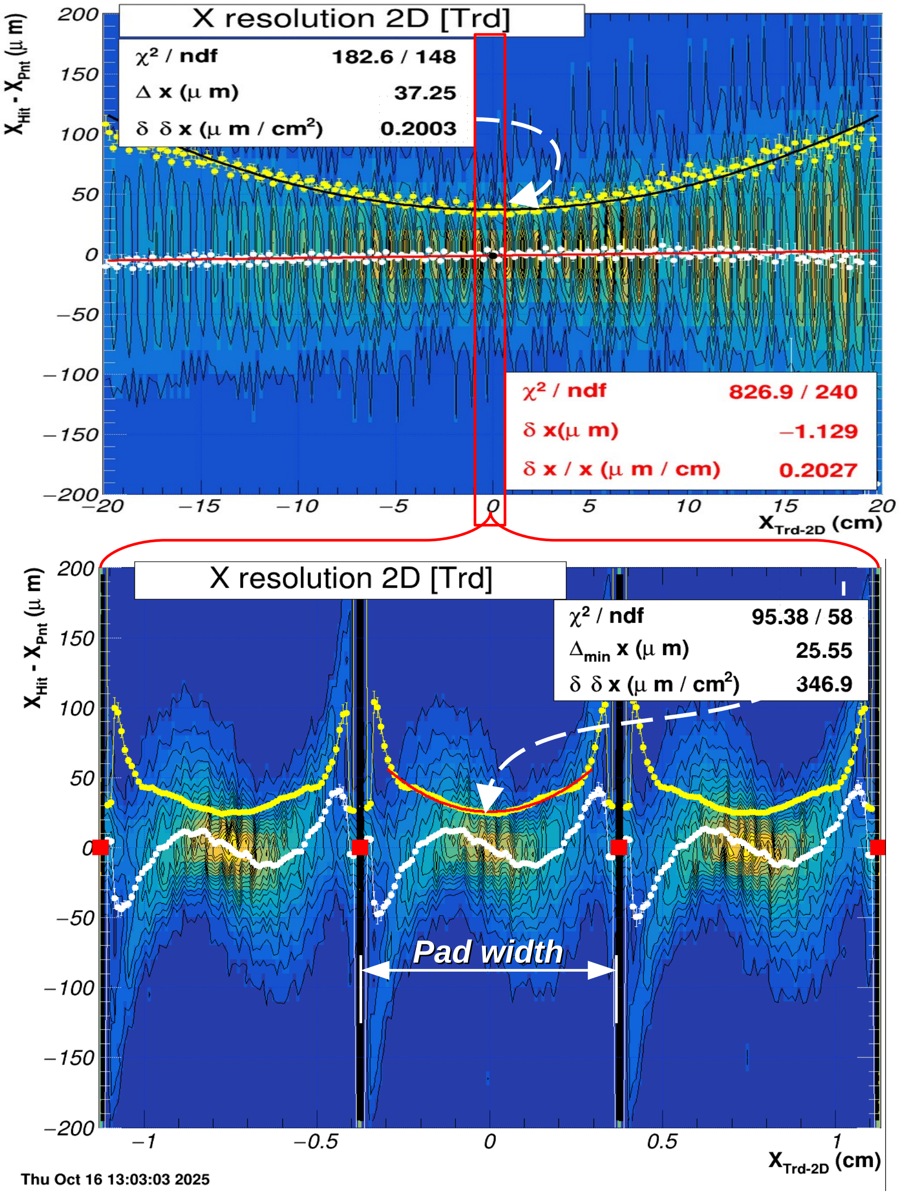


TRD2D uncertainty
$X_{Hit} - X_{Pnt}$

- TRD2D Uncertainty are systematically over-estimated:
  → **σx** overestimate by more than **-25% difference !!**
  → **σx >= 25.5 μm !!**
  → **σx** depends **on** (θ, φ) and pad topology. Both dependencies are not described by the reco !
  → Systematic effects δx = ±50 μm are visible.

- However since **σ_{Trk} ~ 450 μm ~ 10 x σ_{Hit}** tracks at mCBM are not precise enough to constrain TRD2D x uncertainty !





Position reference definitions
uncertainty influence

Are the errors correctly reconstructed ?

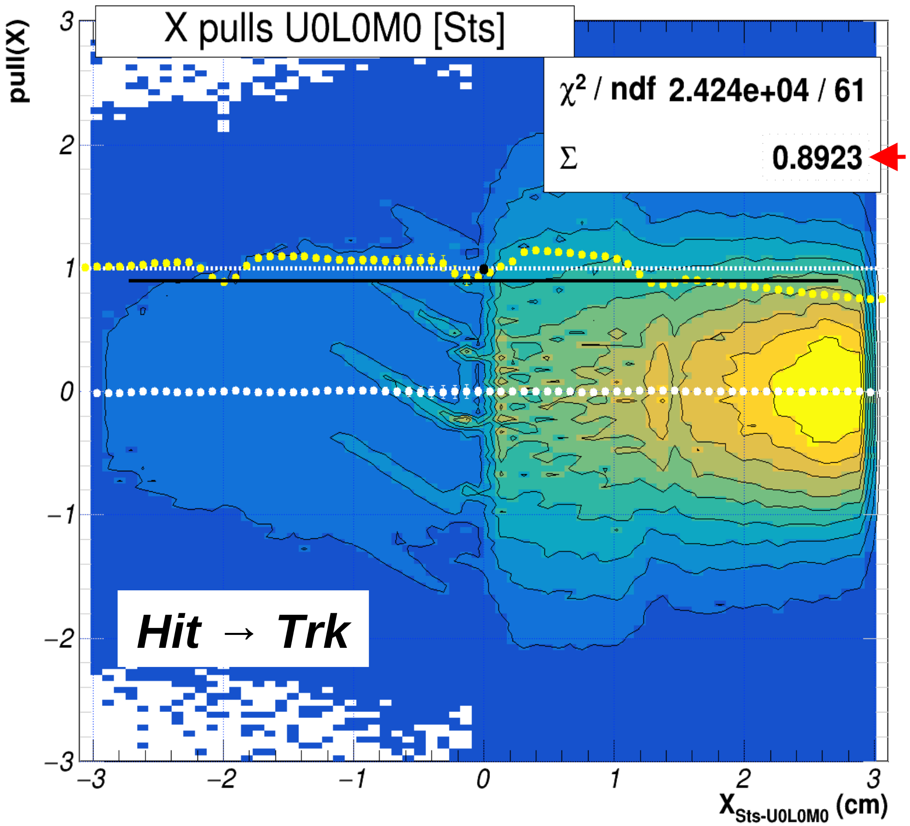
→ sigma of pulls(X_{Hit}) = **ΔX / Σx** = $(X_{Hit} - X_{Trk\,|\,Pnt}) / (\sigma^2 x_{Trk\,|\,Pnt} + \sigma^2 x_{Hit})^{1/2}$

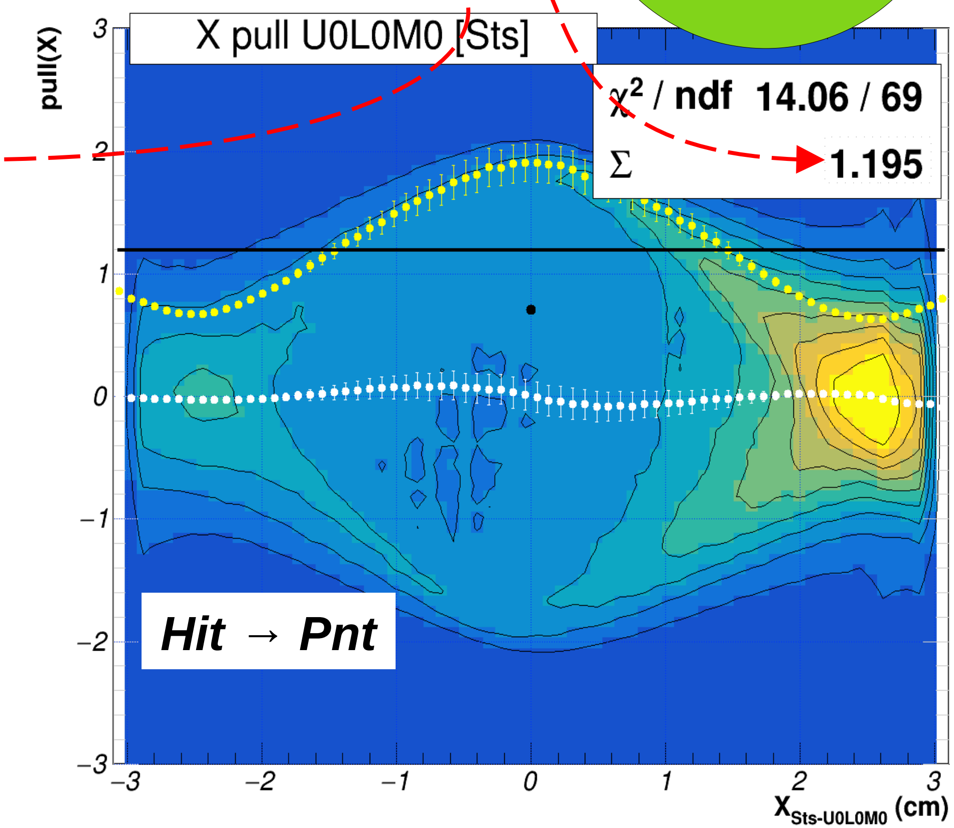
→ intrinsic resolution [MC]Σx = **8.86 μm** **-19.5% difference !!**

→ [MC]Σx = **70.31 μm**; **> +11% difference !!**

→ uncertainty dependence on (θ, φ) not accounted by reco.

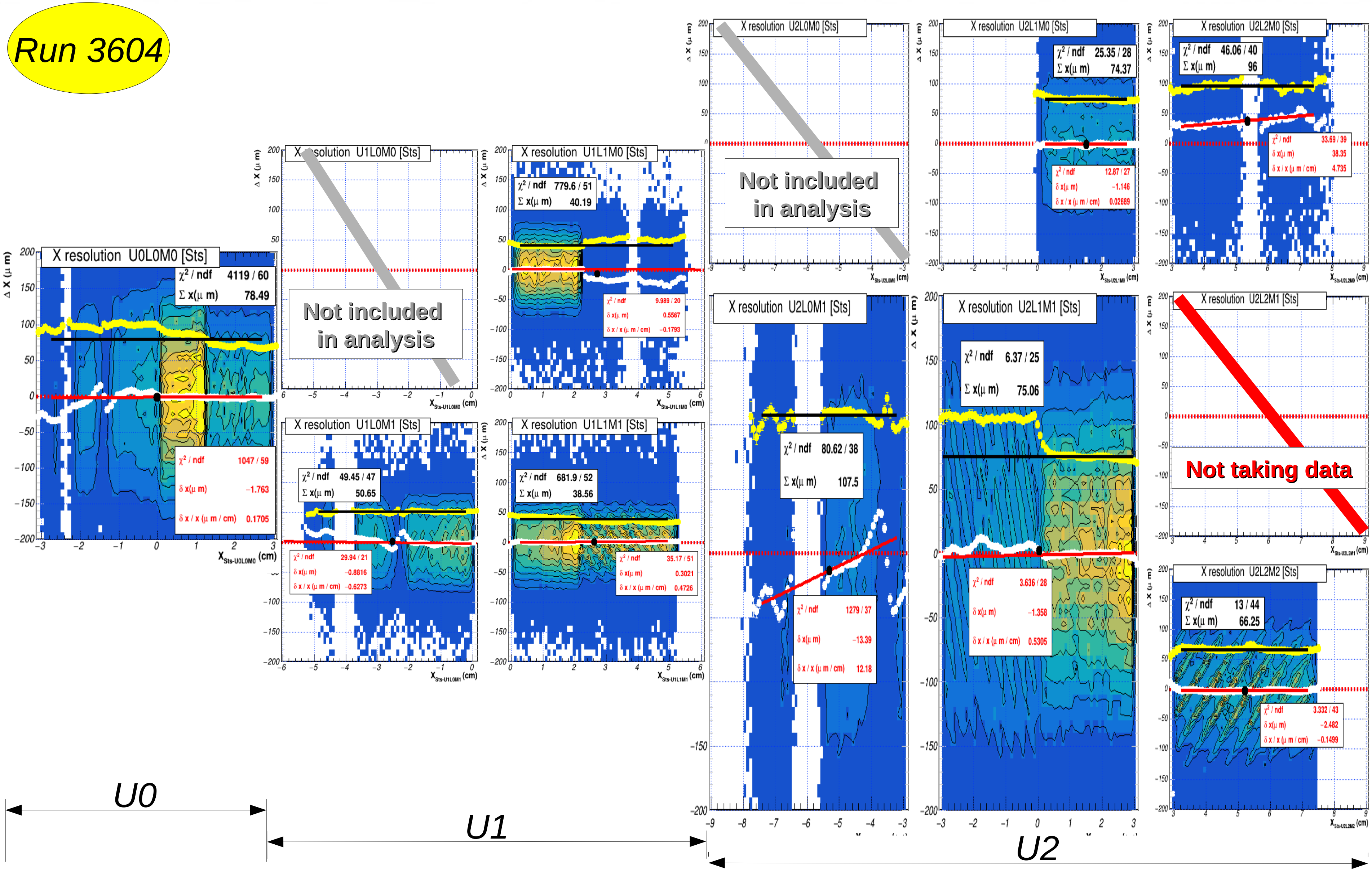
Au-Au
Beam 1.23A GeV
Interaction mbias
mCBM
MC





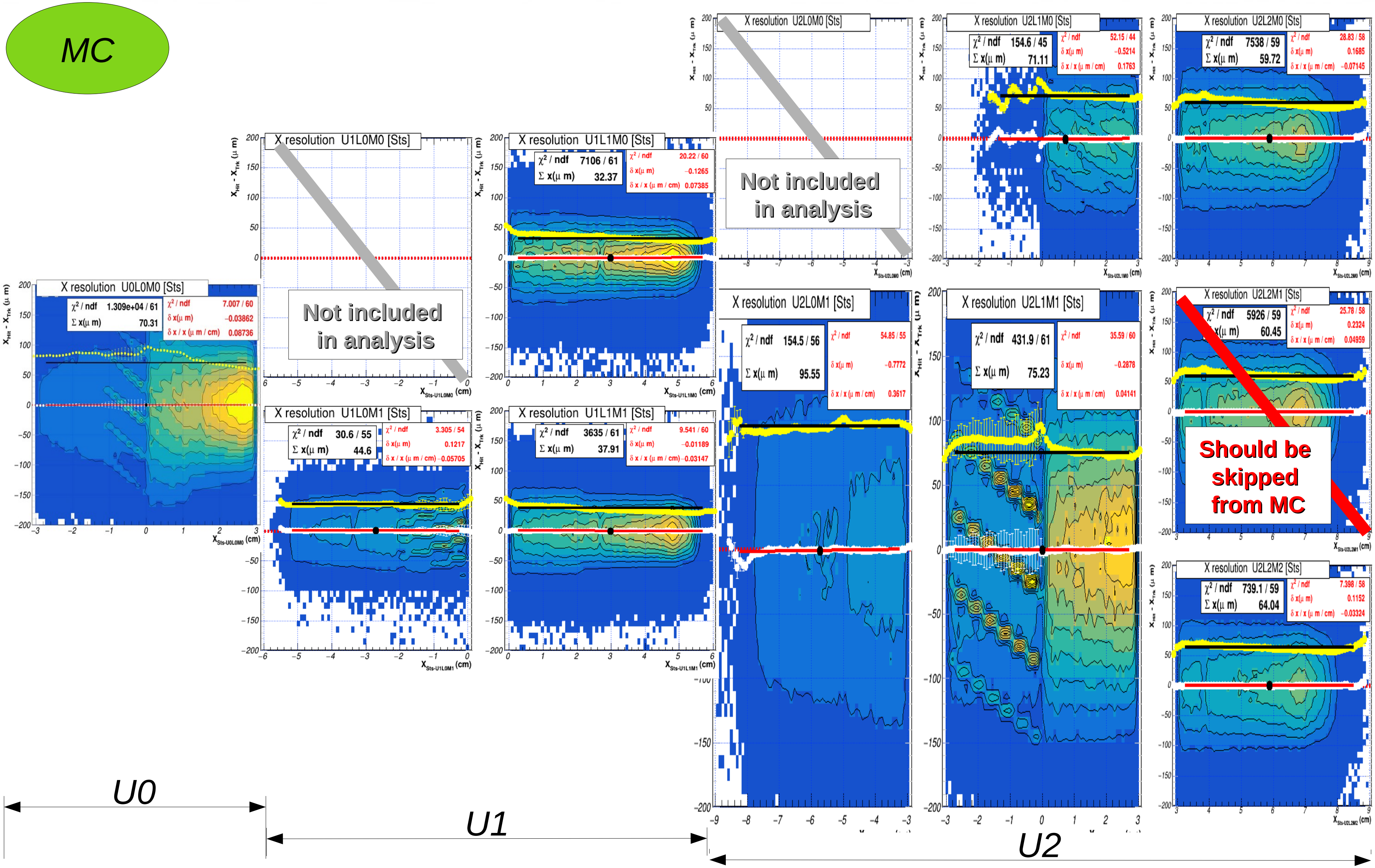
Full STS residuals [mCBM]

X_{Hit} - X_{Trk}

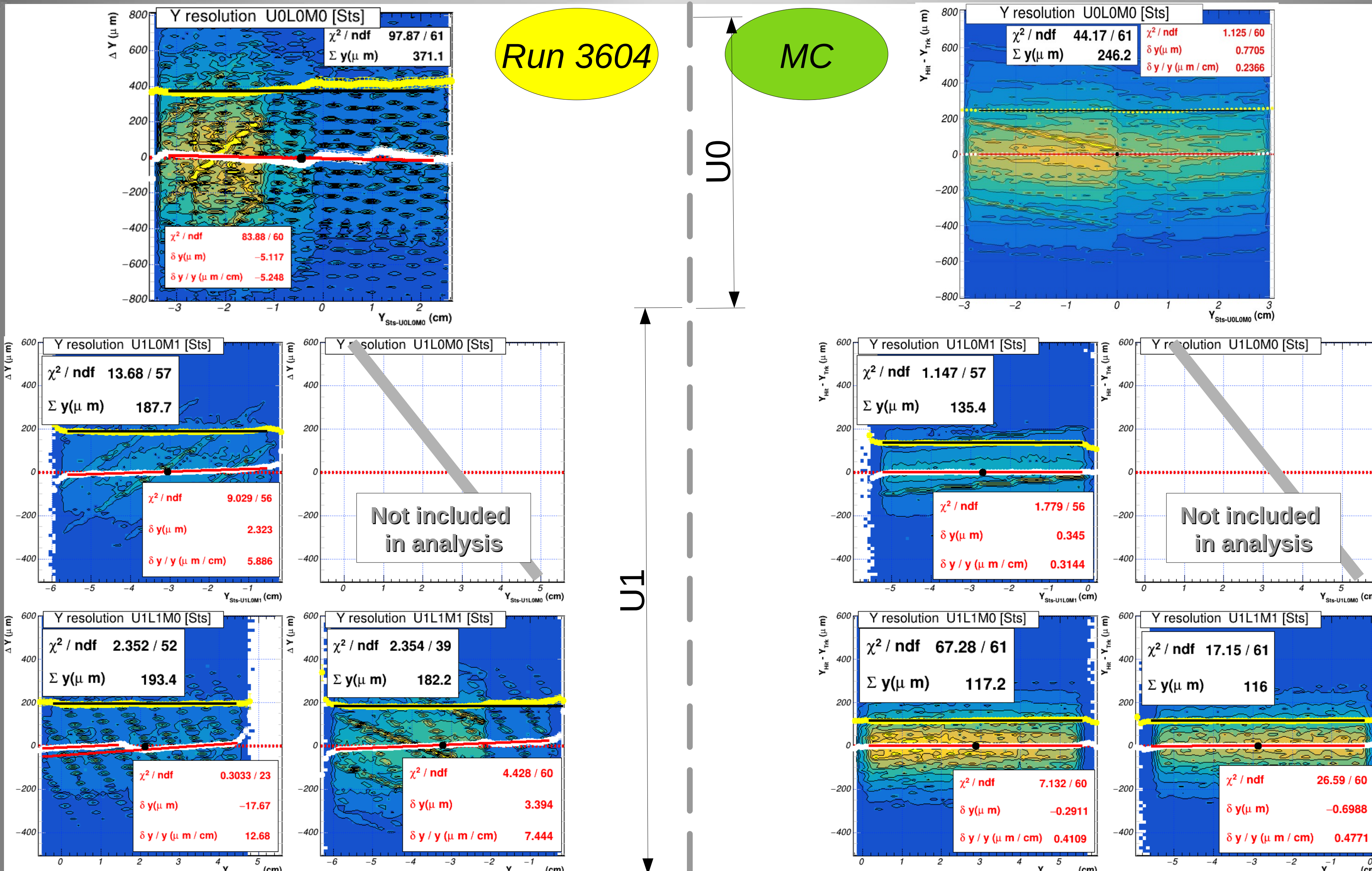


Full STS residuals [MC]

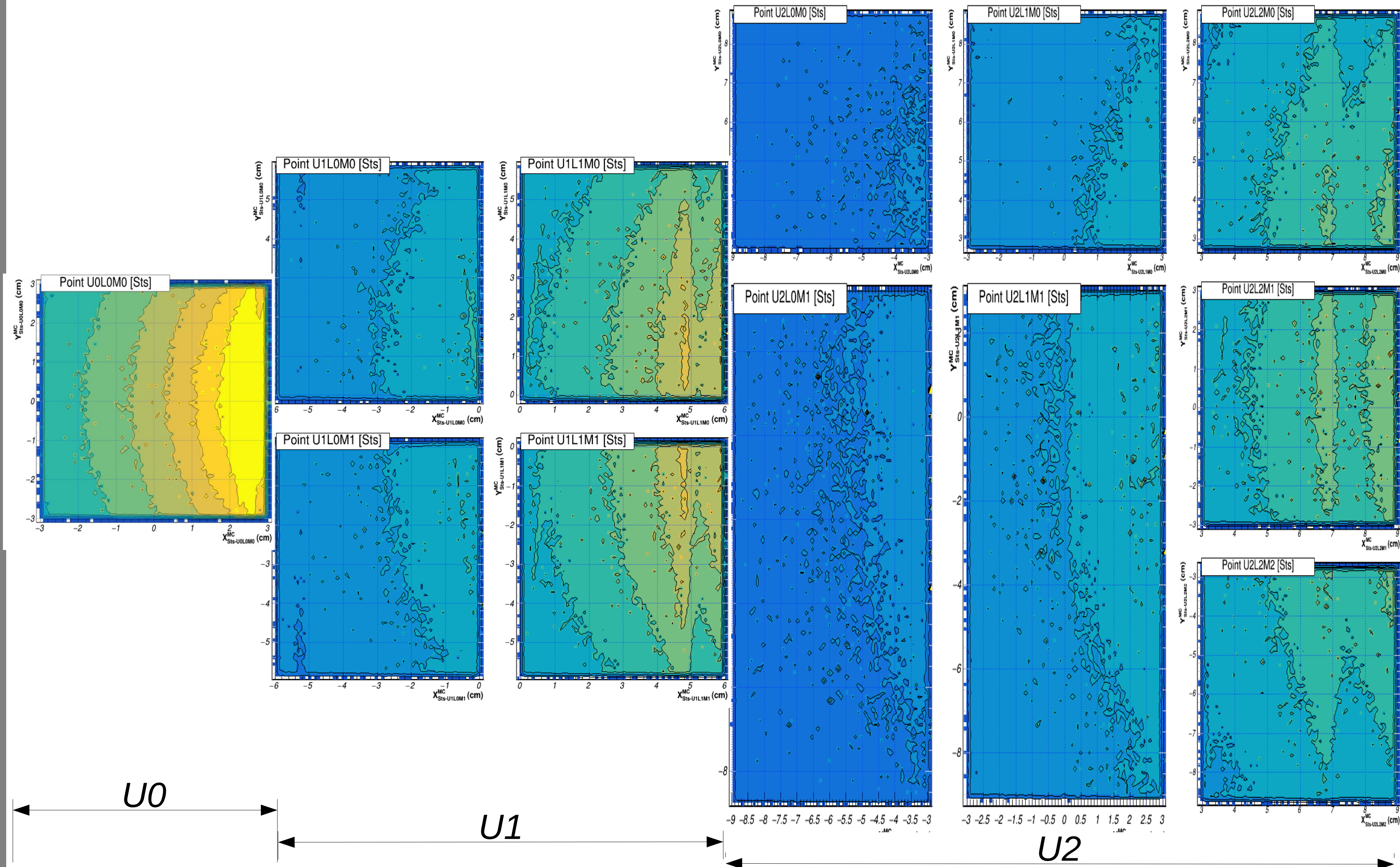
X_{Hit} - X_{Trk}



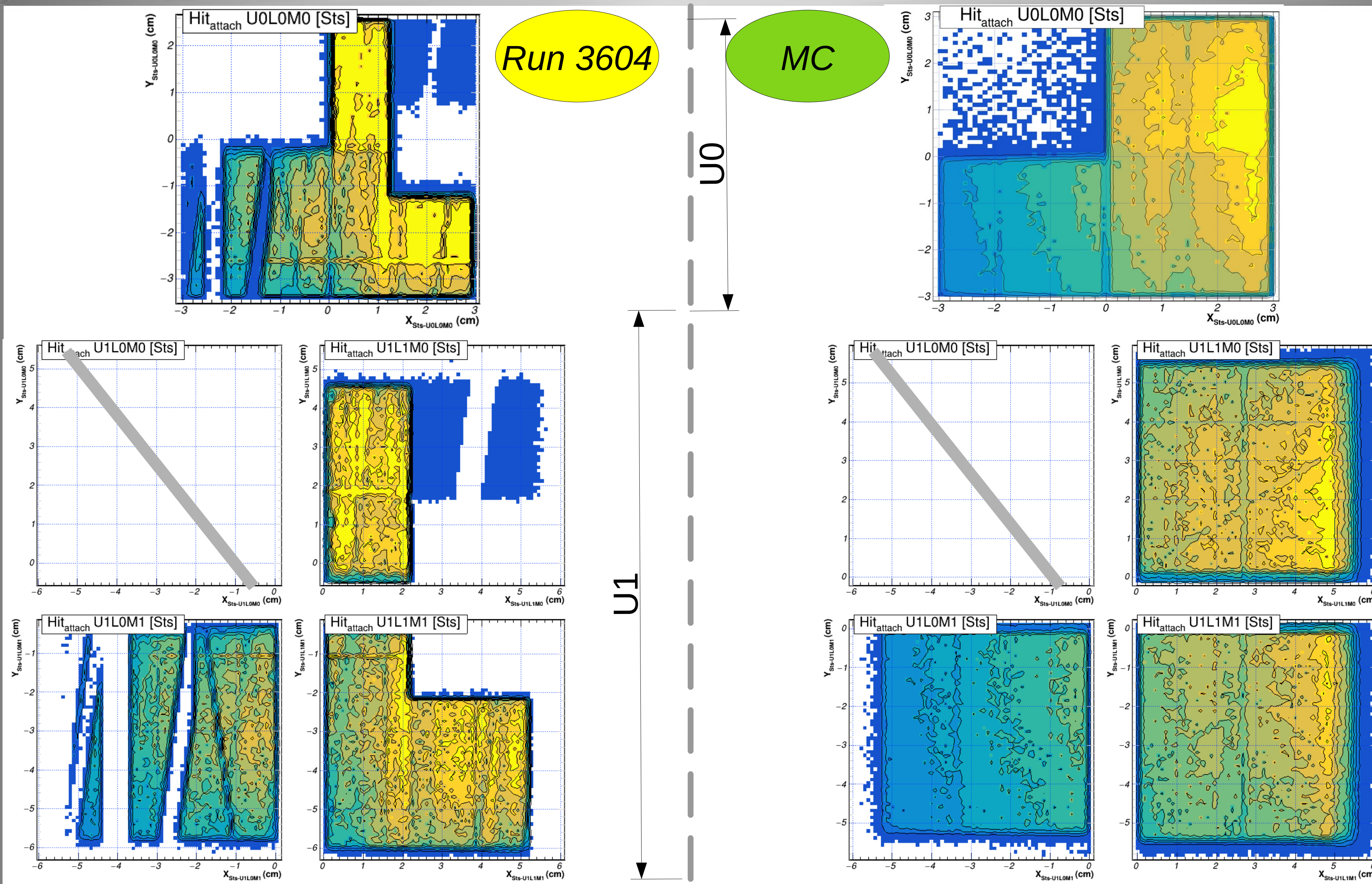
STS residuals [STS/U0 & U1]
Y_{Hit} - Y_{Trk}



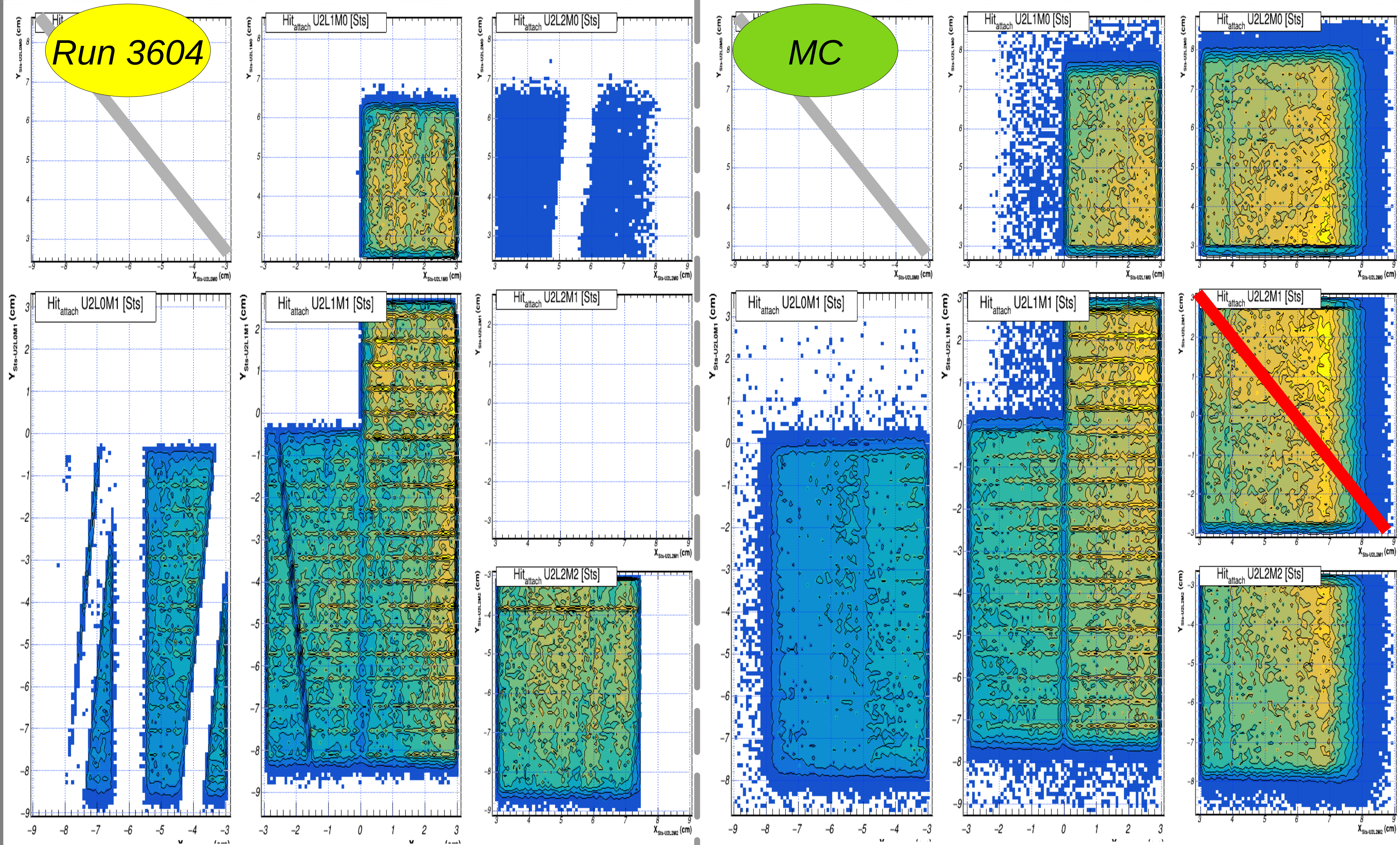
MC production



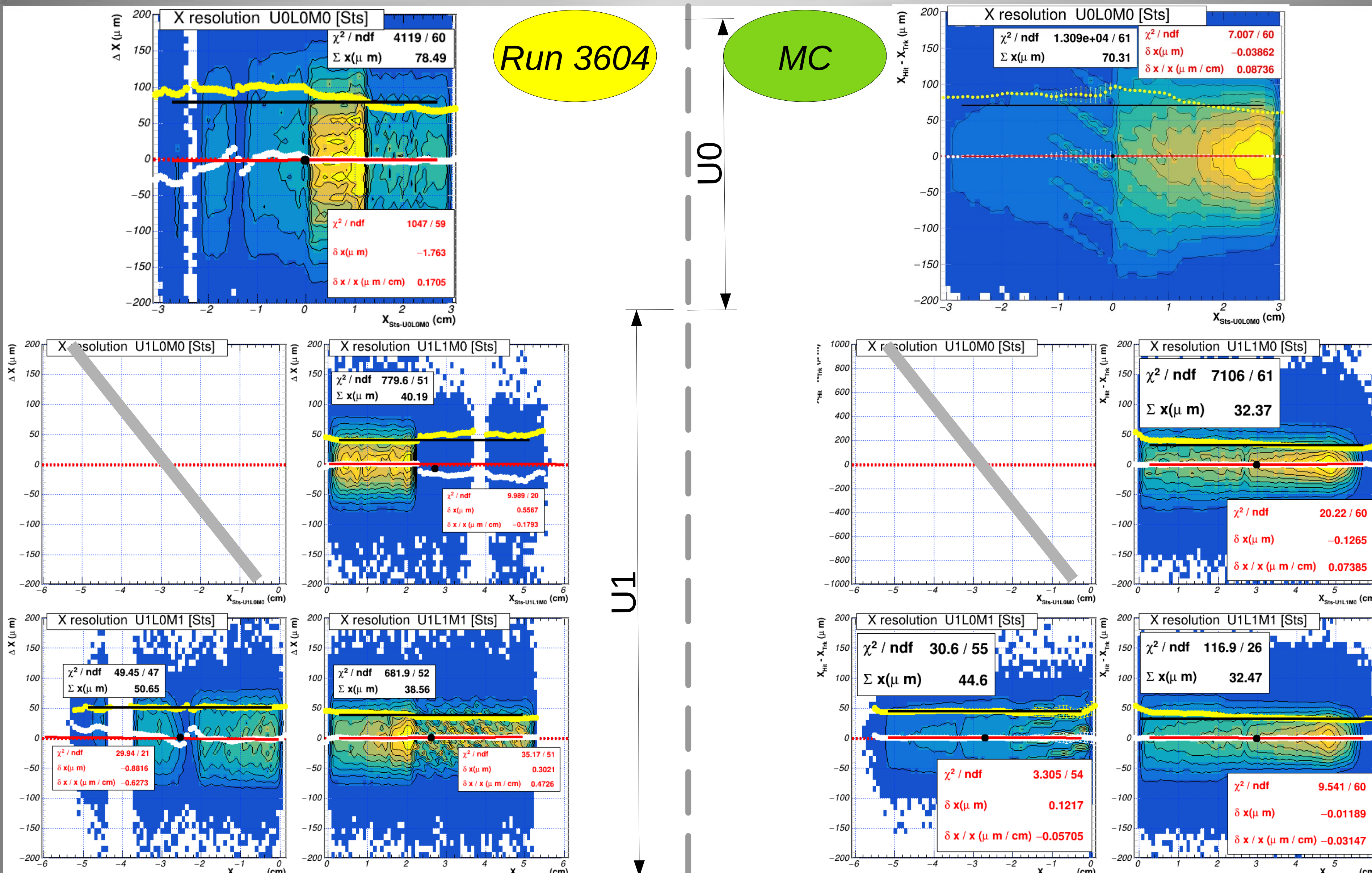
STS hits on long tracks [STS/U0 & U1]



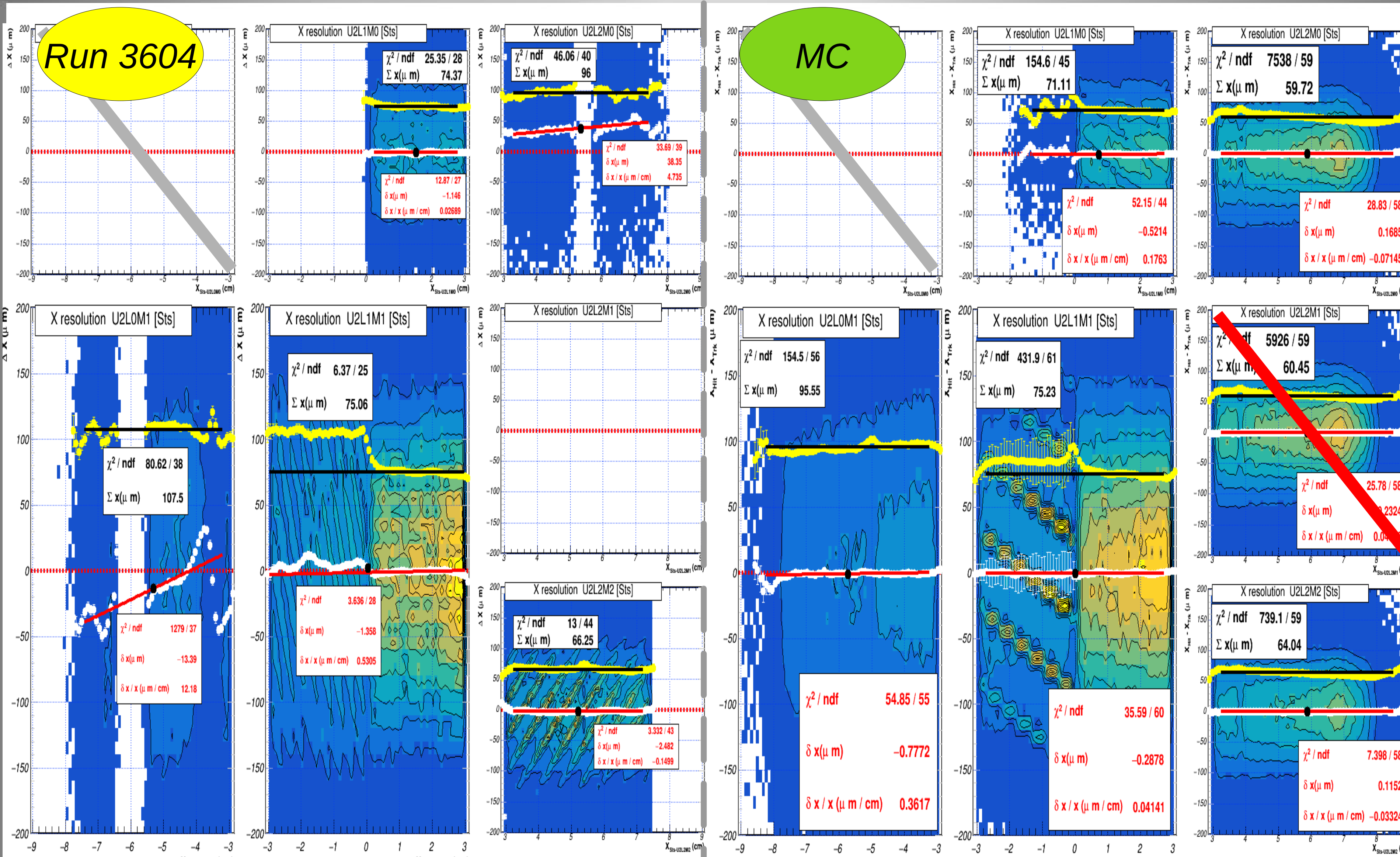
STS hits on long tracks [STS/U2]



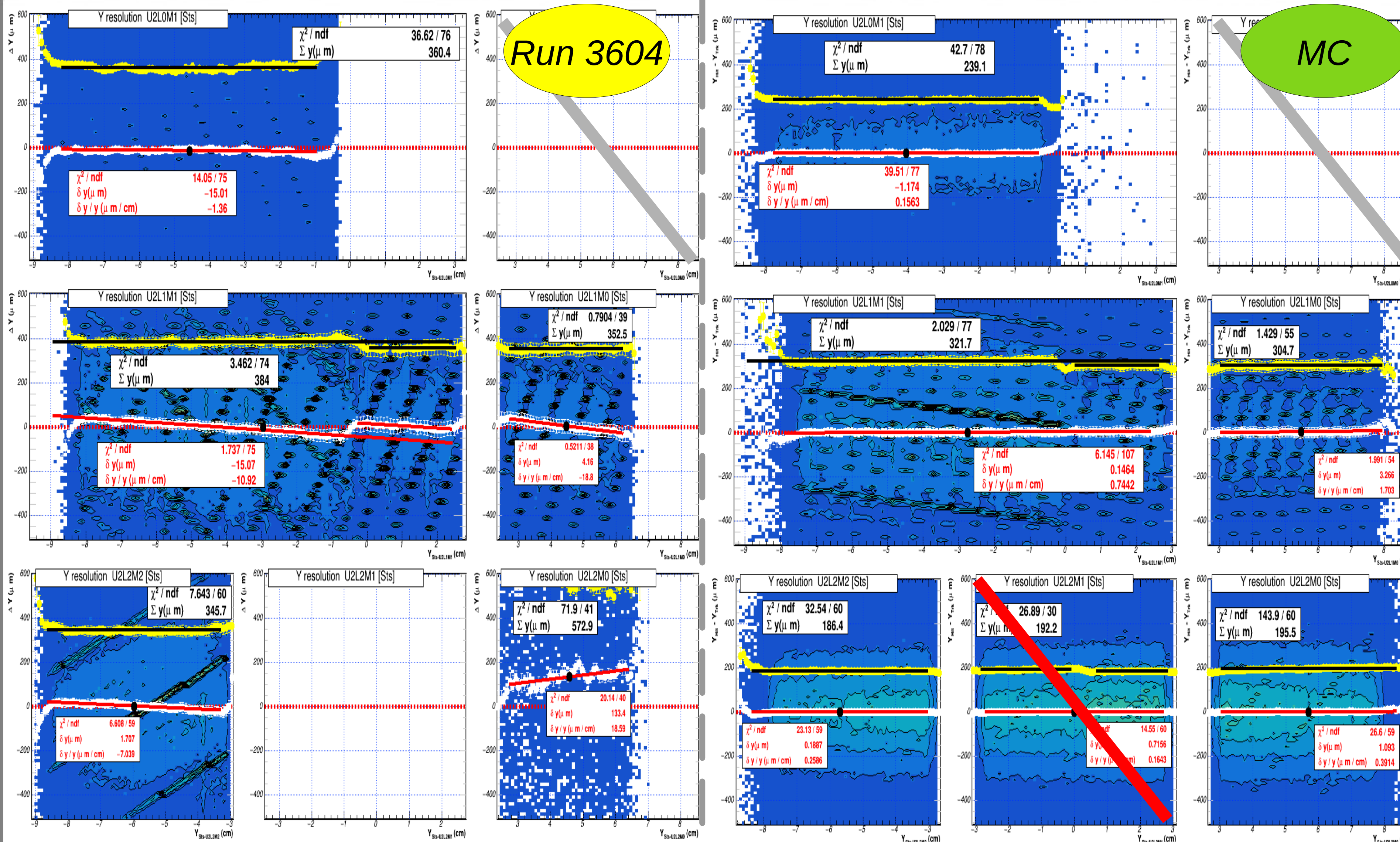
STS x resolution Trk – Hit [STS/U0 & U1]



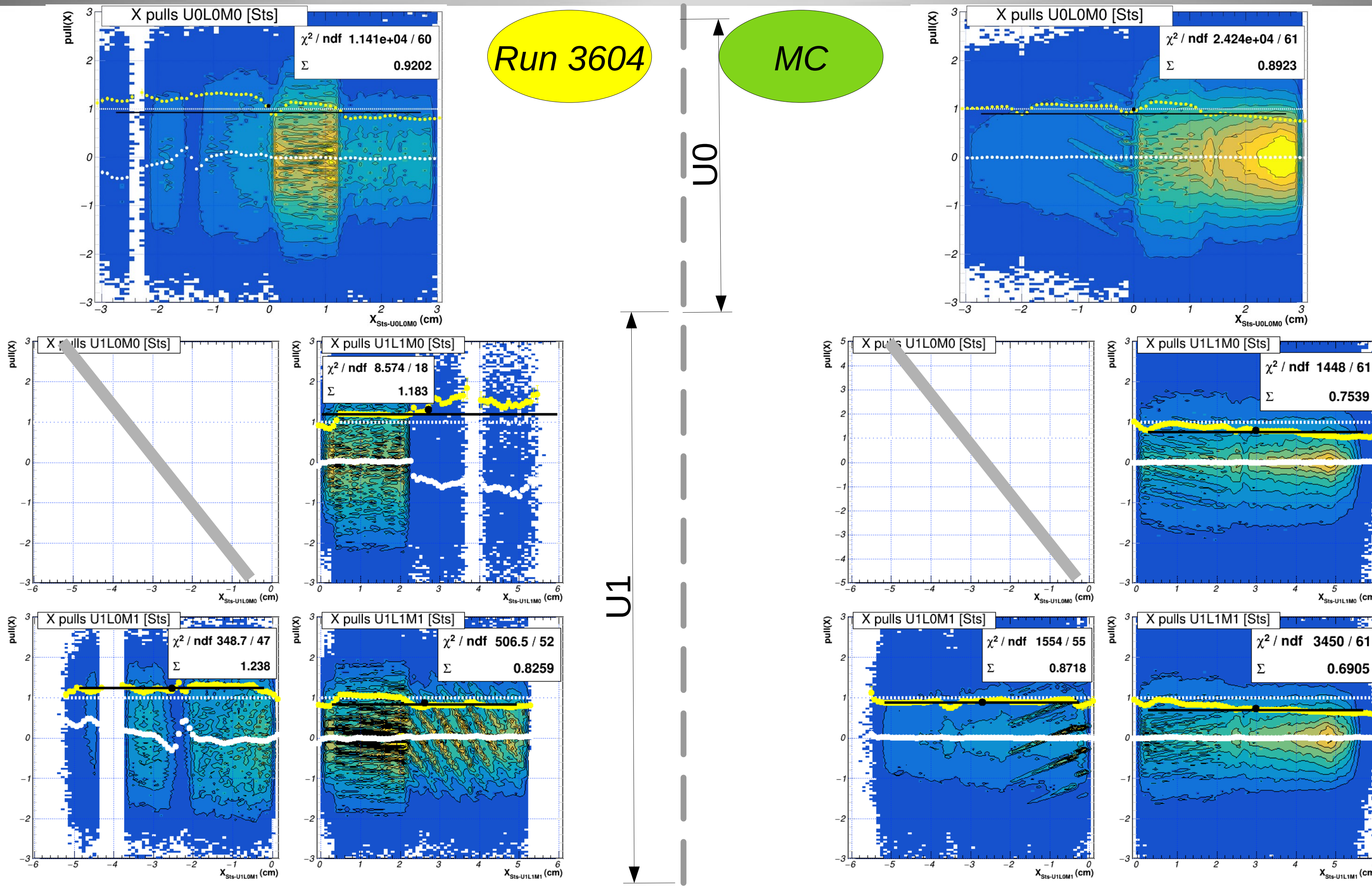
STS x resolution Trk Hit [STS/U2]



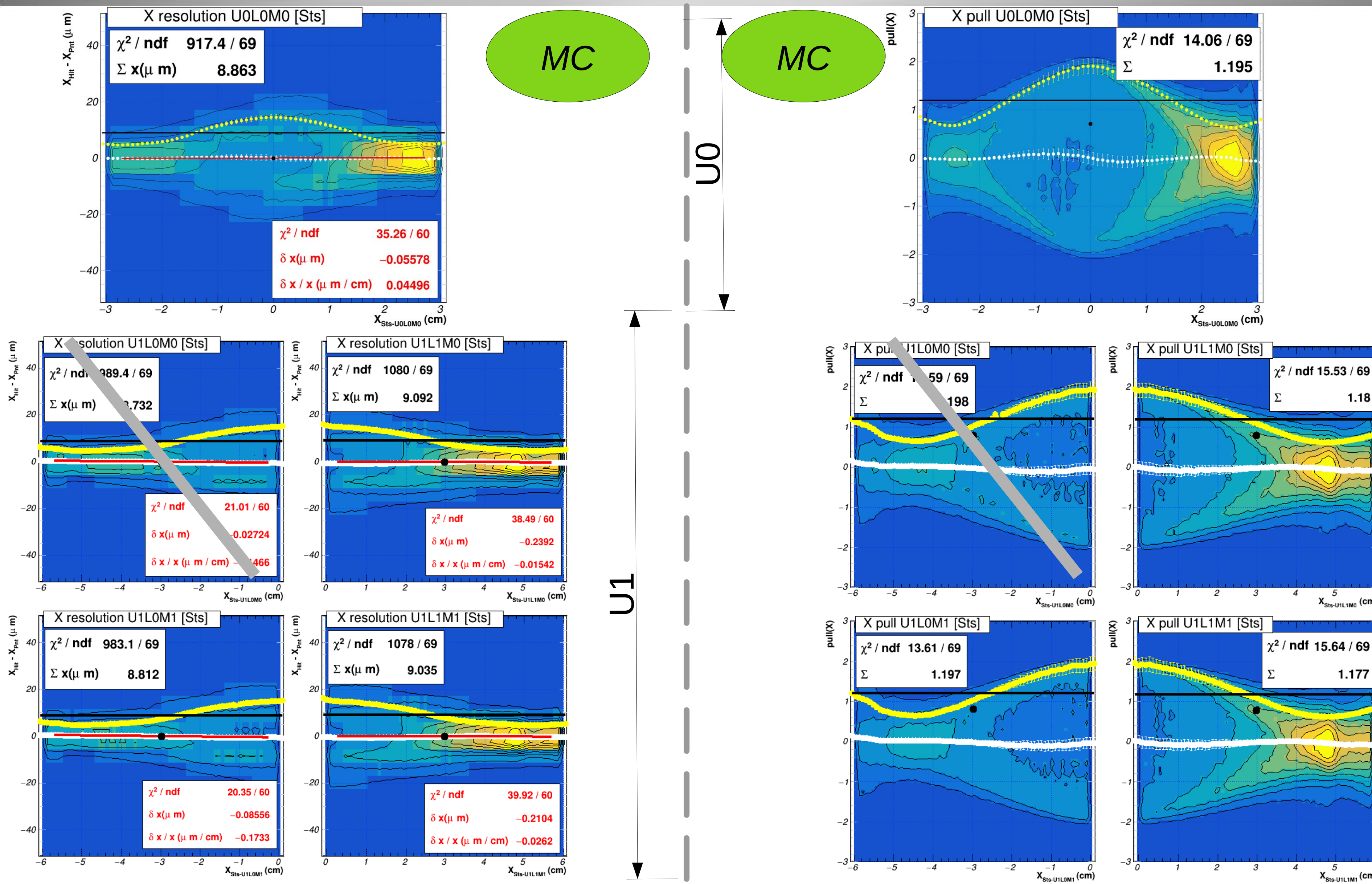
STS y residuals Trk - Hit [STS/U2]



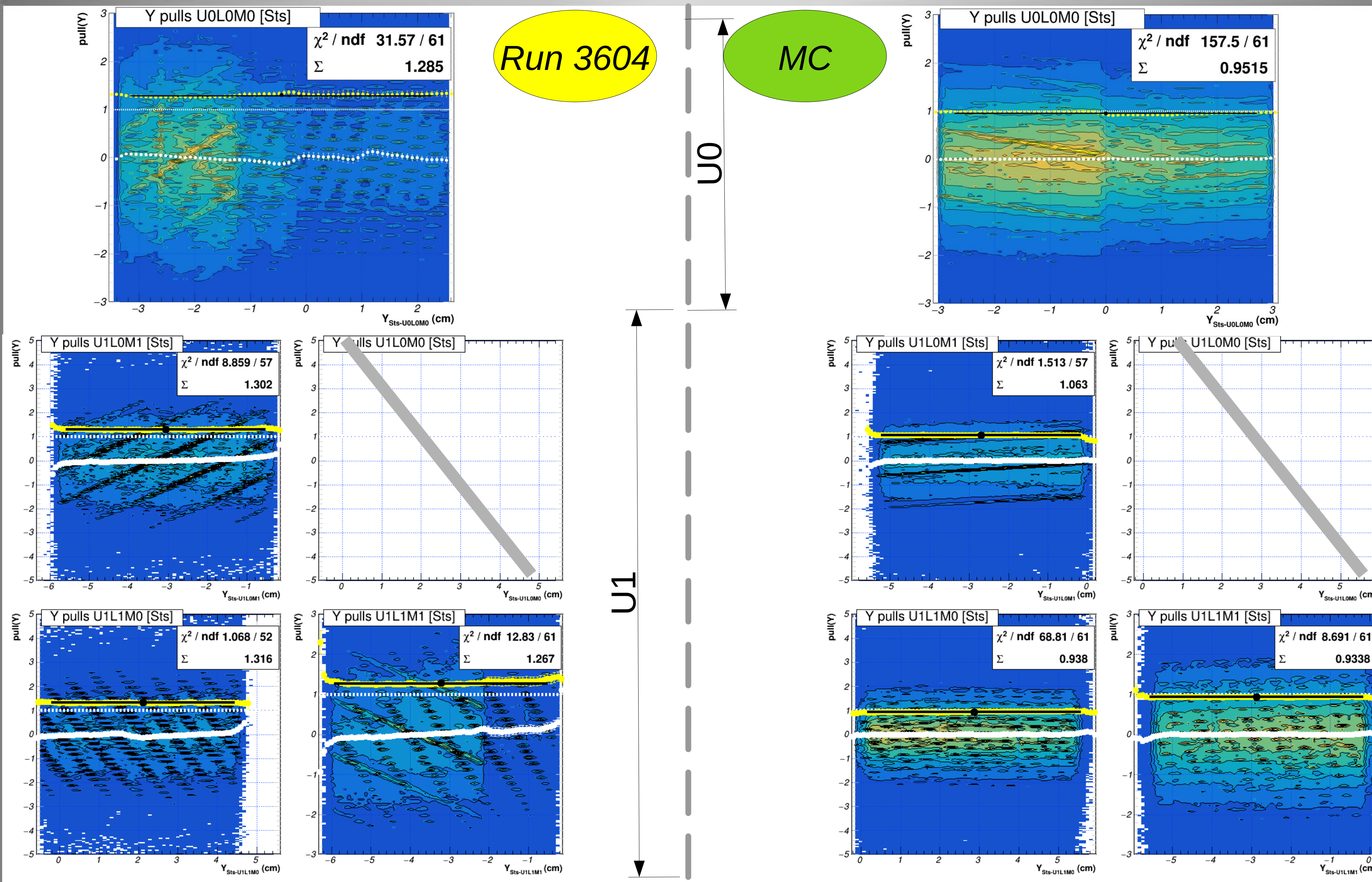
STS x pulls Trk – Hit [STS/U0 & U1]



STS x error estimation Hit – Pnt [STS/U0 & U1]



STS y pulls Trk – Hit [STS/U0 & U1]



STS y error estimation Trk – Hit [STS/U0 & U1]