ALICE TPC Upgrade

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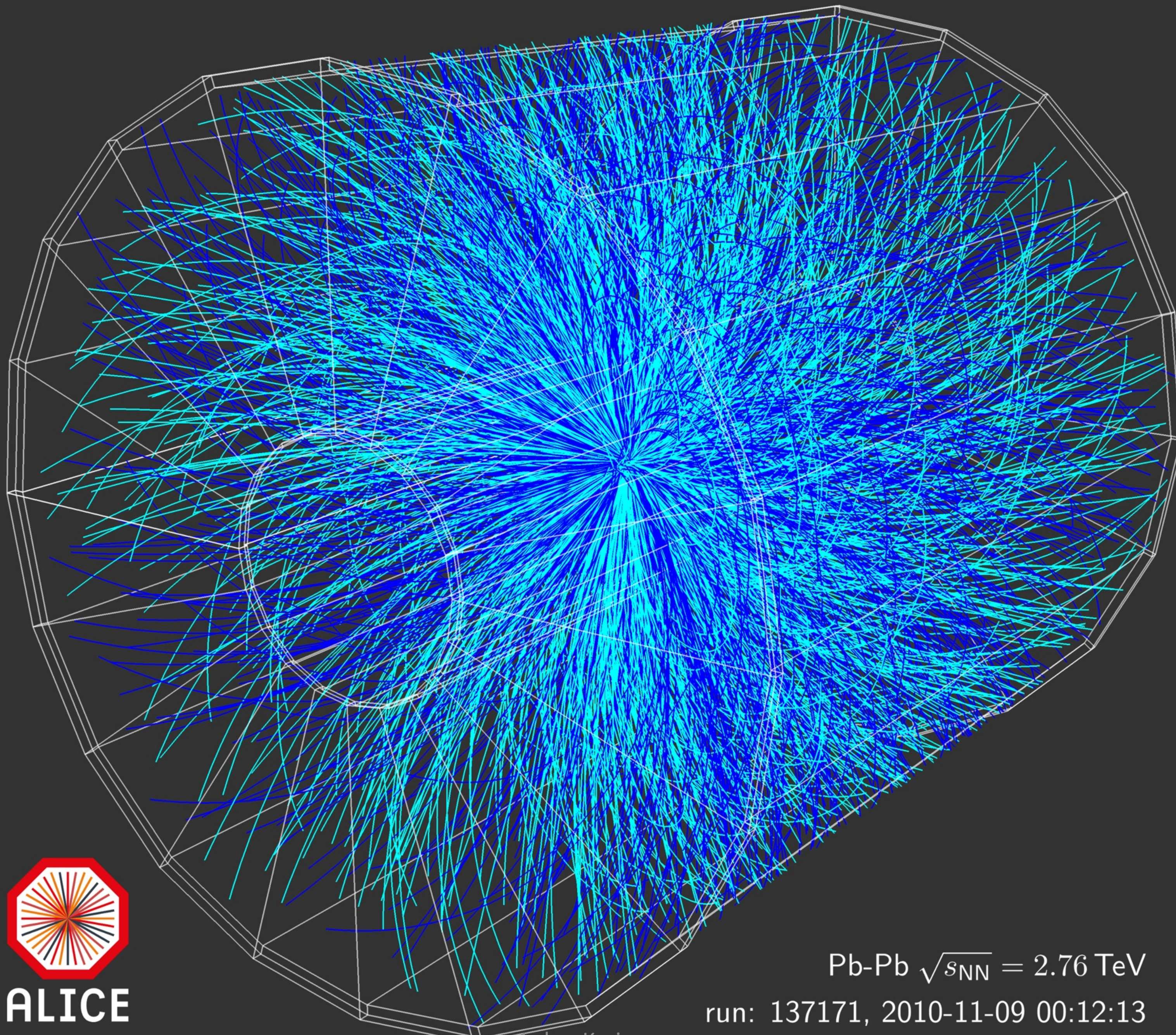
4. Annual MT Meeting

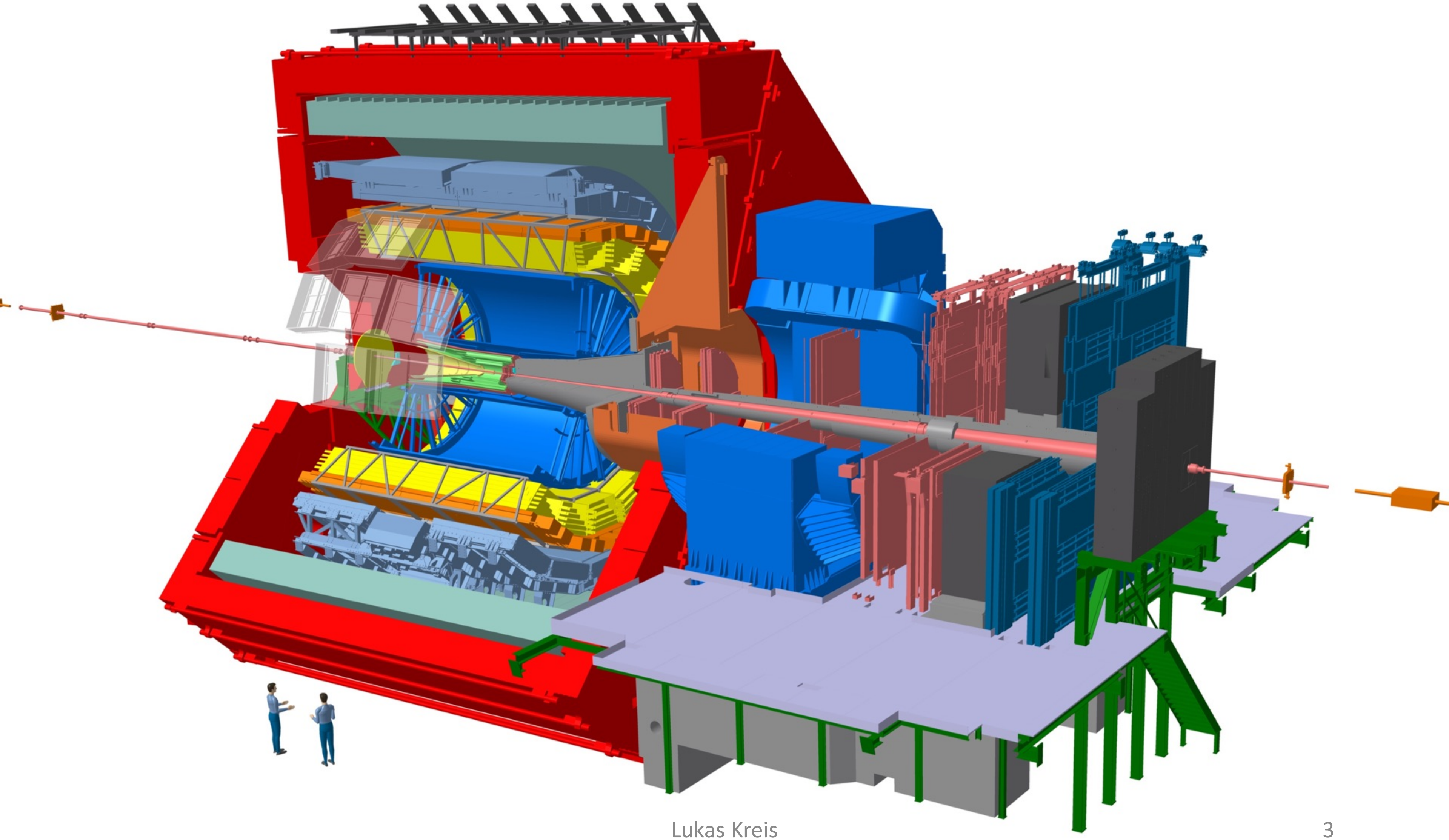
13.6.2018

Overview

Introduction
Chamber assembly
Chamber QA


ALICE
Pb-Pb $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV
run: 137171, 2010-11-09 00:12:13

ALICE (after the Upgrade)



Why do we upgrade ALICE?

Rich physics program after LHC Long Shutdown 2

- Rare probes and their coupling with the medium

Benefit from ALICE detector strengths

- excellent particle identification
- tracking in high-multiplicity environment

However high statistics of Pb-Pb collisions are required

TPC Upgrade

After LS2 50 kHz Pb-Pb collision rate

Problem MWPCs would limit event rate

Solution GEMs will enable continuous data taking

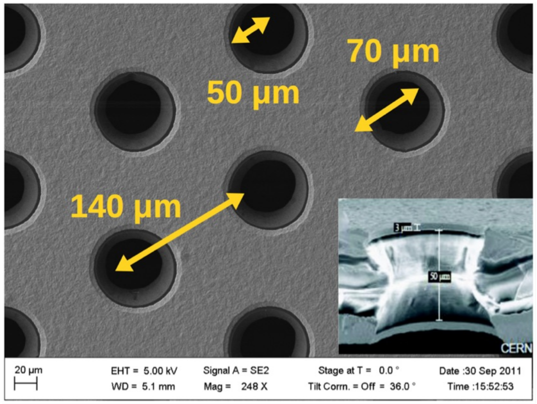
Retain performance at 100 times the collection rate

Gas Electron Multiplier

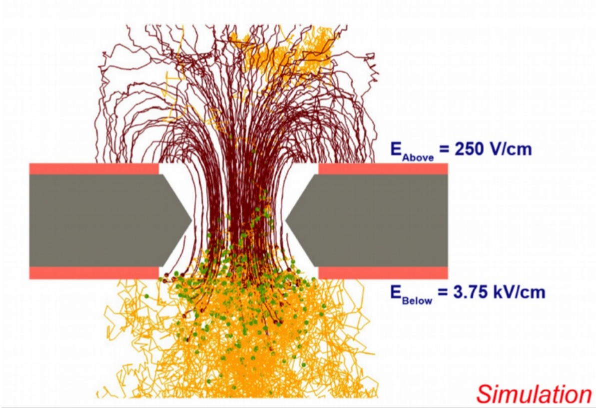
Polyimide foil $\sim 50\ \mu m$

Copper coating $\sim 5\ \mu m$

Photolithographic etching

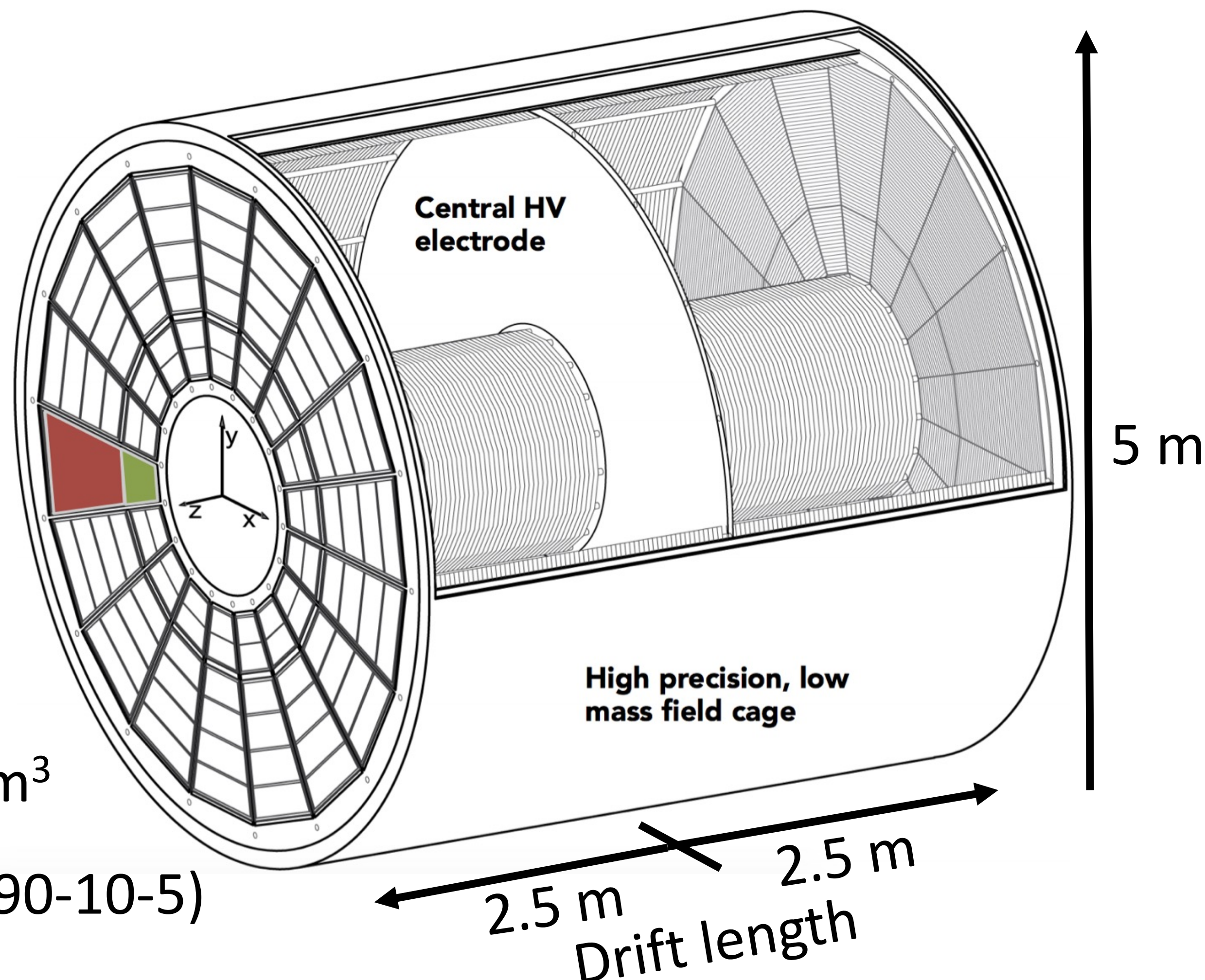


Very strong electric field
in the holes $\mathcal{O}(50\ \mathrm{kV/cm})$



ALICE Time Projection Chamber

2 x 2 x 18
readout
Chambers



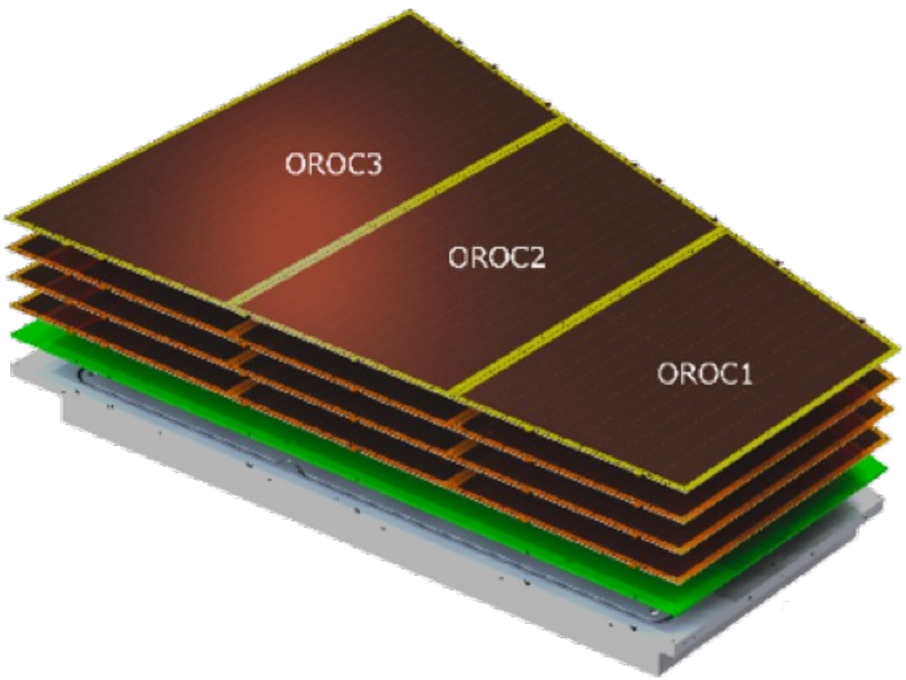
Volume 90 m^3

Ne-CO_2-N_2 (90-10-5)

Drift field 400 V/cm

Outer Readout Chamber

3 stacks of 4 GEMs

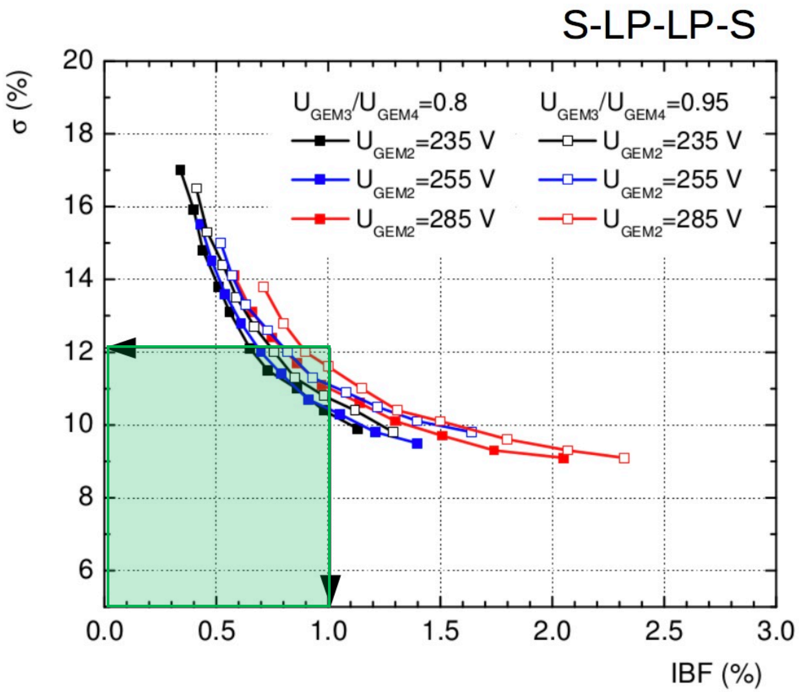


active area 0.7 m^2

S-LP-LP-S layout

Good working point

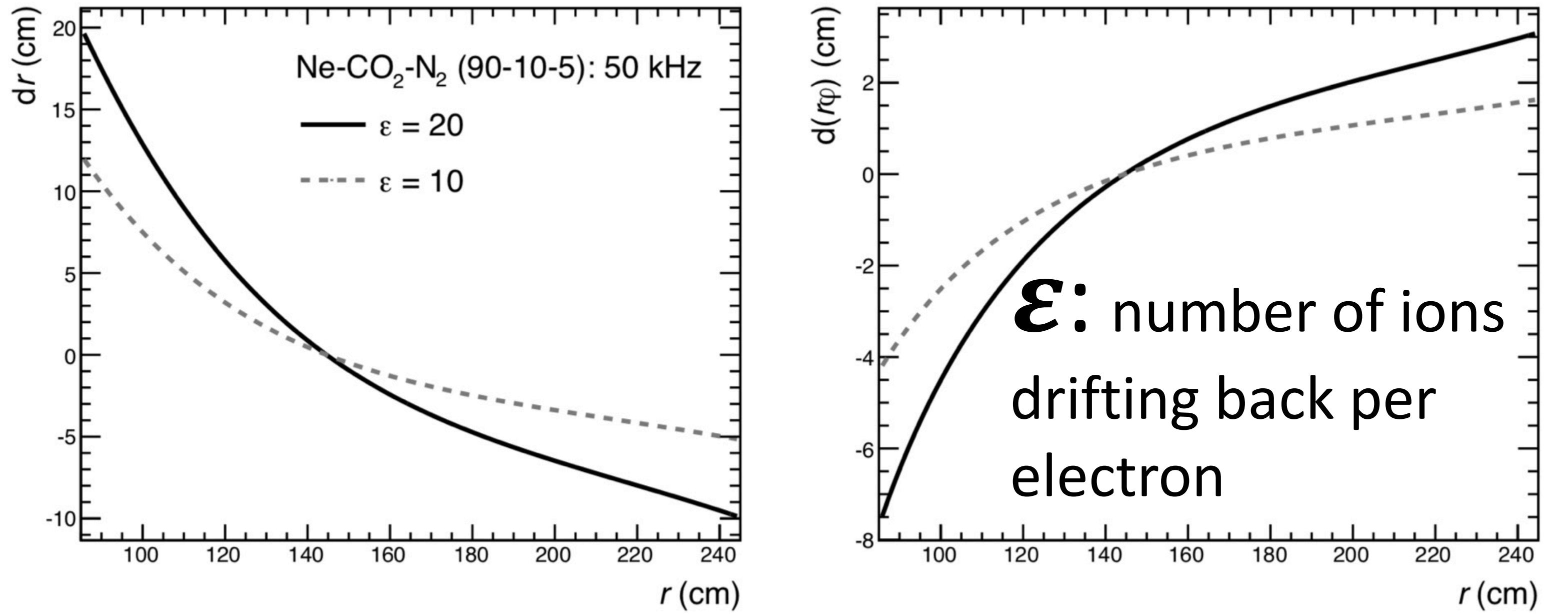
- Local energy resolution
- Ion back-flow



Space-charge distortions

Ion drift time $\sim 0.16\ s$ Interaction rate 50 kHz

Ion pile-up from ~ 8000 events



$\mathcal{O}(20\ \mathrm{cm})$ distortions on intrinsic resolution of $\mathcal{O}(0.02\ \mathrm{cm})$!

Space-charge distortions

Ion drift time $\sim 0.16\ s$ Interaction rate 50 kHz

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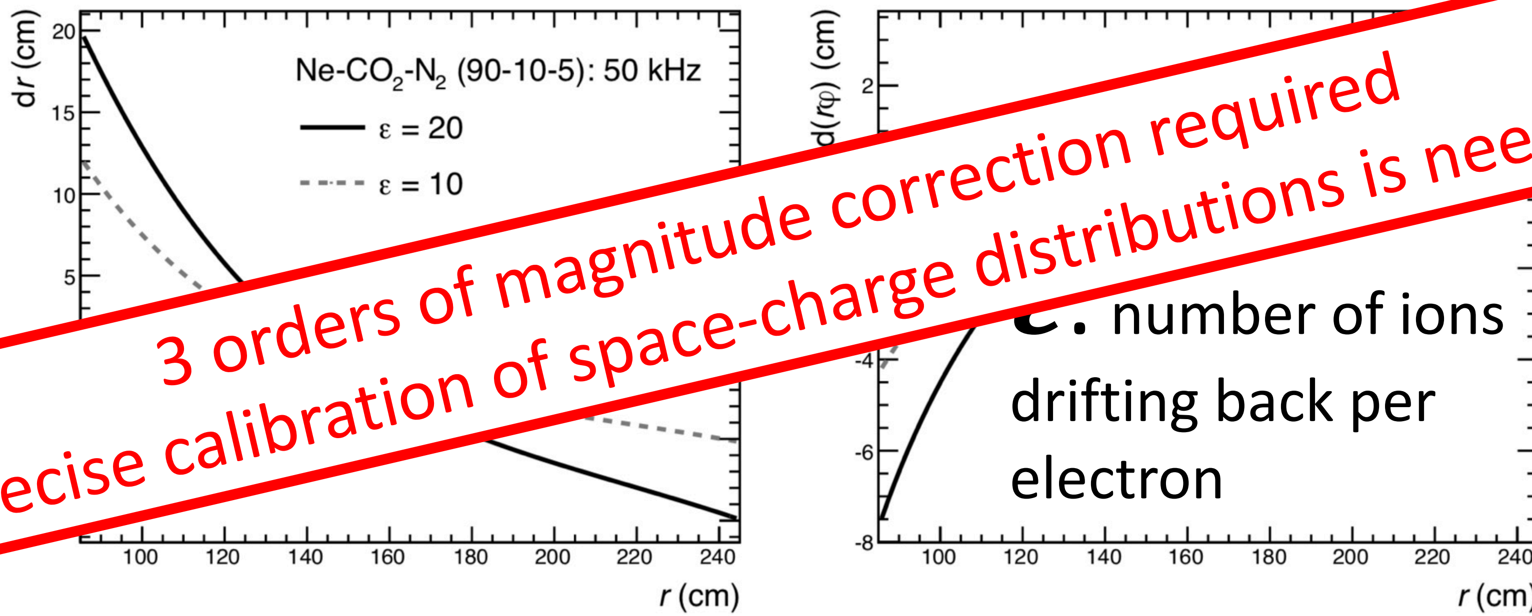


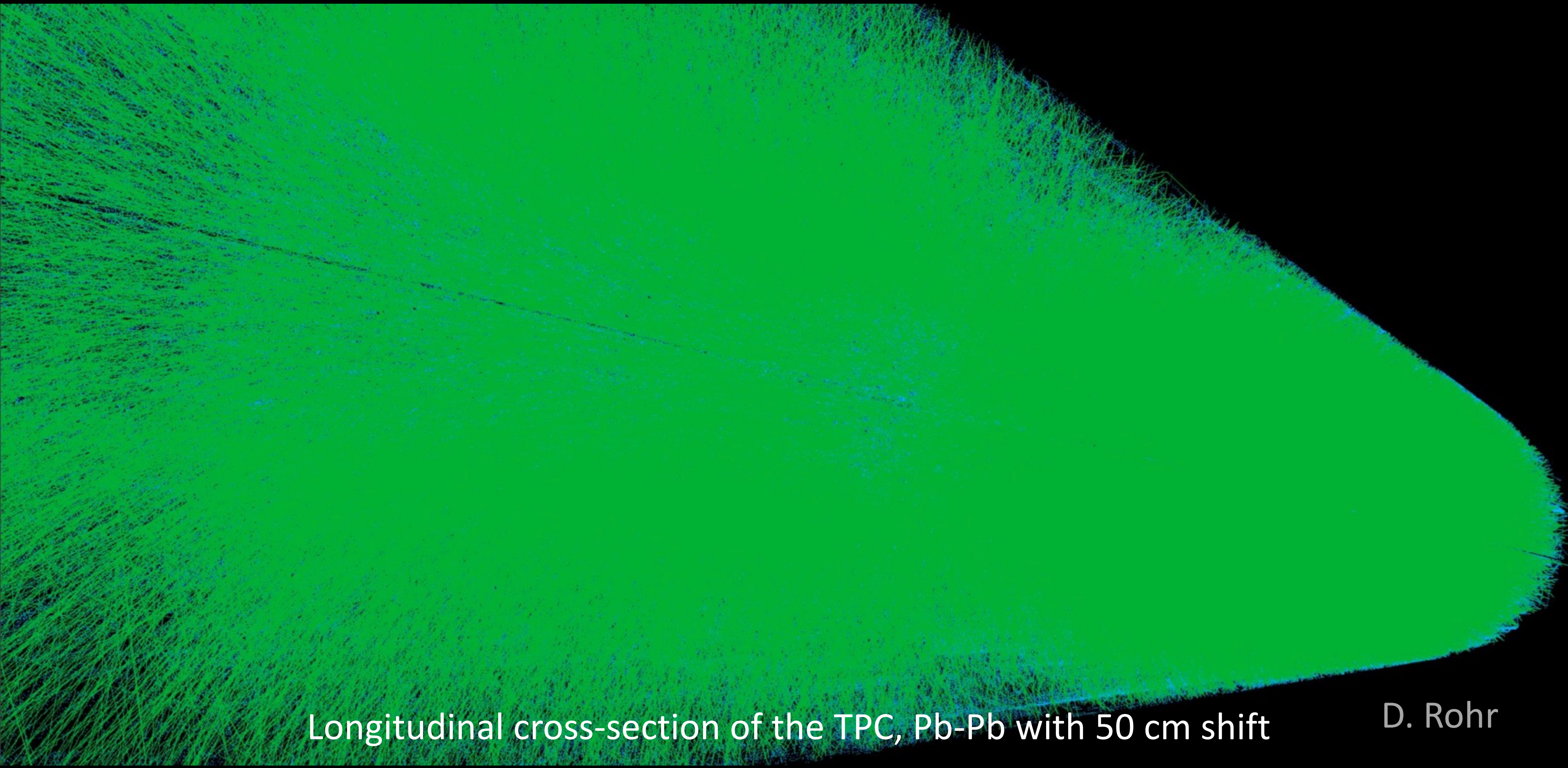
3 orders of magnitude correction required

precise calibration of space-charge distributions is needed

$\mathcal{O}(20\ \mathrm{cm})$ distortions on intrinsic resolution of $\mathcal{O}(0.02\ \mathrm{cm})$!

5 ± 3.5 Events pile-up in the TPC

Electron drift time ~ 92 μs



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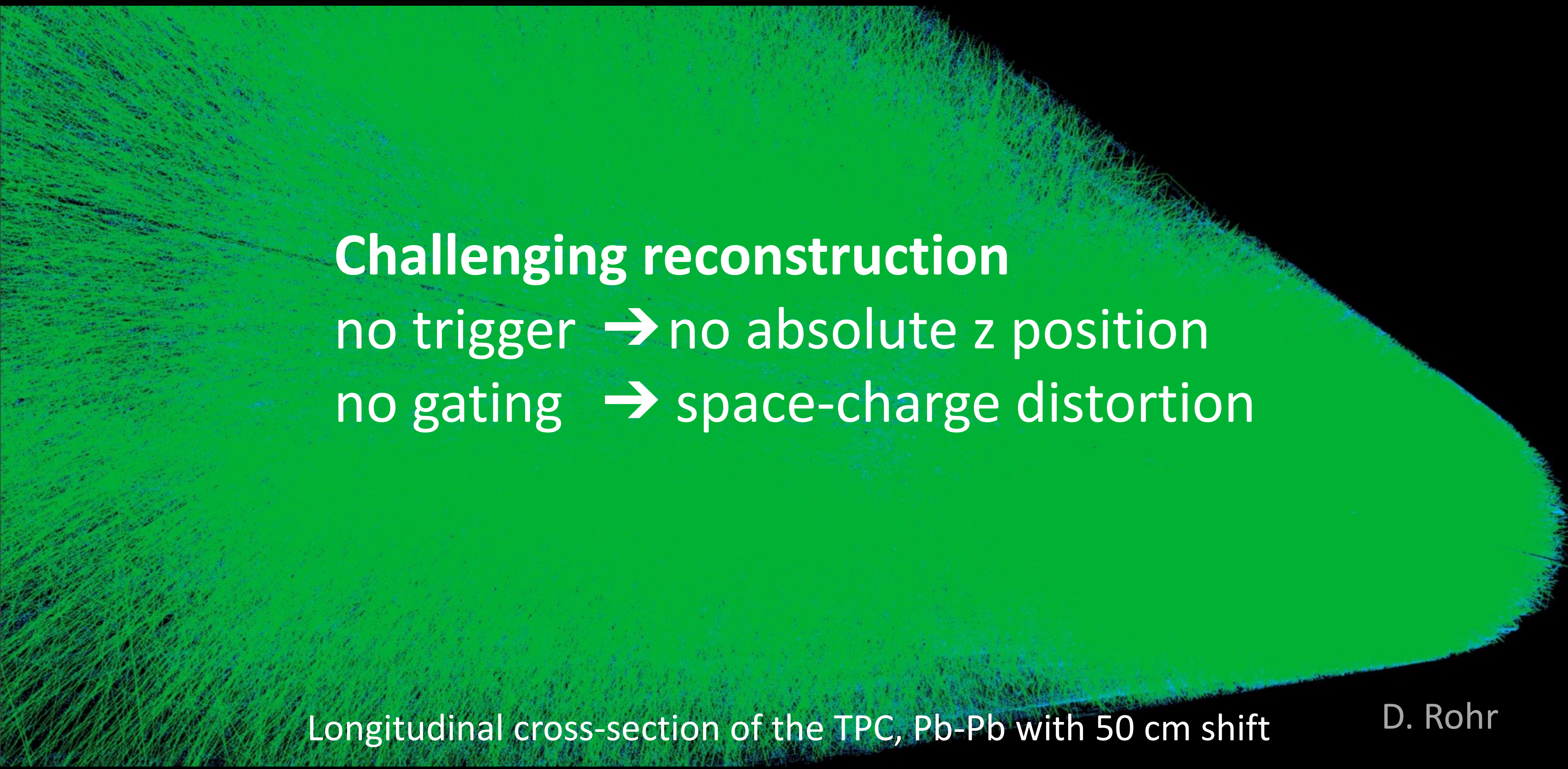


Challenging reconstruction

no trigger → no absolute z position

no gating → space-charge distortion

Longitudinal cross-section of the TPC, Pb-Pb with 50 cm shift

D. Rohr

Track reconstruction

Absolute z-position

Standalone tracking in the Inner Tracking System

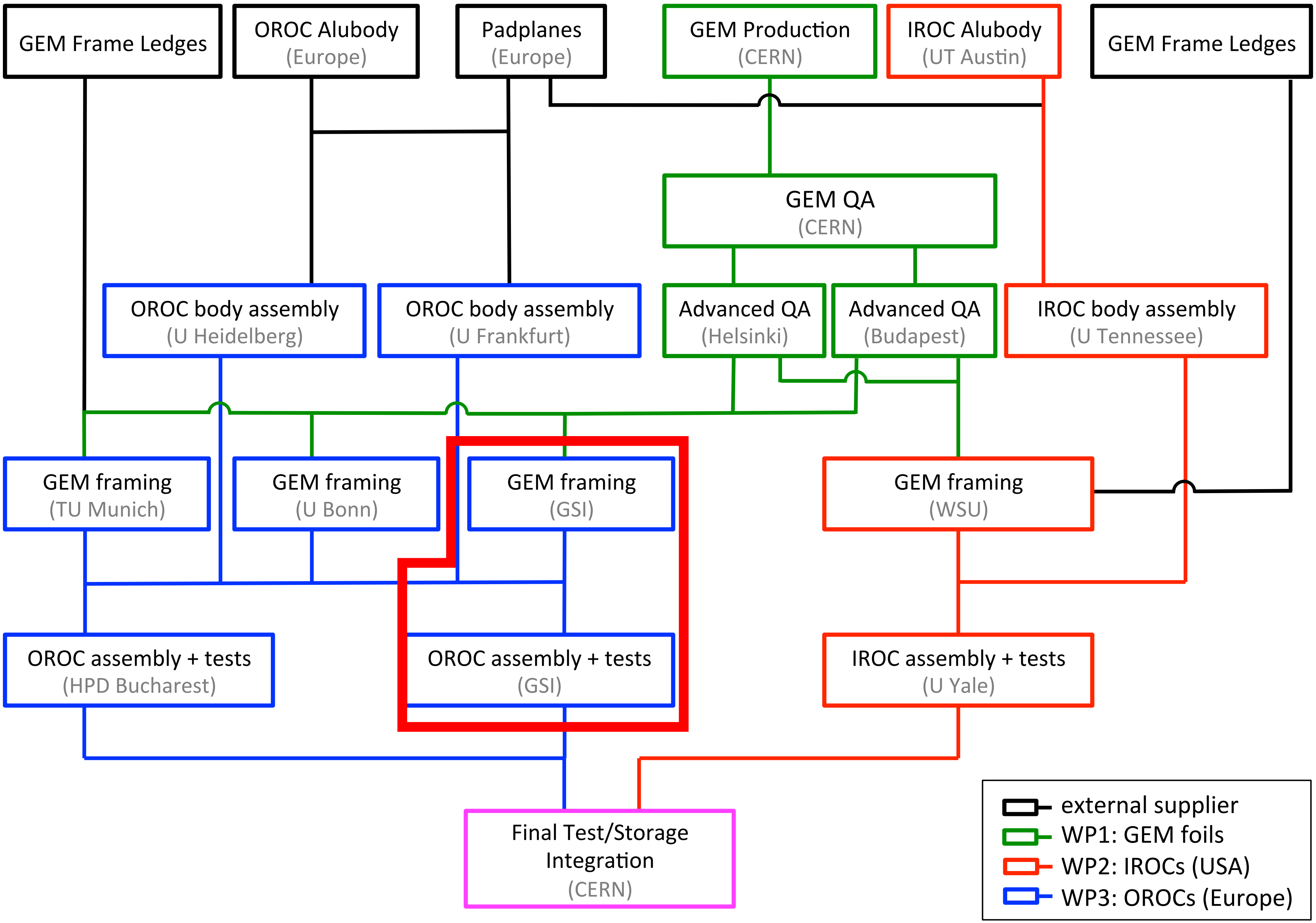
Standalone tracking in the TPC

Match TPC to ITS track based on time

Improve precision by a combined fit

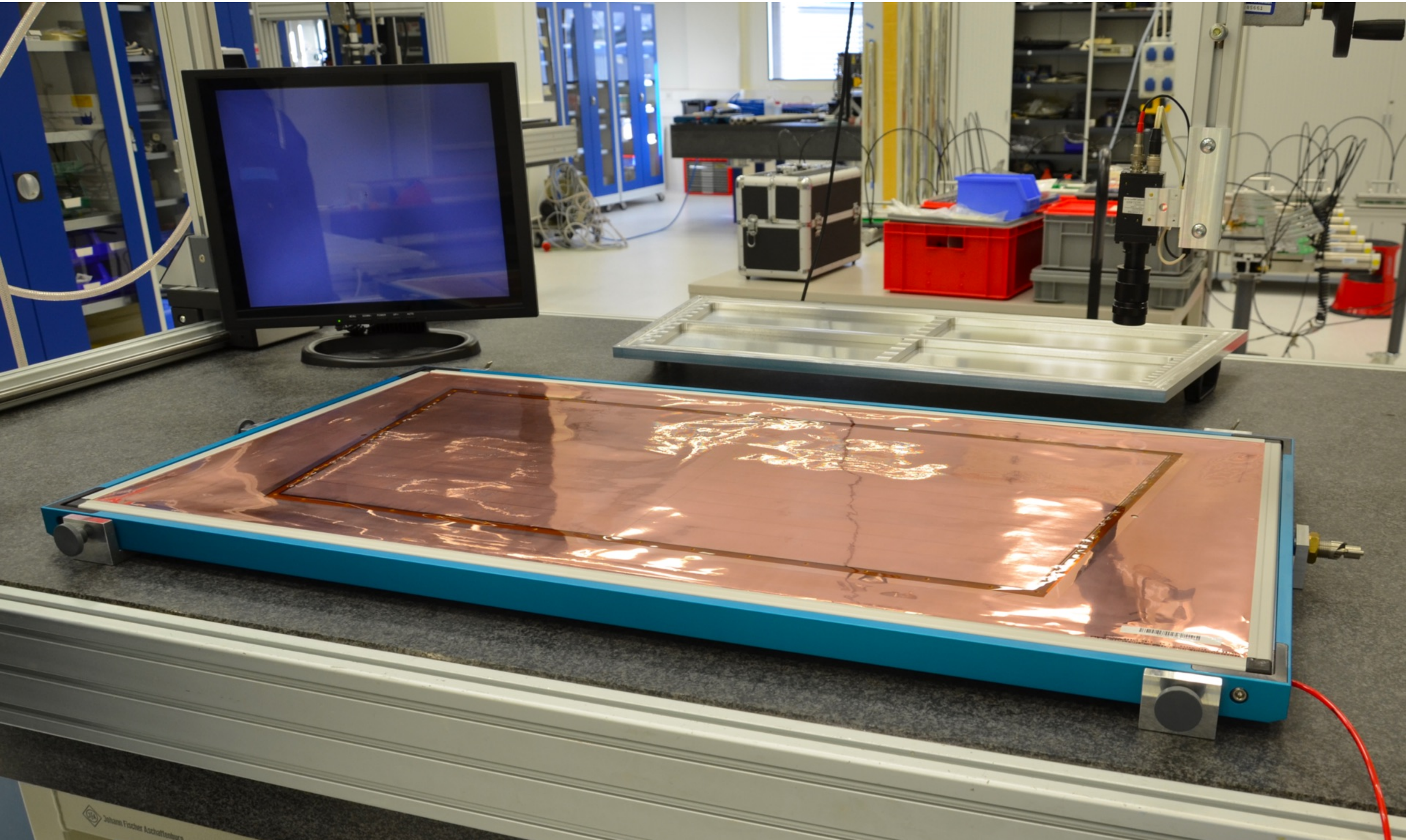
Space-charge distortions

Distortion map calculated using ITS and TRD

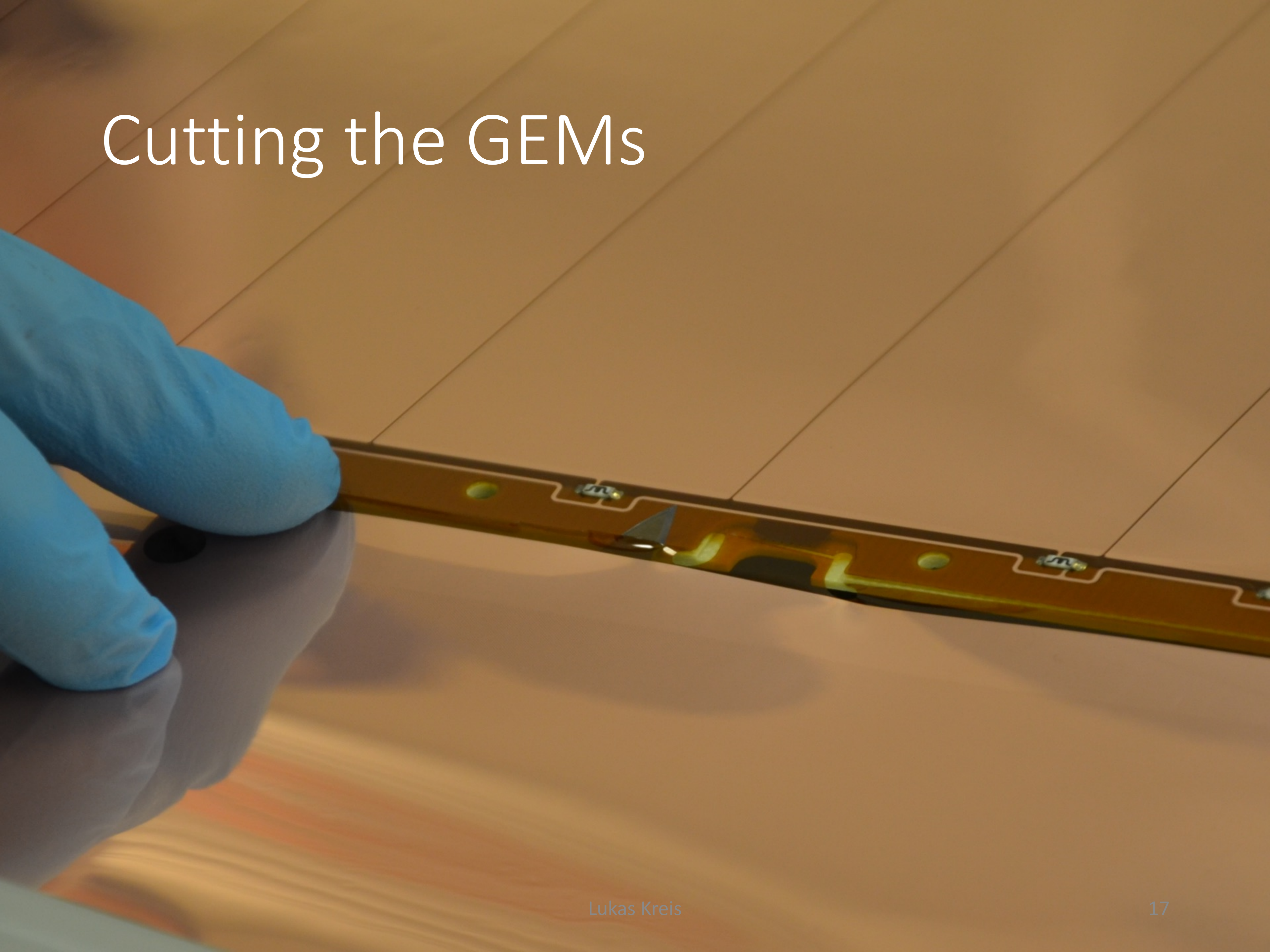

GEM Frame Ledges
OROC Alubody
(Europe)
Padplanes
(Europe)
GEM Production
(CERN)
IROC Alubody
(UT Austin)
GEM Frame Ledges
GEM QA
(CERN)
OROC body assembly
(U Heidelberg)
OROC body assembly
(U Frankfurt)
Advanced QA
(Helsinki)
Advanced QA
(Budapest)
IROC body assembly
(U Tennessee)
GEM framing
(TU Munich)
GEM framing
(U Bonn)
GEM framing
(GSI)
GEM framing
(WSU)
OROC assembly + tests
(HPD Bucharest)
OROC assembly + tests
(GSI)
IROC assembly + tests
(U Yale)
Final Test/Storage
Integration
(CERN)
external supplier
WP1: GEM foils
WP2: IROCs (USA)
WP3: OROCs (Europe)

Chamber assembly

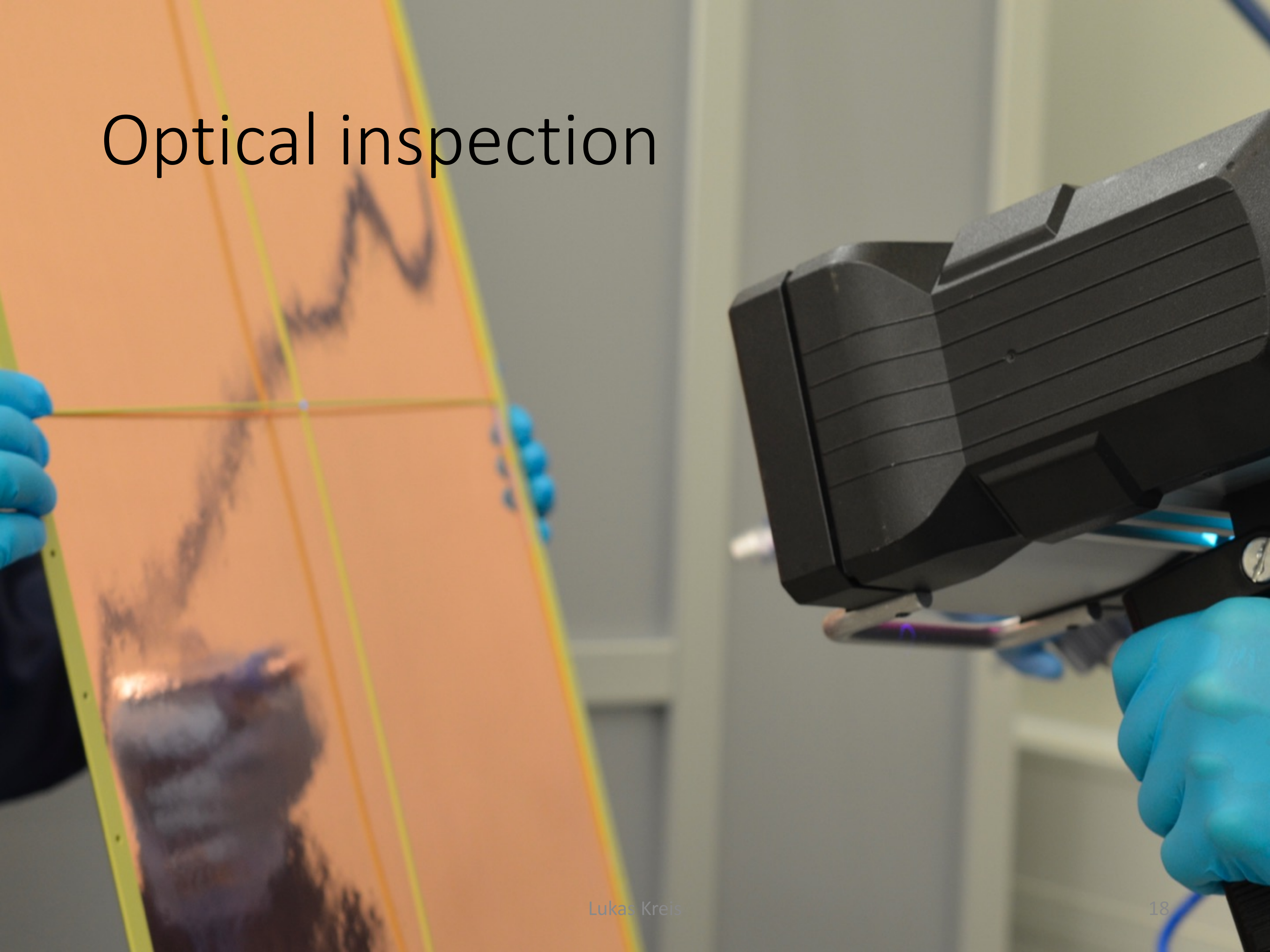
GEM framing



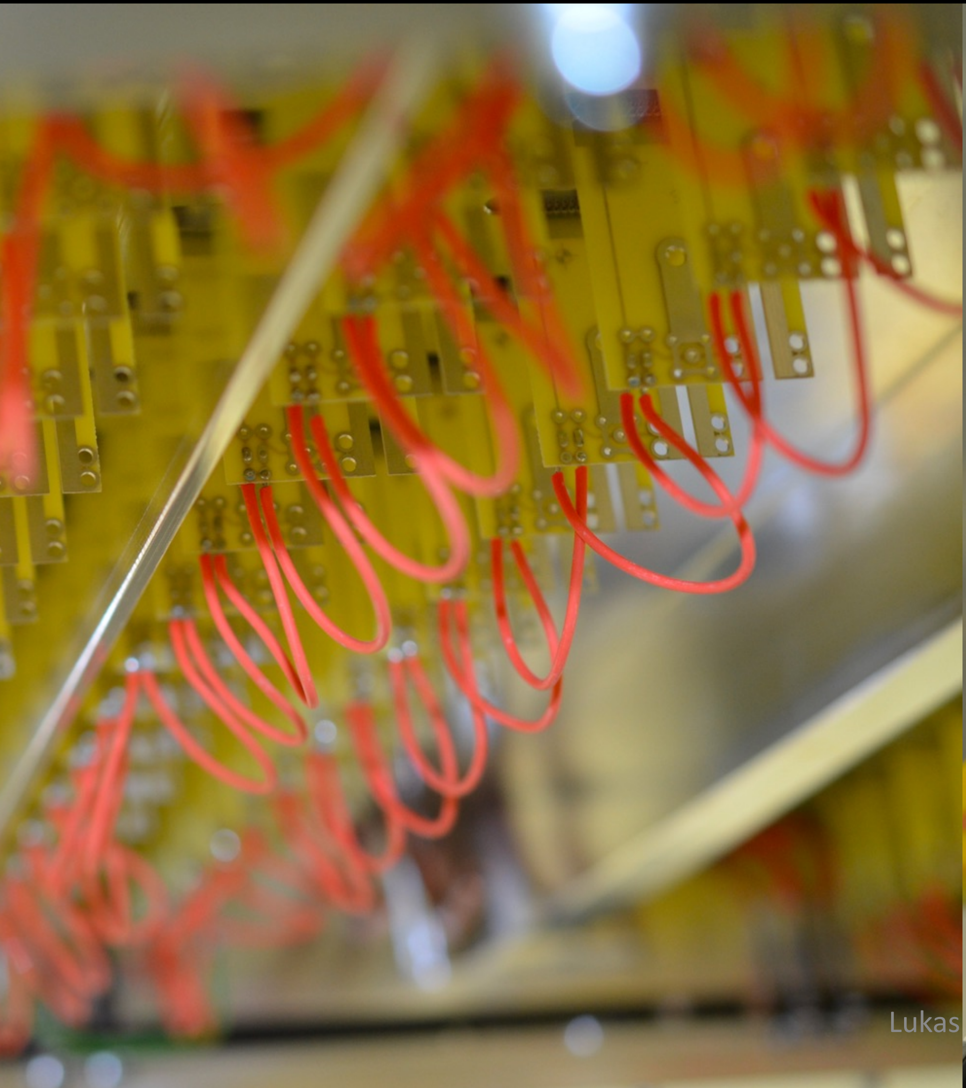
Cutting the GEMs

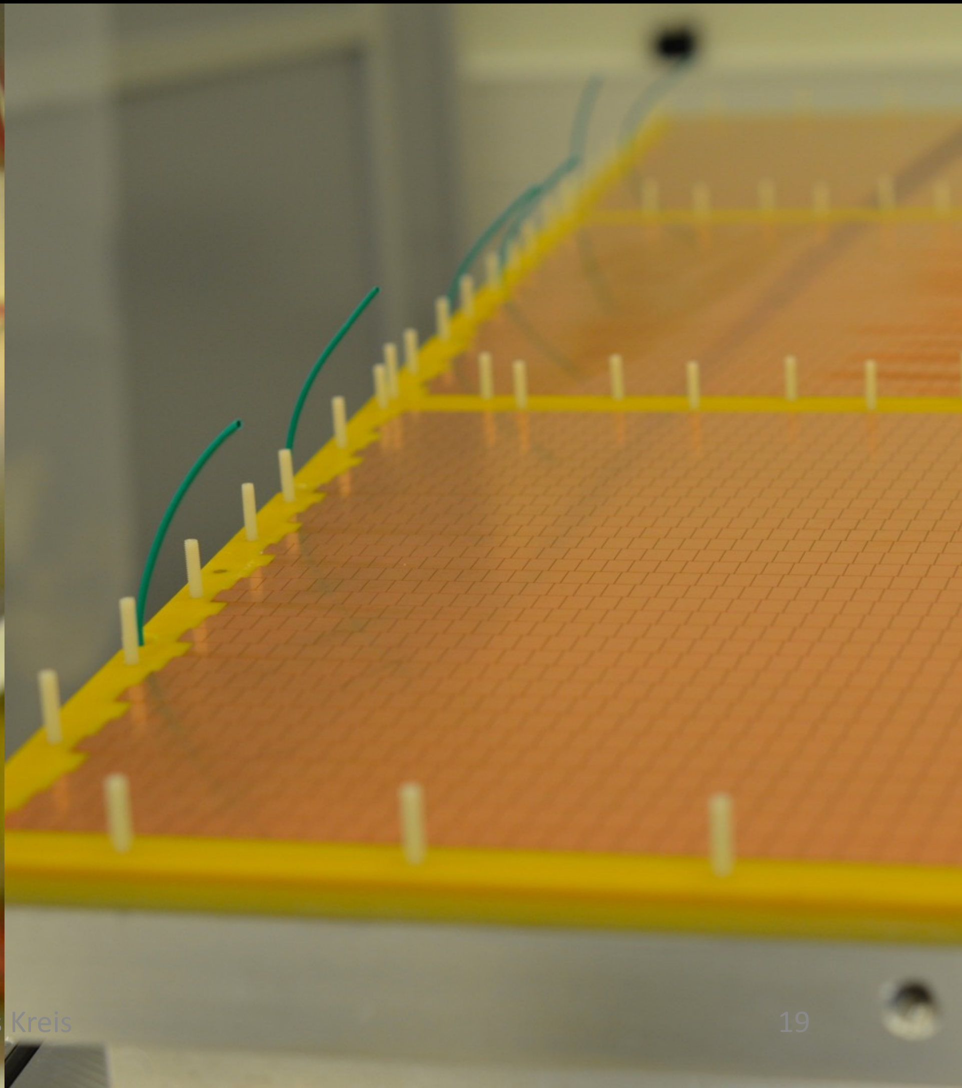


Optical inspection

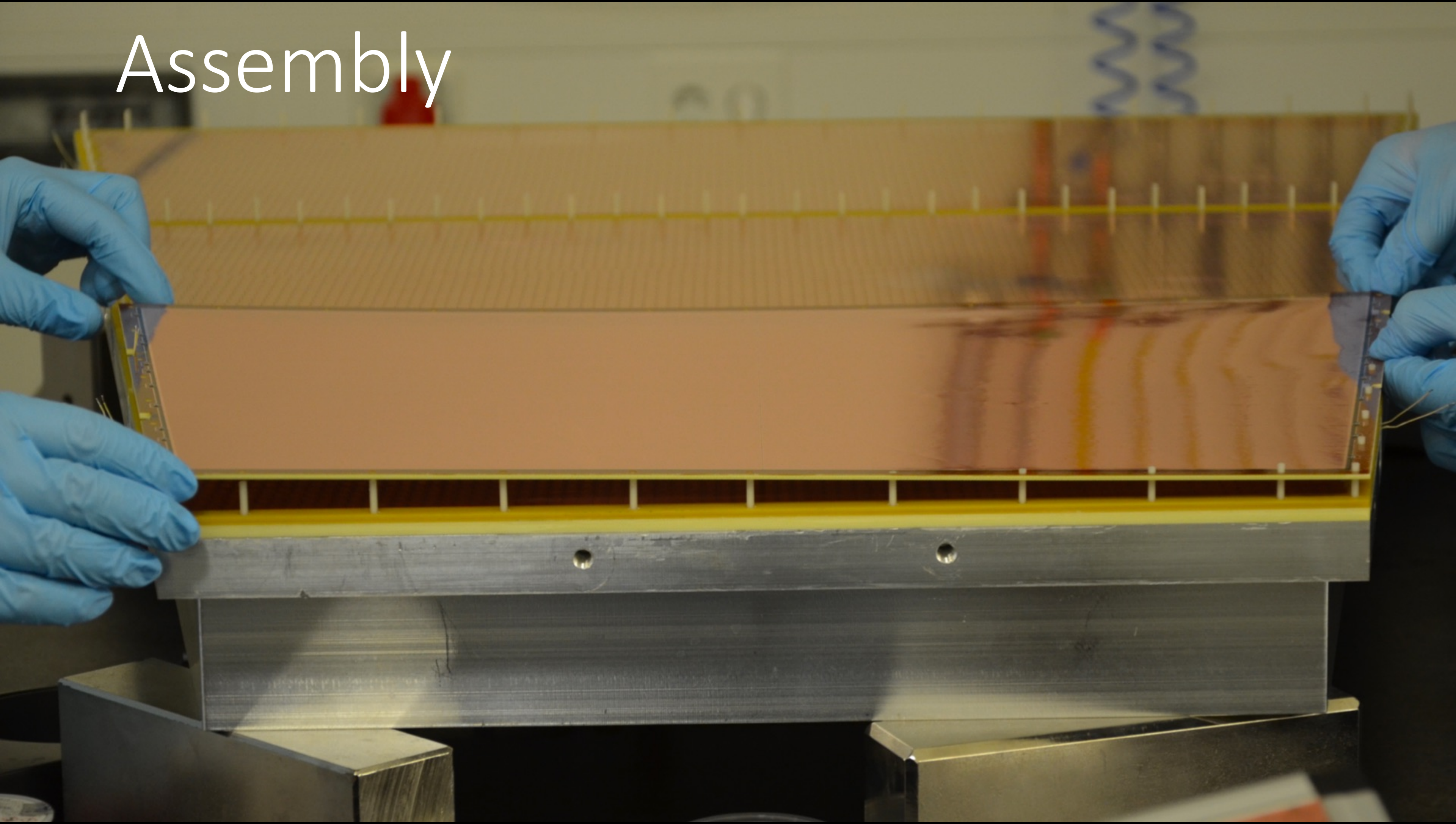


Checking OROC

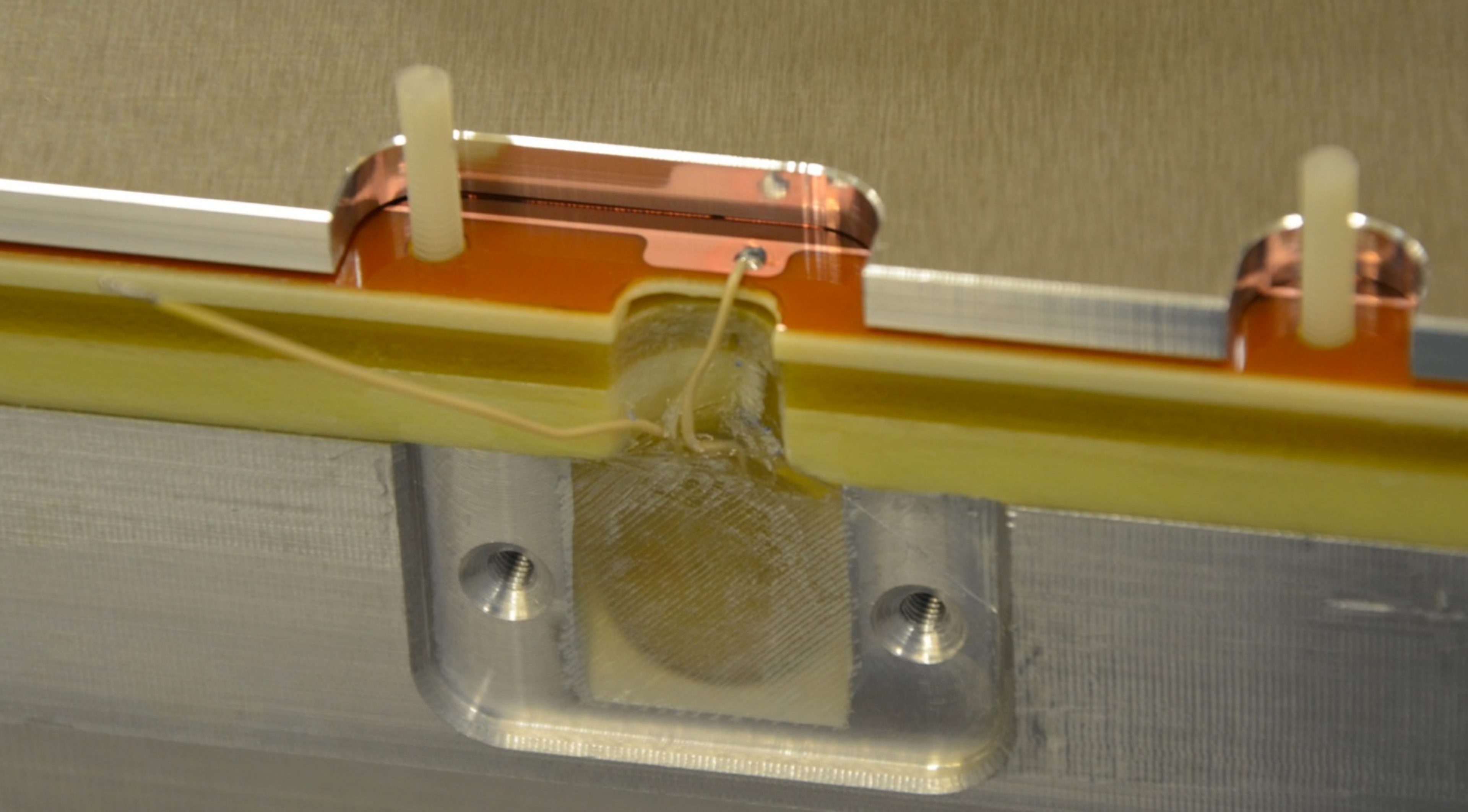




Assembly



Soldering HV connection



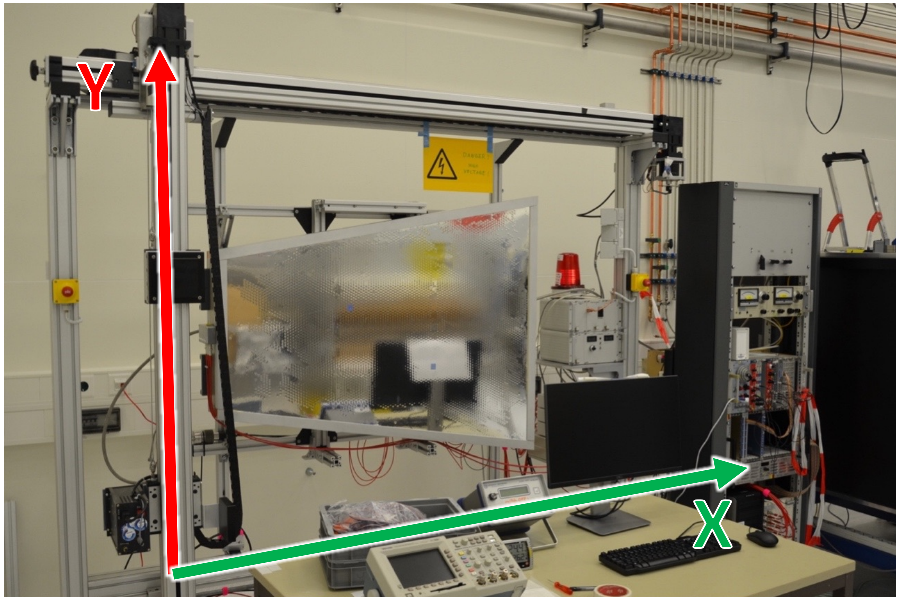
Chamber quality assurance

1. First Scan
2. Gas tightness
3. Gain curve
4. Energy resolution
5. Gain uniformity
6. Ion back-flow uniformity
7. Full x-ray irradiation test
8. HV-wire irradiation

Test setups

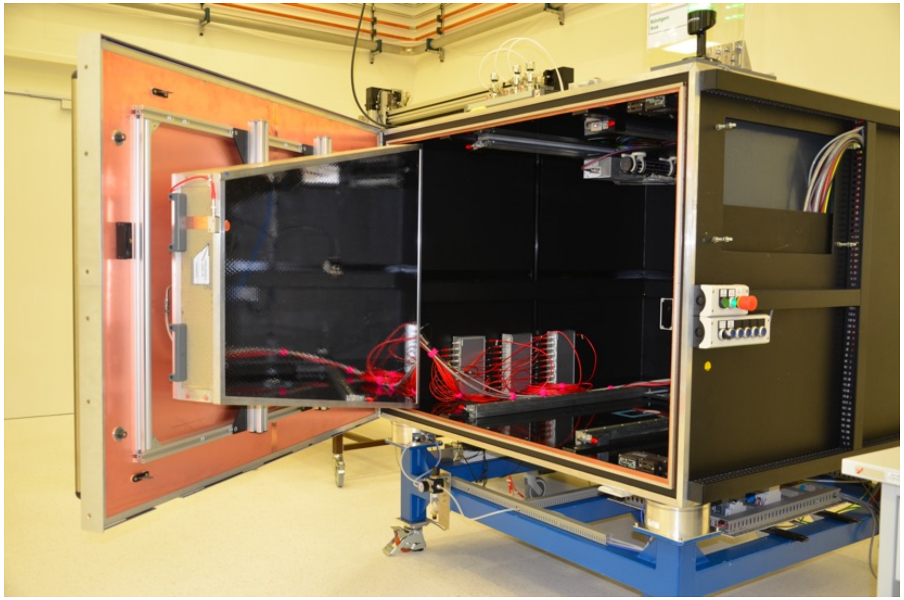
XY-scanning

X-ray gun and ^{55}Fe source



Full area irradiation

X-ray guns

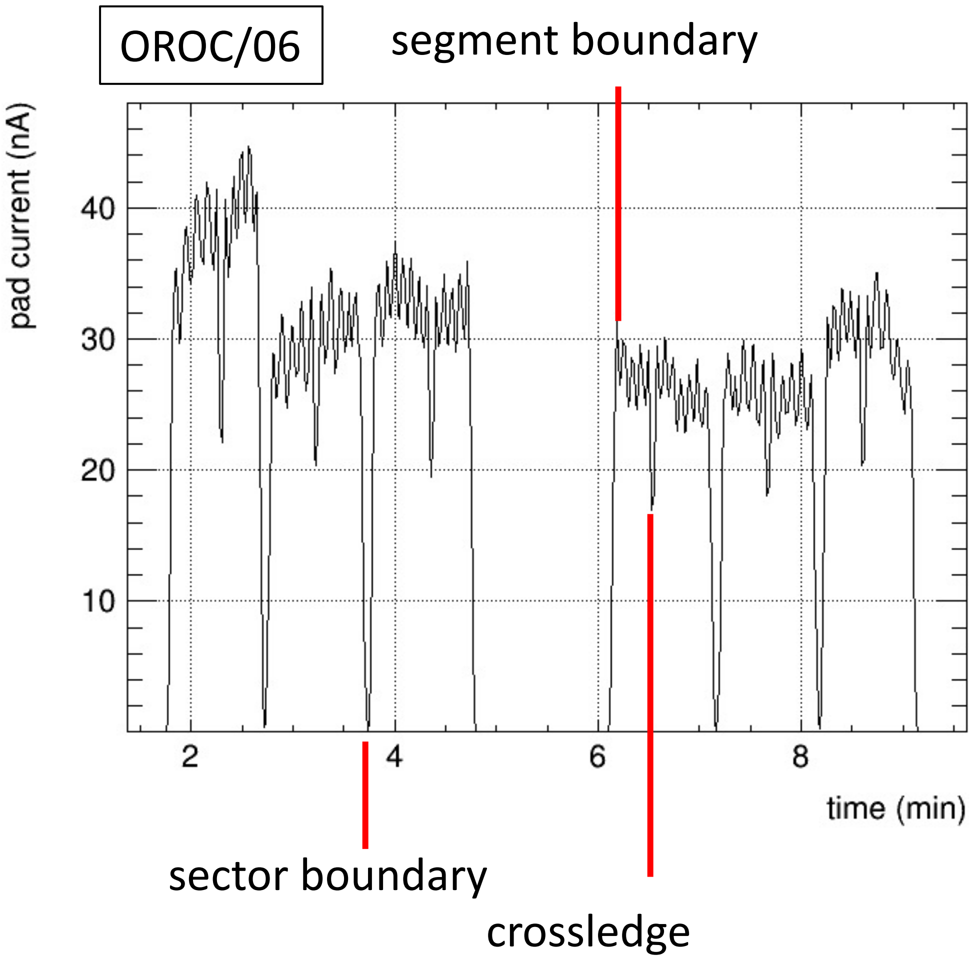


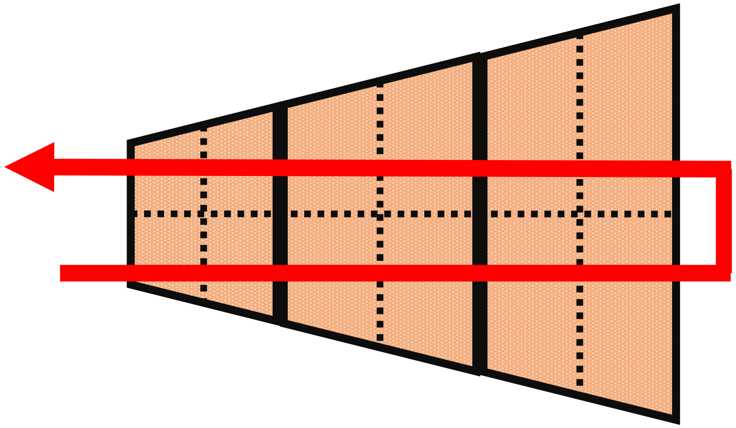
First scan

X-ray gun moves across GEMs

Checks if segments are alive

Integrated pad current





Gain curve

$Gain = \frac{I_{pads}}{eN_eR}$

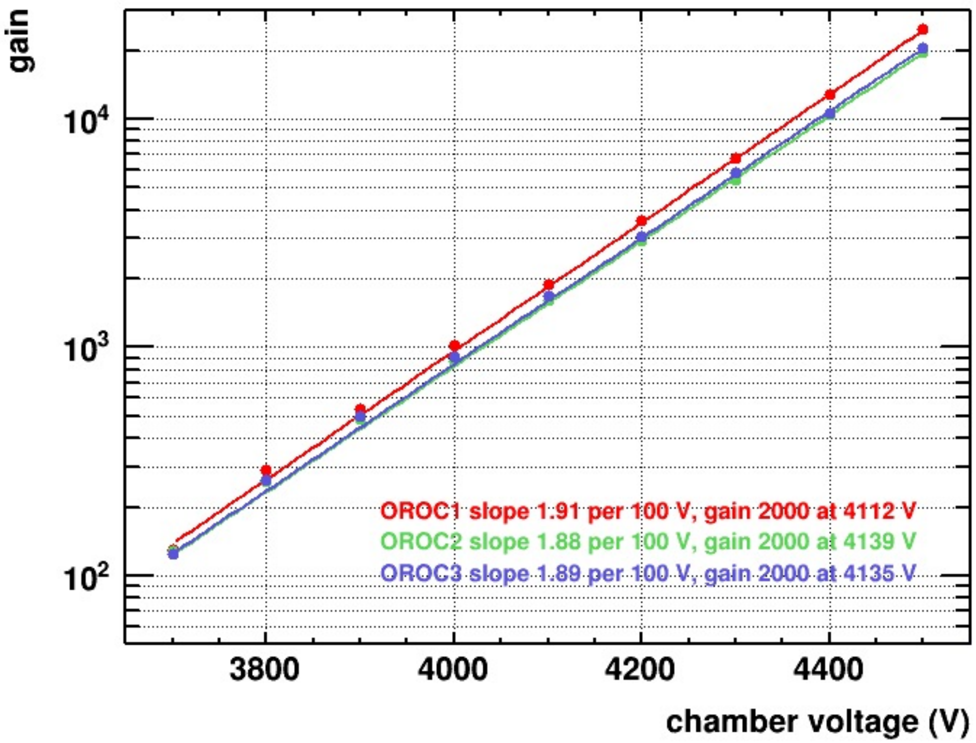
X-ray rate R

number of electrons N_e

^{55}Fe x-ray source

Find voltage for a gain of 2000

OROC/06



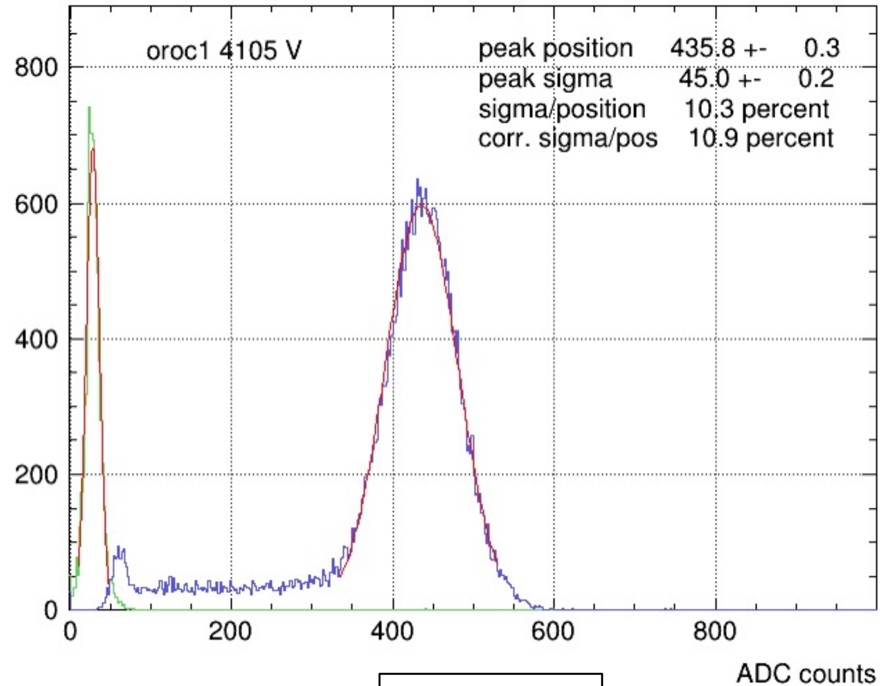
Energy resolution

$OROC1\ \sigma(E)/E = 10.9\%$

Collimated ^{55}Fe source

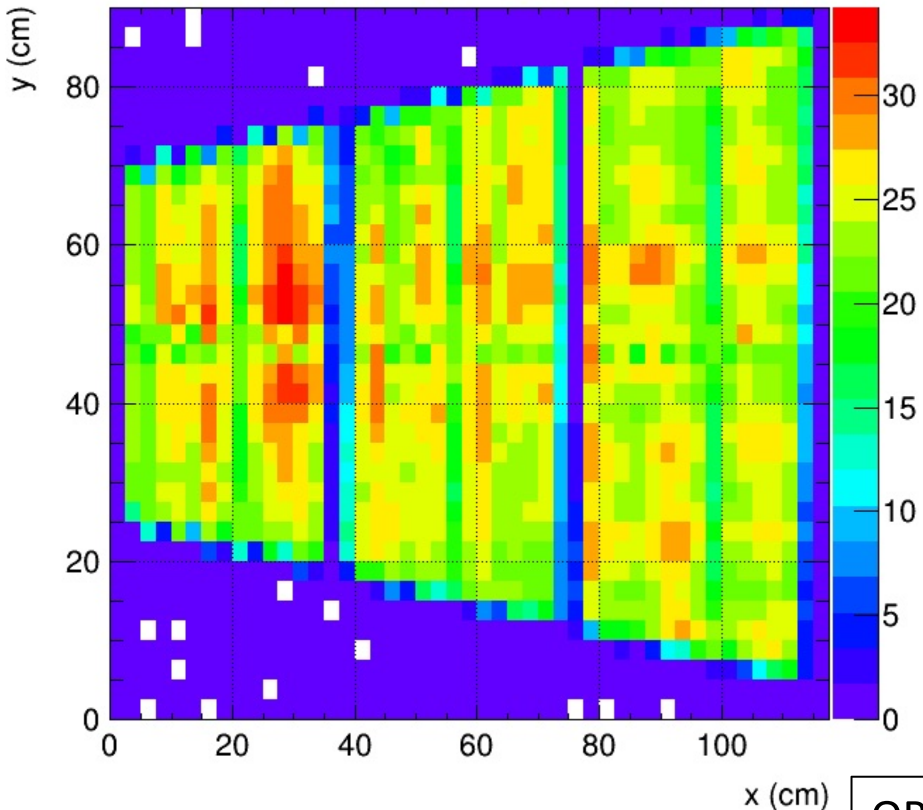
Spectrum at nominal gain

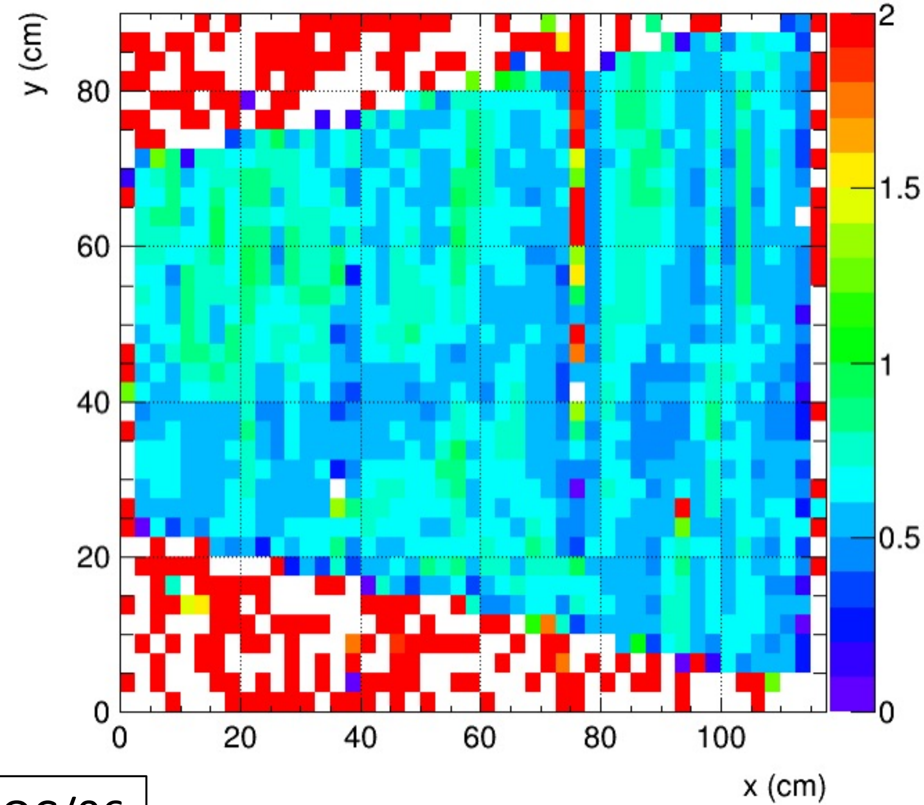
Fit determines resolution



OROC/06

Gain and ion backflow



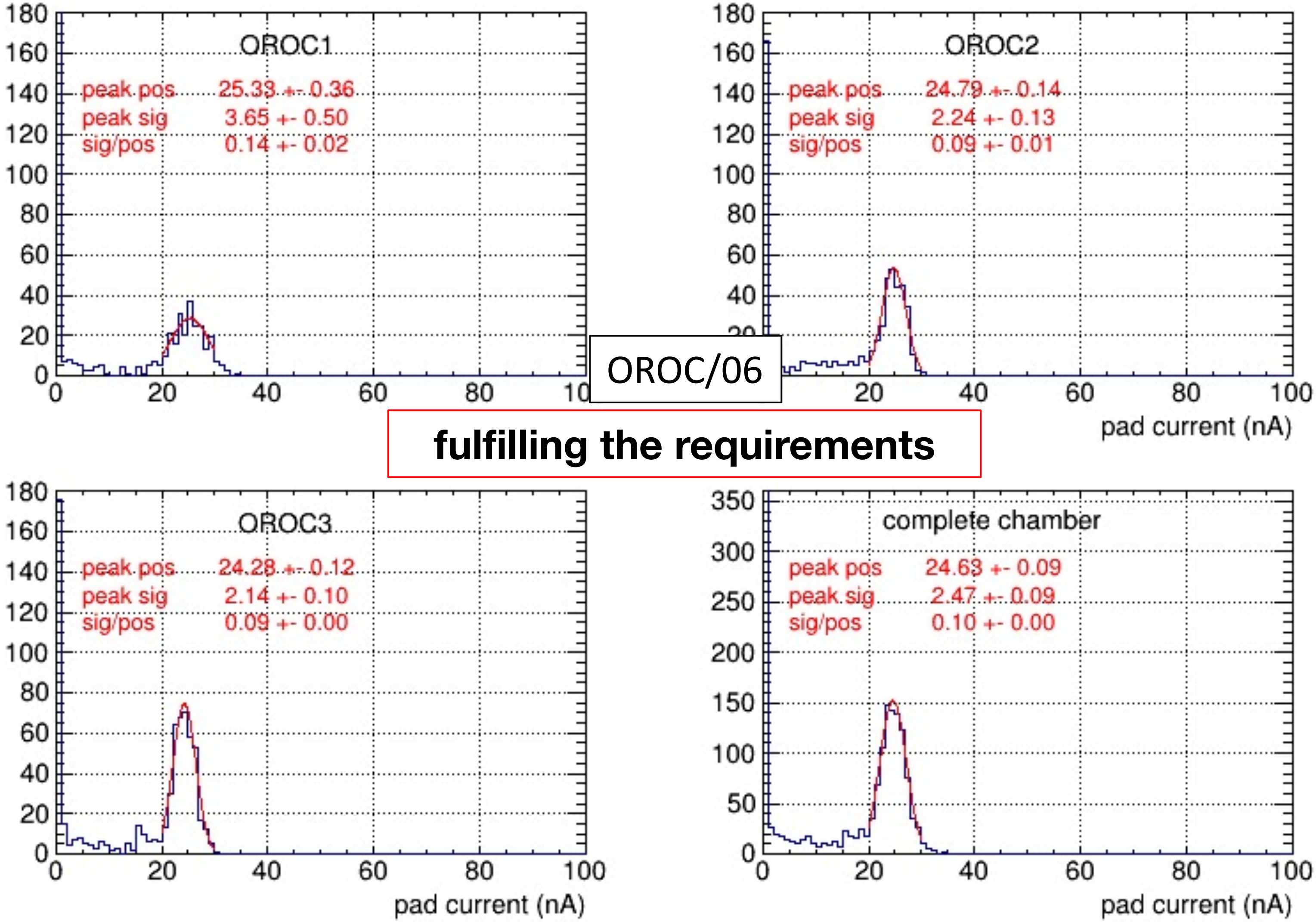


OROC/06

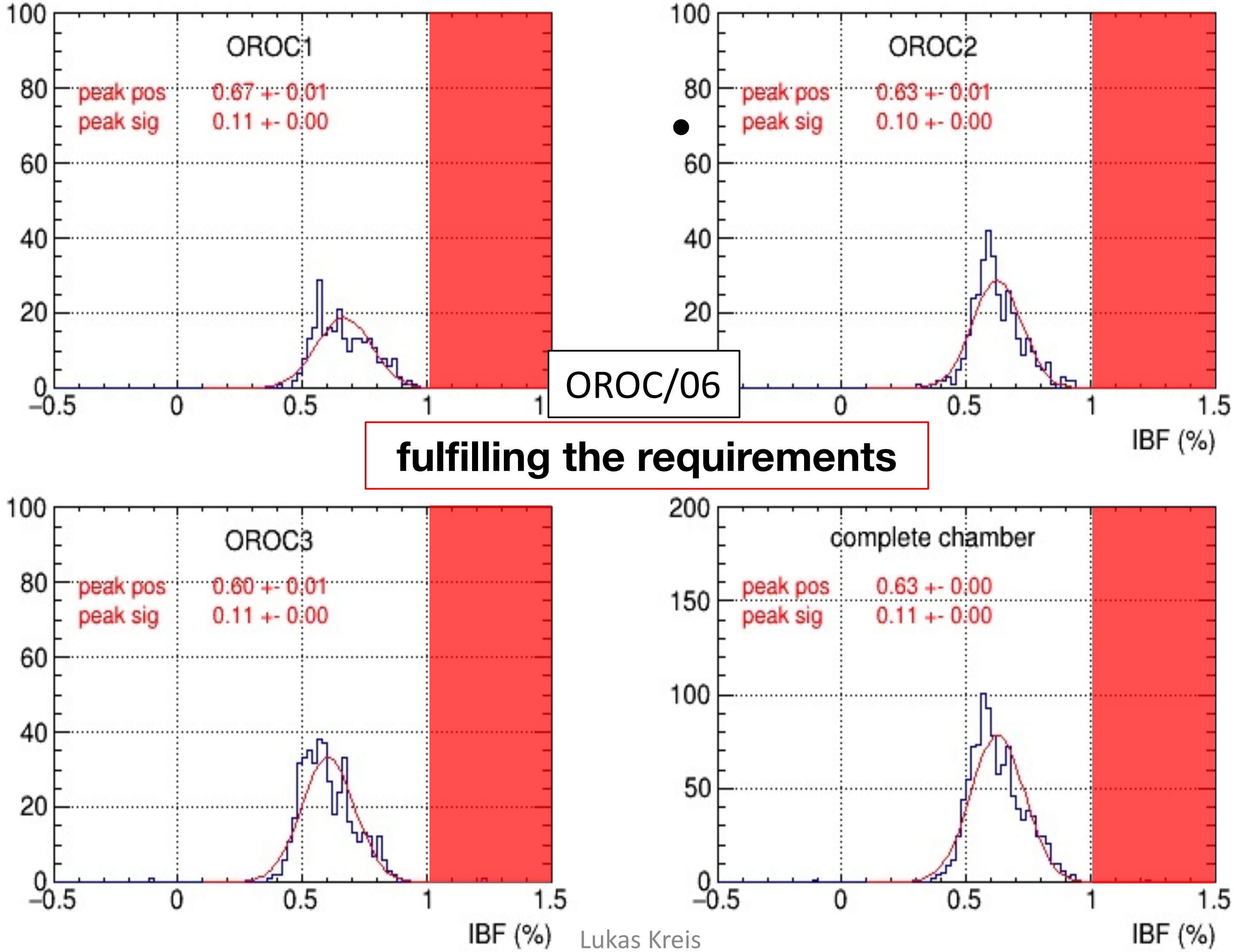
Gain

$$IBF = \frac{I_{cathode}}{I_{pads}}$$

Gain uniformity



Ion backflow uniformity



Full area irradiation test

Chamber load > Run 3 + 4

Nominal gain = 2000

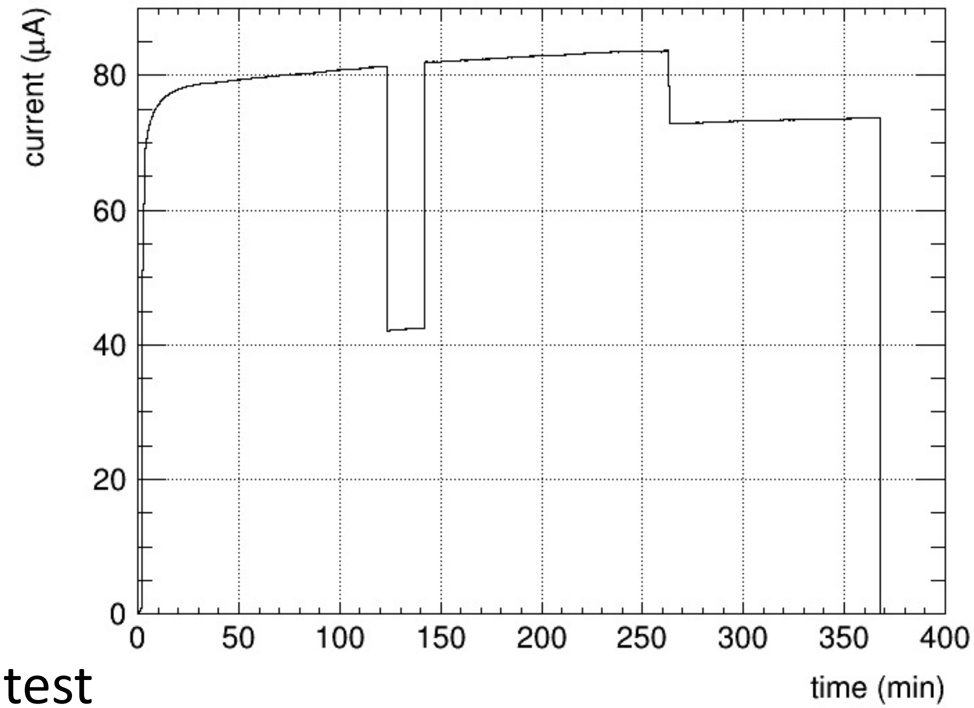
Peak pad current = $10\ \mathrm{nA/cm^2}$

Duration > 6 hours

Look for discharges

Leakage current rechecked after test

OROC/5



fulfilling the requirements

Summary

Rich physics program of ALICE after LS2

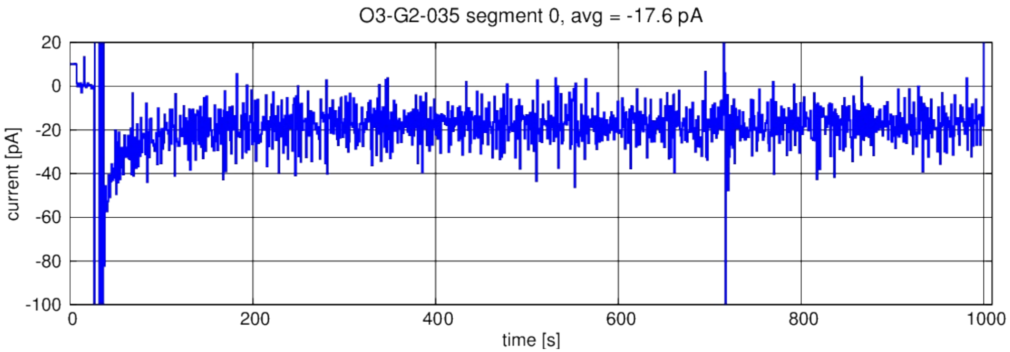
TPC upgrade needed to cope with interaction rate

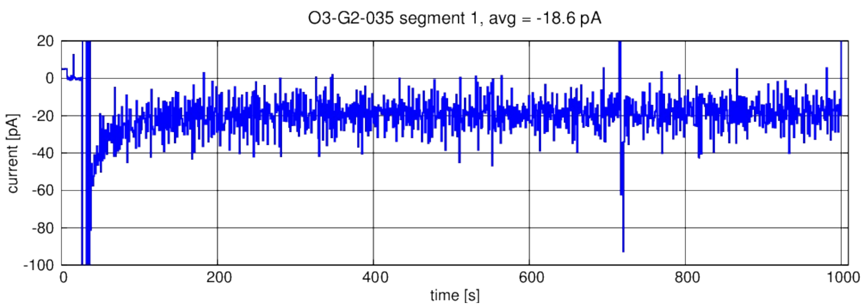
GSI Detector Lab deeply involved in the upgrade

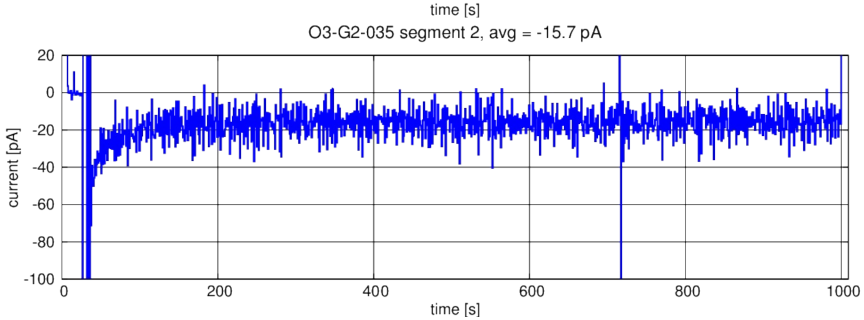
Production of chambers already reached 50 %

Backup

GEM leakage current tests







⋮

segments	$\bar{I}$ / pA
0	-17.6
1	-18.6
2	-15.7
3	-16.3
4	-16.2
5	-17.7
6	-15.4
⋮	⋮

GEM Quality Assurance

CERN production

Helsinki optical check

GSI framing

Leakage current measurement after every step

500 V in nitrogen environment

→ Suitable foils are selected for chamber assembly

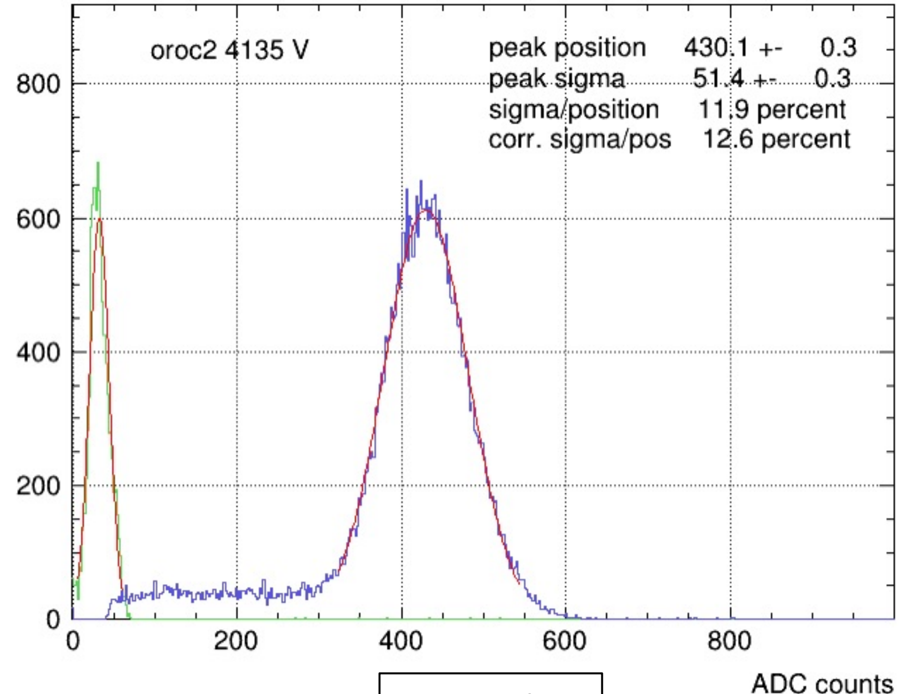
Energy resolution

Collimated ^{55}Fe source

Spectrum at nominal gain

Fit determines resolution

$OROC2\ \sigma(E)/E = 12.6\%$



OROC/06

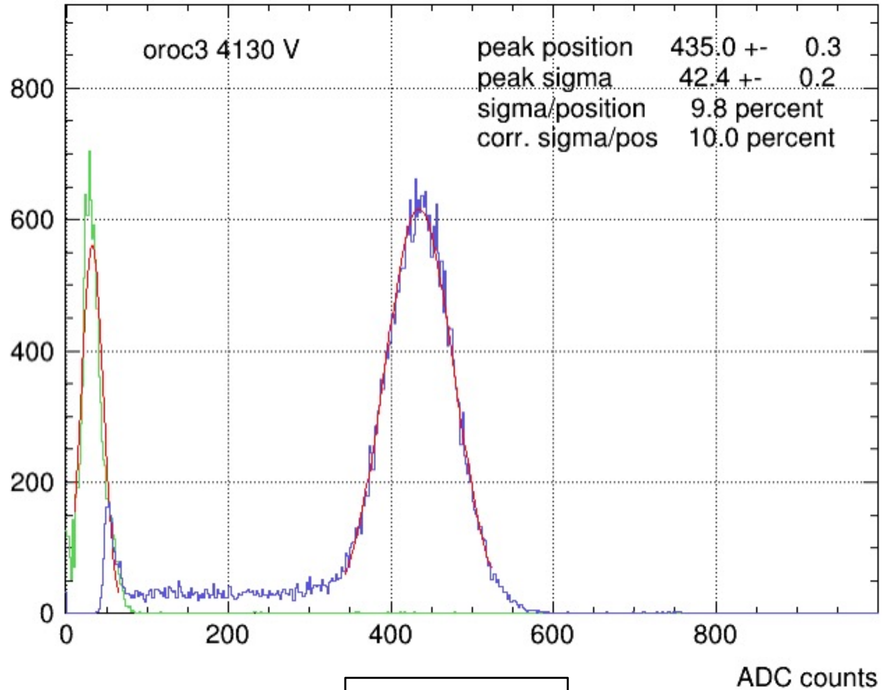
Energy resolution

Collimated ^{55}Fe source

Spectrum at nominal gain

Fit determines resolution

OROC3 $\sigma(E)/E = 10.0\%$

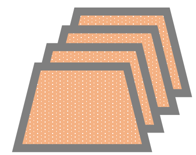
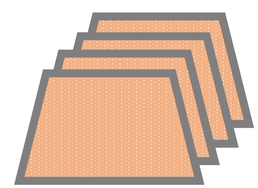
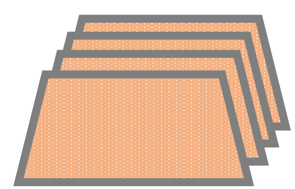


OROC/06

GEM leakage currents

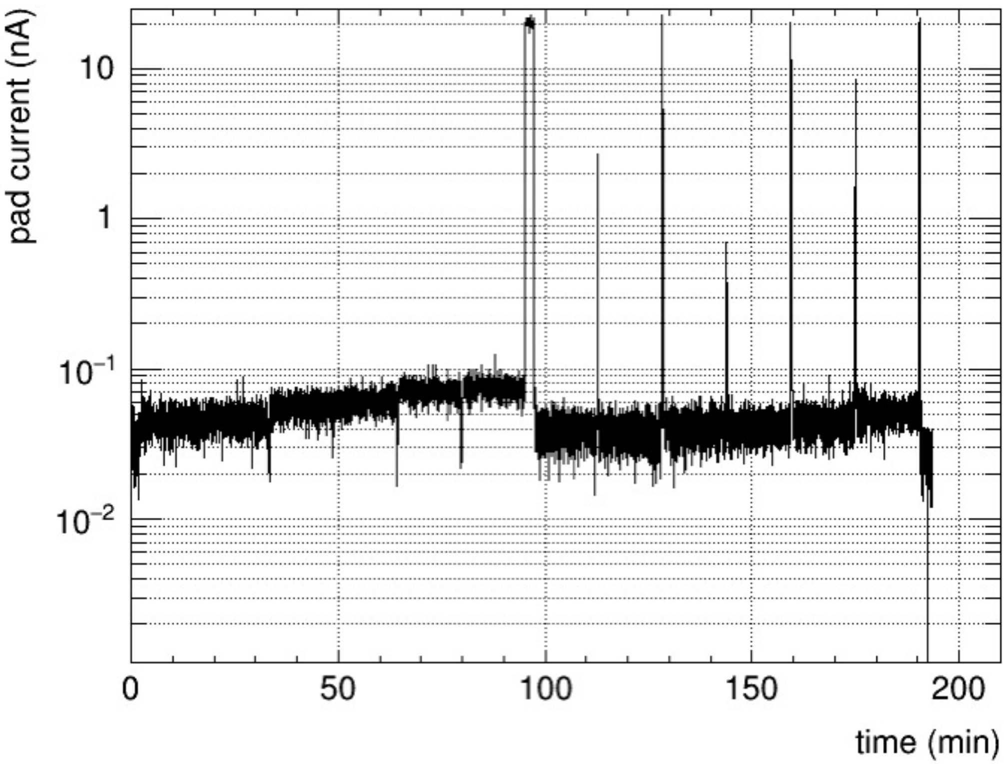
- Measured for each GEM
- Before and after irradiation
- Voltage setting 250 V
- Nominal gas Ne-CO2-N2

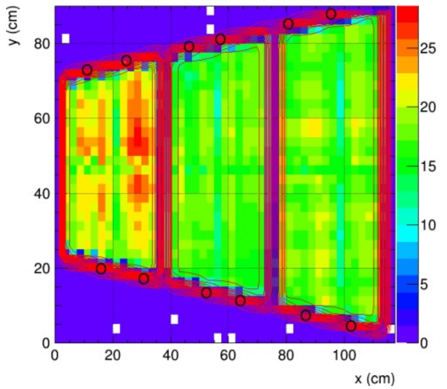
  Charging up of GEM-foils

		I_{leak}/ pA		
	GEM	before	after	
OROC1	1	600	150	👍
	2	160	200	👍
	3	150	150	👍
	4	250	200	👍
OROC2	1	400	250	👍
	2	250	200	👍
	3	200	150	👍
	4	300	300	👍
OROC3	1	950	300	👍
	2	550	250	👍
	3	350	400	👍
	4	800	300	👍

HV-wire irradiation

- Test stability of HV-wire connections
- 15 min per wire
- Short spikes are during movement





No discharges detected 👍