

UPGRADE OF THE ALICE TPC

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ALICE

OUTLINE

- Motivation for the upgrade
- Chamber mass production
- HV system
- Readout system
- Installation
- Summary and outlook



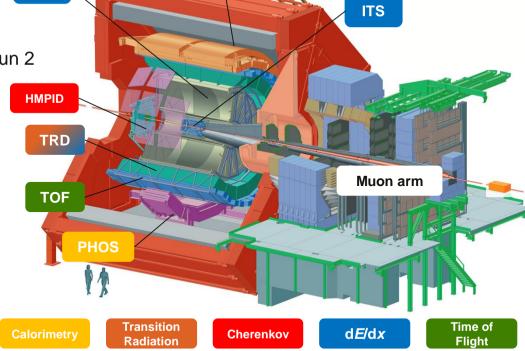
ALICE – A LARGE ION COLLIDER EXPERIMENT

- A dedicated heavy-ion experiment at the CERN LHC
- Study of a high-density, high-temperature phase of strongly interacting matter: Quark-Gluon
 Plasma (QGP)

TPC

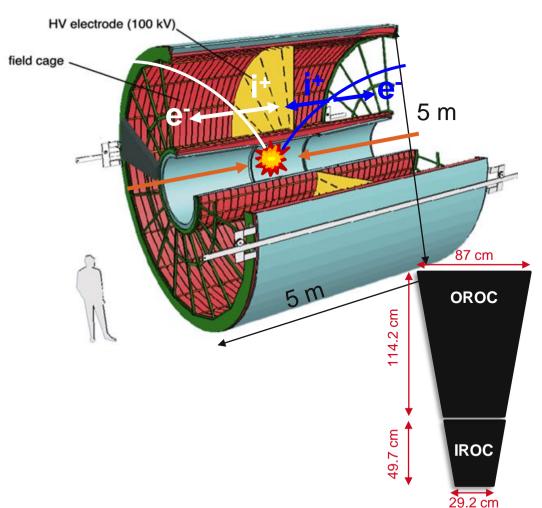
- Unique PID capabilities among all LHC experiments
- Covers broad kinematic range
- Many different PID techniques
- Excellent performance in Run 1 and Run 2





ALICE

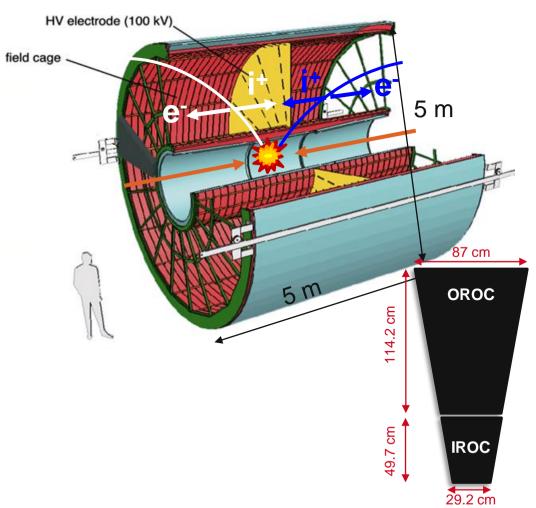
THE ALICE TPC



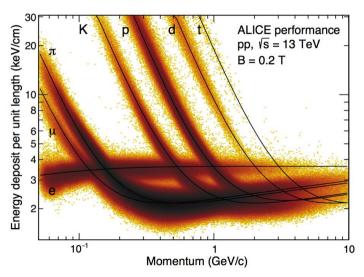
- Acceptance: $|\eta| < 0.9$, $\Delta \phi = 2\pi$
- Low-mass, high-precision field cage
- ~90 m³ active detector medium
- Gas:
 - Ne-CO₂-N₂ (90-10-5) in Run 1
 - Ne-CO₂ (90-10) in Run 1
 - Ar-CO₂ (88-12) in Run 2
 - Ne-CO₂-N₂ (90-10-5) in Run 2
 - Ne-CO₂-N₂ (90-10-5) in Run 3
- 100 kV at the Central Electrode
 - E_{drift} = 400 V/cm
 - $v_{drift} = 2.7 \text{ cm/}\mu\text{s}$
 - max t_{drift} = 92 μs
- 72 MWPCs with pad readout
 - Employ gating grid
 - >550k pads in 159 rows
 - 2x18 Inner and 2x18 Outer Readout Chambers (ROCs)



THE ALICE TPC



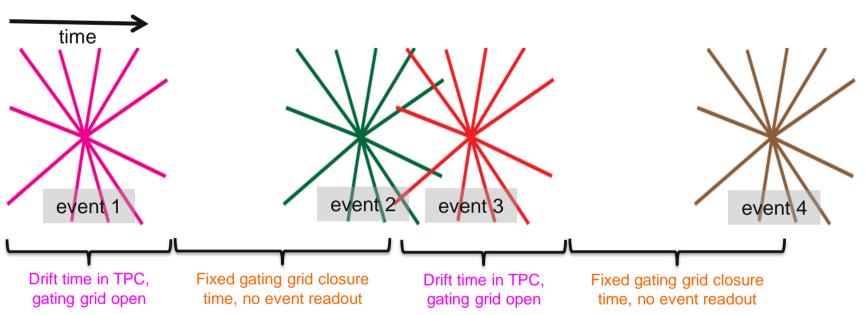
- Acceptance: $|\eta| < 0.9$, $\Delta \phi = 2\pi$
- Low-mass, high-precision field cage
- ~90 m³ active detector medium



Phys. Rev. D 98, 030001 (2018)



GATED OPERATION IN RUN 1 & RUN 2



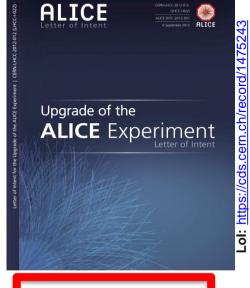
Multi Wire Proportional Chamber readout

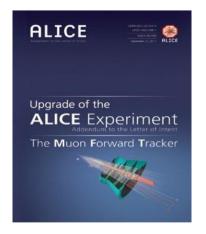
- A pulsed gating grid is used to prevent back-drifting ions from the amplification stage to distort the drift field (ion backflow (IBF) suppression ~10⁻⁵)
- 100 µs electron drift time + 200/400 µs gate closed (Ne/Ar) to minimize ion backflow and drift-field distortions
- 300/500 μs in total limits the maximal readout rate to few kHz (in pp)
- Limitation of readout electronics: ~kHz in Run 2 (2017 pp: 2040 Hz)

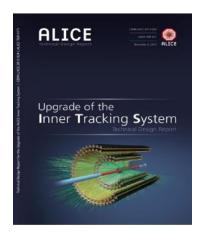
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ALICE UPGRADE

- Motivation: high-precision measurements of rare probes at low p.
 - ✓ cannot be selected with hardware trigger
 - ✓ need to record large sample of events
- Goal: operate ALICE at high rate, record all MB events
 - ✓ 50 kHz in Pb-Pb (~10 nb⁻¹ in RUN 3 and RUN 4)
 - no dedicated trigger, reduce data size (online reconstruction + compression)
 - ✓ preserve PID





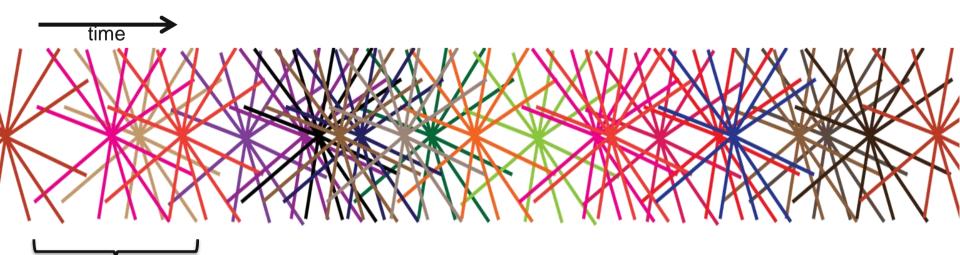








CONTINUOUS OPERATION IN RUN 3 AND BEYOND ALICE



Drift time in TPC

- Maximum drift time of electrons in the TPC: ~100 μs
- Average event spacing: ~20 μs
- Event pileup: 5 on average
- Triggered operation not efficient
- Minimize IBF without the use of a gating grid

Continuous readout with GEMs

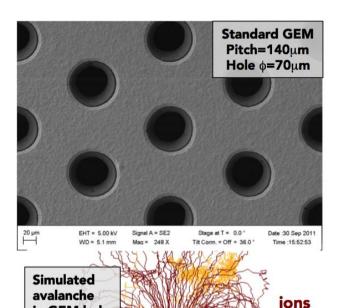
(Gas Electron Multiplier, F. Sauli 1996)

F. Böhmer et al., NIM A 719 (2013) 101

in **GEM** hole

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ALICE TPC UPGRADE FOR RUN 3



GFM-based readout chamber

- Micro-patterned gas detector for electron multiplication
- Proven to work reliably in high-rate applications
- → Application in a TPC with continuous readout required significant R&D effort in order to preserve excellent momentum and dE/dx resolution

Requirements for GEM readout:

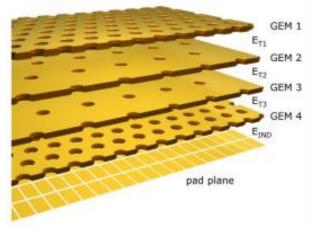
- Operate at the gain of 2000 in Ne-CO₂-N₂
- IBF < 1% at gain = $2000 \rightarrow \varepsilon = 20$
- Local energy resolution $\sigma_E/E < 12\%$ for ⁵⁵Fe
- Stable operation under LHC conditions
- + new electronics (negative polarity, continuous readout mode)
- + novel calibration and online reconstruction schemes
 (data compression by factor 10-20 and distortion corrections)

F. Böhmer et al., NIM A 719 (2013) 101, M. Berger et al., NIM A 869 (2017) 180

electrons

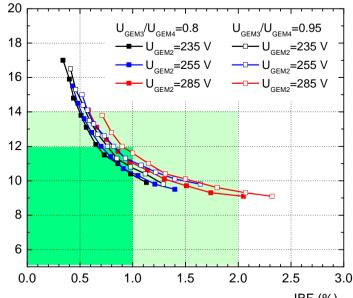
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ALICE TPC UPGRADE FOR RUN 3



Solution:

- Quadruple GEM stacks with different hole pitch and rotation of whole pattern
- Optimized field configuration and gain profile
- Robust against discharges



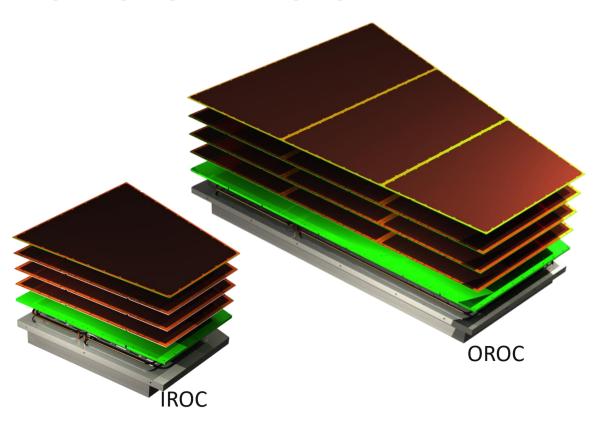
Compromise between IBF and energy resolution (σ) optimization



FROM GEM TO ROC



GEMS FOR THE UPGRADE

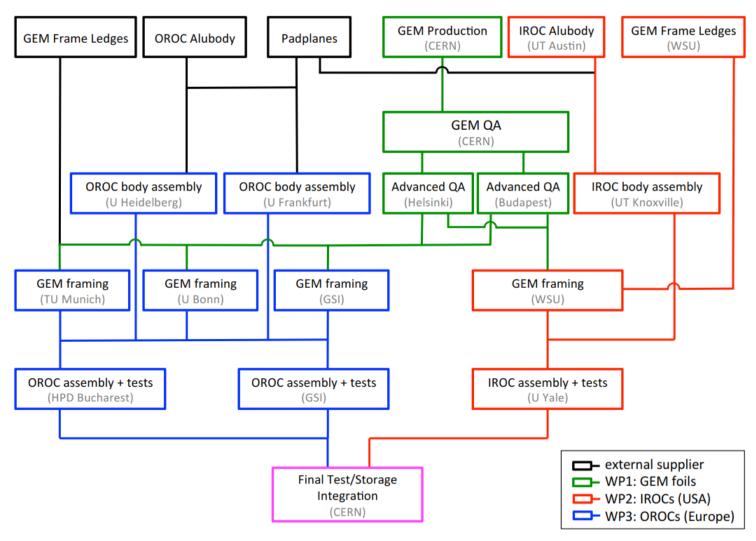


- Large-size single-mask foils from CERN PCB workshop
- 1 stack in IROC, 3 stacks in OROC





ROC MATERIAL FLOW

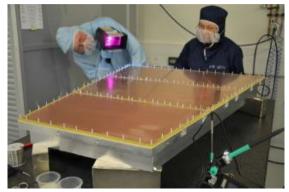


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FROM GEM TO ROC

- GEM production at CERN
 - Production rate: 40-60 GFMs/month.
- GEM QA
 - After every production step / shipping: HV test at identical conditions at all institutes
 - Dedicated long-term stability test
- GEM framing
- ROC assembly and testing
 - 2-3 IROCs/month
 - 4 OROCs per month (2 assembly sites)
 - Each chamber is packed in its own gas box
- Final stress test and storage at CERN
 - Full irradiation with hadrons or X-rays







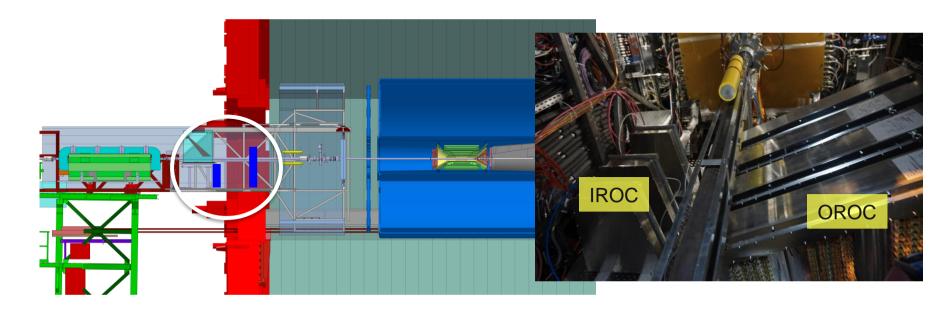


ROC TESTS IN THE ALICE CAVERN AT THE LHC

Goals:

- Test IROCs and OROCs under radiation conditions that are comparable to Run 3
- Exercise operation of newly developed HV hardware and control tools

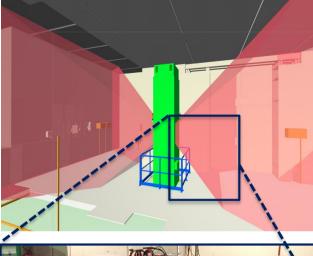
Test area close to LHC beam pipe, where doses up to 10 times of Run 3 are reached ROC can be tested in their own gas enclosure

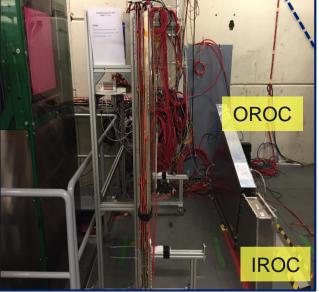


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ROC TESTS AT GIF++ AT CERN





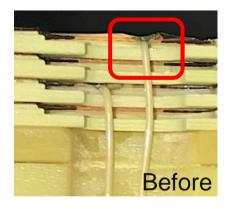


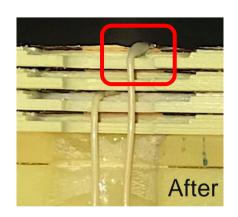
- Not all ROCs could be tested at LHC before the end of RUN 2
- Test campaign at the Gamma Irradiation Facility (GIF)
 - \sim 13 TBq ¹³⁷Cs source, E_y = 662 keV
 - Gamma flux ~ 5×10⁶ s⁻¹ cm⁻² (at ~ 3 m from the source)
 - · Comparable conditions to cavern tests
- Possibility to test up to 8 ROCs per week

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IRRADIATION TESTS SUMMARY

- Cavern and GIF++ tests allow to irradiate ROC with >10x higher particle load on GEM stack
- Imperfections around solder points can be reliably identified
- 10% of assembled stacks affected
- Problem solved by applying small amount of epoxy in critical spot
- All ROCs certified for stable operation in Run 3







ROCS READY FOR INSTALLATION

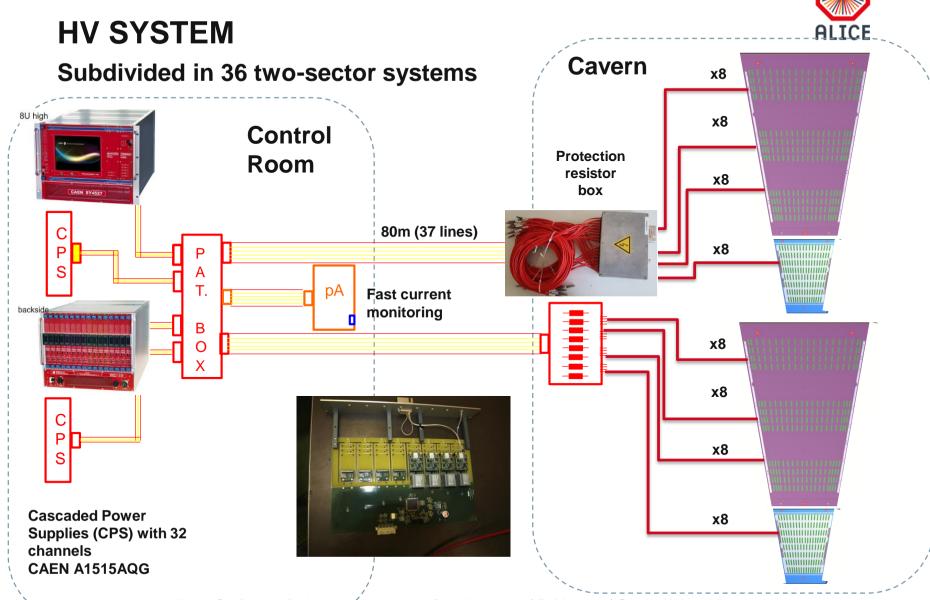
- Storage of final chambers in installation clean room at CFRN
- Finalization: Installation of temperature sensors

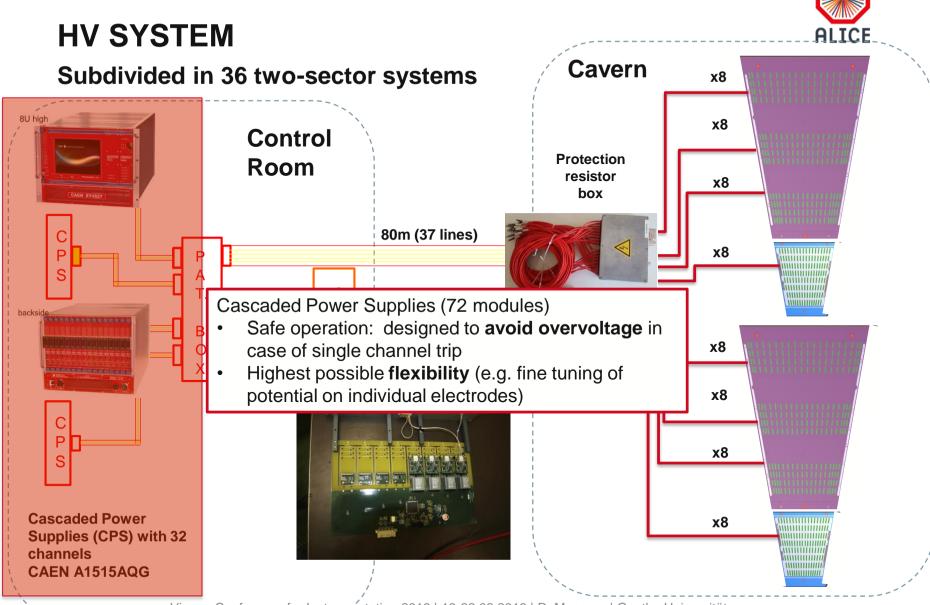


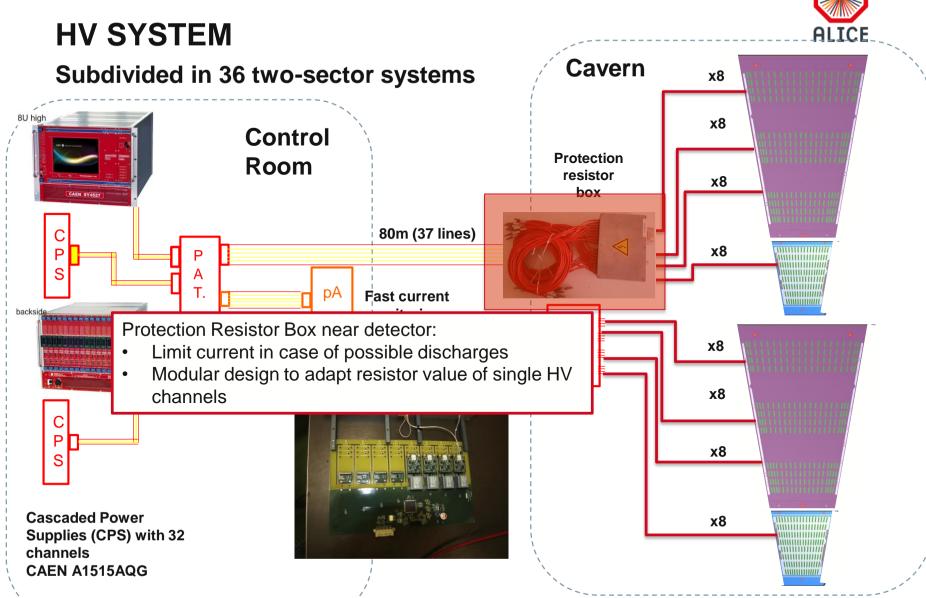
All ROCs are ready for installation on the TPC in spring 2019

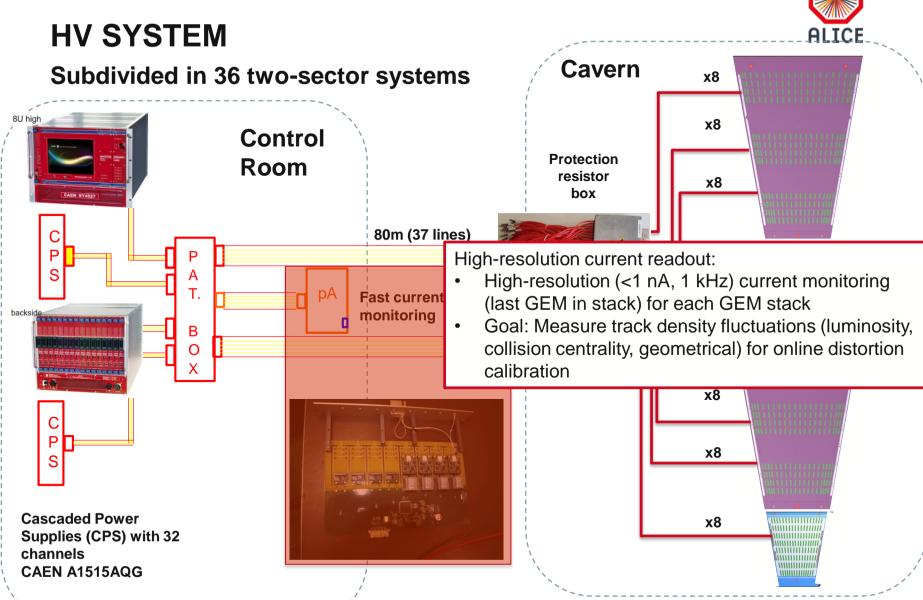


HV SYSTEM HOW TO OPERATE GEM SAFELY











READOUT SYSTEM

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TPC READOUT

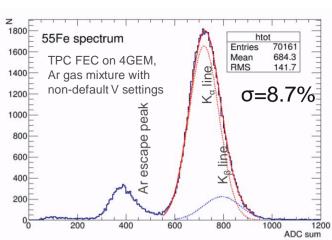
Front-End Card

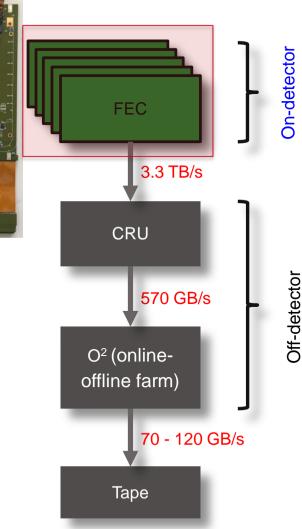
3276 Front-End Cards (FEC):

- SAMPA ASIC (130 nm TSMC CMOS):
 Integrated Pre-Amp + Shaper (t_{peak}=160ns) +
 10-bit ADC + DSP (not used by TPC)
- Radiation hard data and control link: CERN
 GBT system

System noise: 670e

All ADC values are transferred at 5 MHz (no compression)



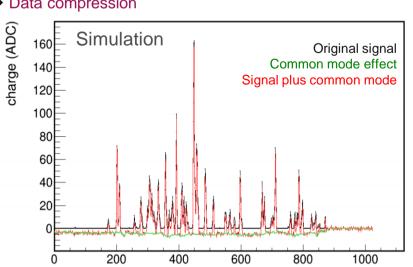




TPC READOUT

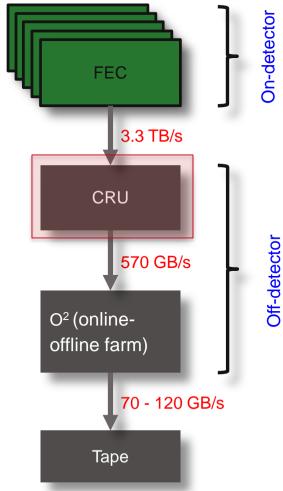
Common Readout Unit (CRU) (FPGA-based readout card):

- PCI-E40 board from LHCb (designed by CPPM)
- Located in First-Level-Processors (FLPs) of the ALICE O² online-offline farm
- Data-processing in CRU FPGA: Decoding, Sorting, Common-Mode Filter + Cluster-Finding
 - → Data compression



Baseline shift due to Common Mode Effect at high occupancies



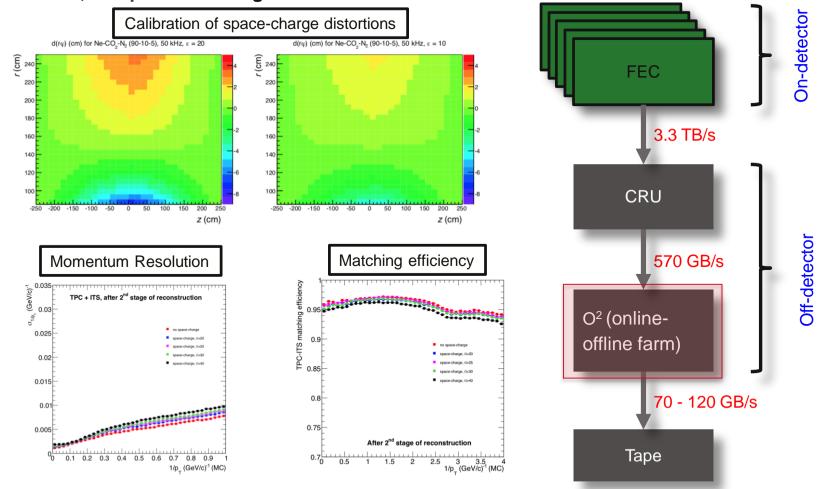


timebin



TPC READOUT

Prompt online reconstruction in ALICE O² online-offline farm: Distortion corrections, compression using track model





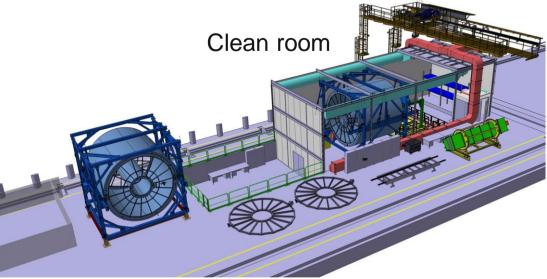
INSTALLATION

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INSTALLATION

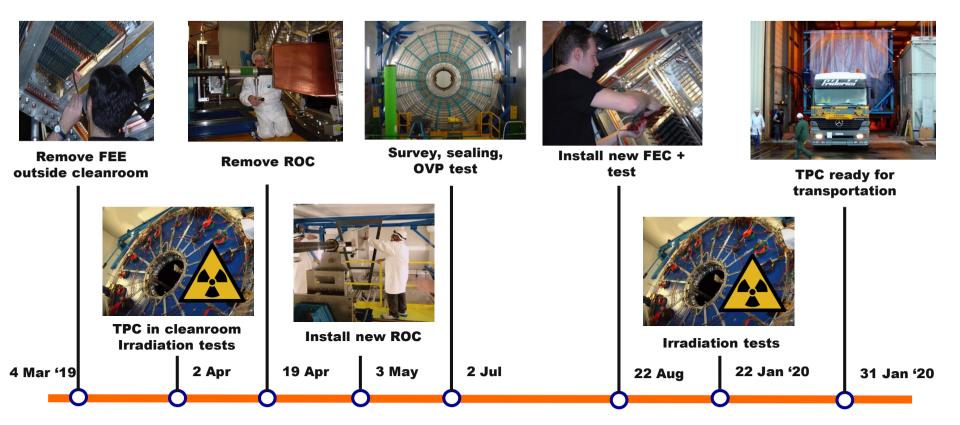
- LS2 started in December 2018
- Dismounting and extraction of the TPC: this week
- TPC is moved to the surface in two weeks
- 40 weeks for swapping the chambers and commissioning before the TPC is mounted in the cavern again







TPC REWORK



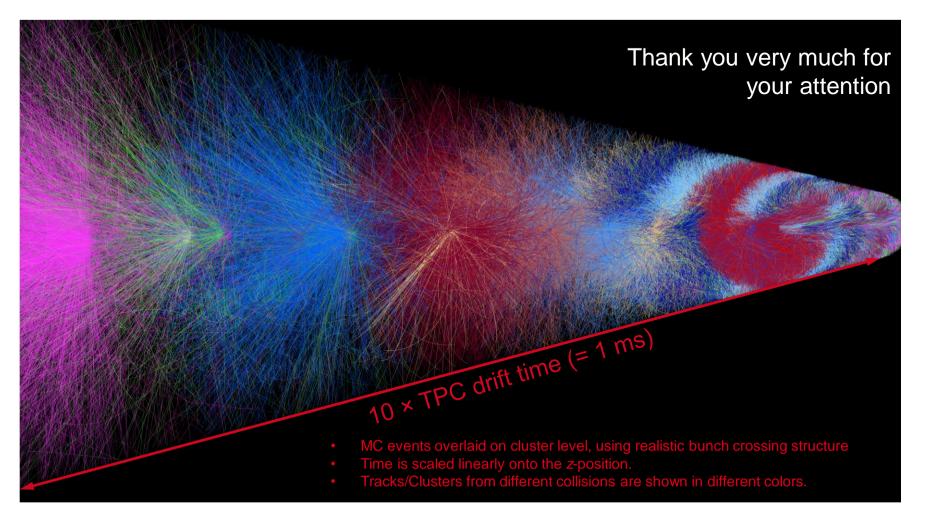


SUMMARY AND OUTLOOK

- ALICE TPC is being upgraded for Run 3 to operate at 50 kHz rate in Pb-Pb collisions
- No gating. Continuous readout with GEMs
- Extensive R&D led to the 4-GEM configuration, fulfilling all requirements
- Mass production finished
- Extensive testing procedure of chambers under realistic conditions
- New HV system was tested successfully
- New electronics for continuous readout successfully tested
 - Performance within specifications
 - Mass production finalized in Q2 2019
- Outlook:
 - TPC on the way to surface, installation and pre-commissioning about to start



LOOKING FORWARD TO Pb-Pb COLLISIONS IN RUN3





BACKUP



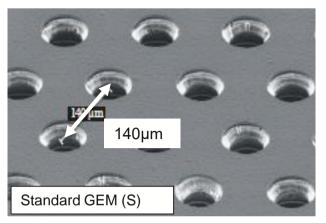


TPCU MILESTONES

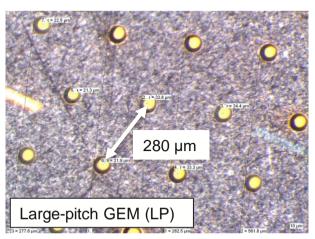
| \checkmark | R&D and Prototyping | 2012-2015 |
|--------------|---|-----------------------|
| ✓ | LHCC approval (TDR, TDR Addendum, TDR Addendum UCG) | June 2015 |
| ✓ | Engineering design Review (EDR) | November 2015 |
| ✓ | Training | |
| \checkmark | GEM and chamber final design review | June 2016 |
| \checkmark | Pre-production: | finalized |
| \checkmark | Production Readiness Review | March 2017 |
| \checkmark | Mass production (40 x IROCs + 40x OROCS) | 2017-2018 |
| | Installation | April 2019 – Mar 2019 |

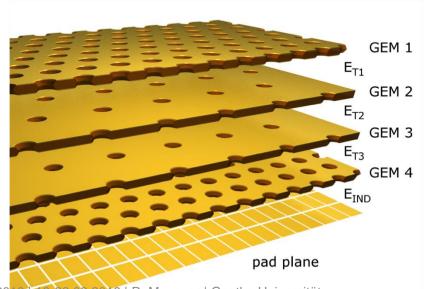
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BASELINE SOLUTION: 4-GEM SETUP



- Requirements not fullfilled with a standard 3-GEM configuration
- New readout chambers employ standard (S) and large-pitch (LP) GEMs in a configuration S-LP-LP-S
- Optimized HV settings

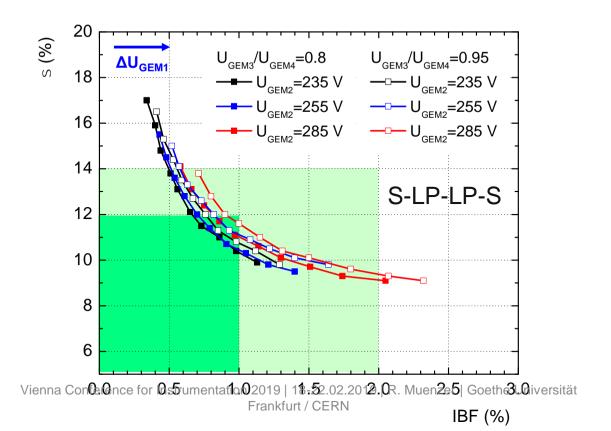






HV SETTINGS OPTIMIZATION

- IBF and energy resolution have to be optimized in parallel
- Conservative operational limits: IBF < 1 %, local energy resolution < 12 % for ⁵⁵Fe
- Extended operational range: IBF < 2 %, energy resolution < 14 %





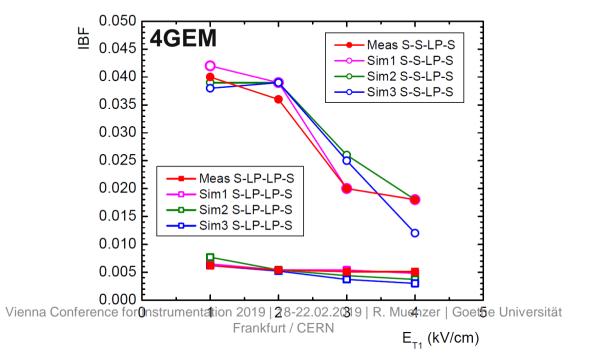
IBF SIMULATIONS

Garfield/Magboltz (Tokyo)

Systematic scan of parameter space

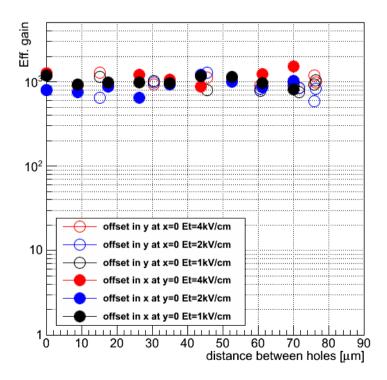
- gas composition
- 3- and 4-GEM configuration, different geometries
- tuning of simulations by adjusting <u>hole alignment</u>

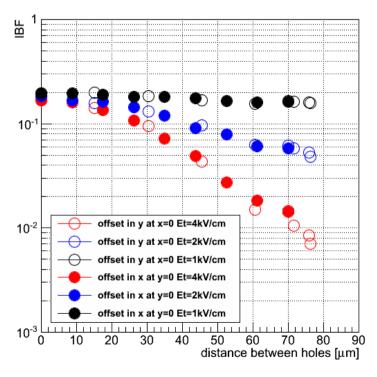
IBF quantitatively well described by simulations





HOLE ALIGNMENT



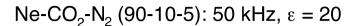


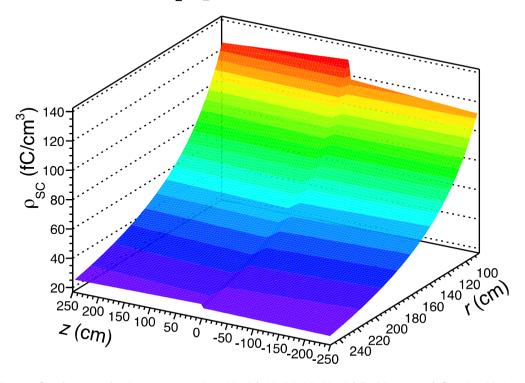
- Gas gain (left) and the IBF (right) in a 2GEM system as a function of the hole offset between two layers
- Need random misalignment: rotate foils (masks) by 90°



SPACE CHARGE DISTORTIONS

- · Ion blocking in GEMs not as efficient as with gating grid
- Ions from 8000 events pile up in the drift volume at 50 kHz Pb-Pb collisions (t_{d ion} = 160 ms)
- Total number of ions in drift volume strongly depends on IB: $n_{tot} = n_{ion} * IB * G_{eff}$; $\epsilon = IB * G_{eff} 1$

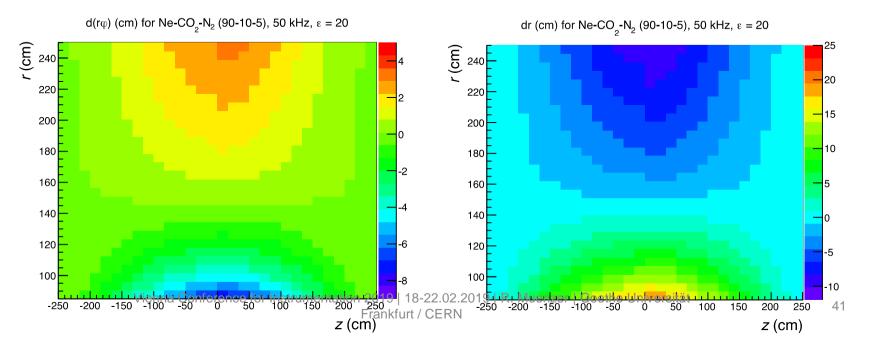






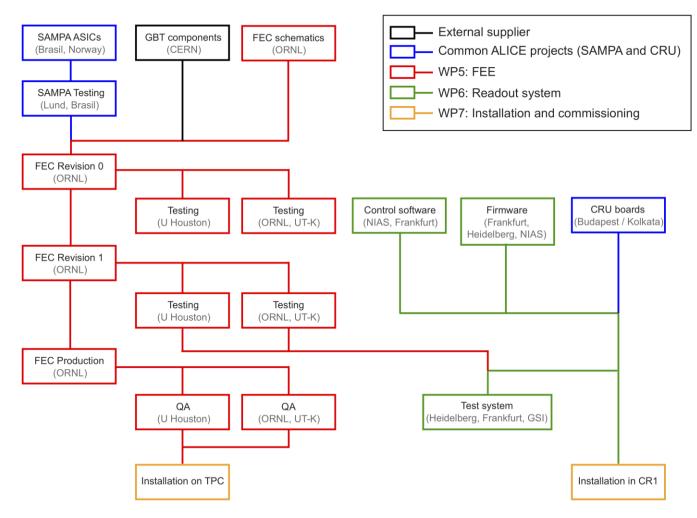
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- Total number of ions in drift volume strongly depends on IB: n_{tot} = n_{ion} * IB * G_{eff}; ε= IB * G_{eff}-1
- 1% of IBF at $G_{\text{eff}} = 2000 \ (\varepsilon = 20)$
 - distortions up to $dr \approx 20$ cm and $dr \varphi \approx 8$ cm (at small r and z)
 - well below 10 cm for the largest part of drift volume
- Corrections to $\mathcal{O}(10^{-3})$ are required for final calibration (to the level of intrinsic resolution, σ_{ro} ~ 200 µm)
- 2-stage calibration and reconstruction scheme



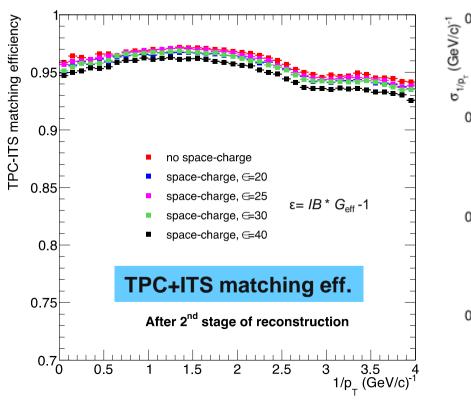


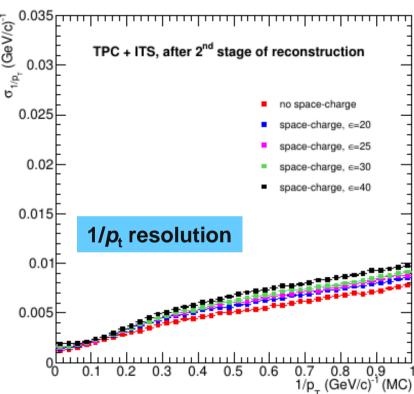
FEC MATERIAL FLOW





EXPECTED PERFORMANCE





Testing limits of calibration procedure at up to twice the nominal ion density ($\varepsilon = 40$)

- tracking efficiency not compromised
- slight decrease in p_t resolution at low momenta
 - does not compromise physics program

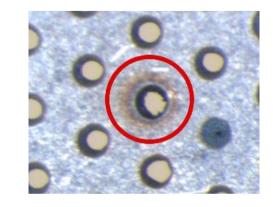
STABILITY AGAINST DISCHARGES

The breakdown appears when the total charge in the avalanche reaches critical value Q_{max}

Highly ionizing particles/high rate of radiation may induce creation of streamers which can then transform into sparks.

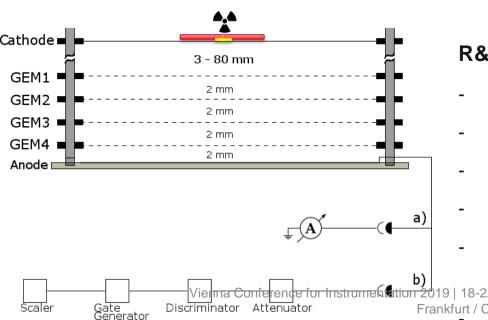
Spark in GEM:

- $\Delta V_{GEM} \rightarrow 0$
- May trigger secondary and propagated discharges
- may be harmful to the detector and electronics (large energy released)



0.1005

0.101



R&D:

- 10x10 cm² GEMs
- Modular setup
 - 1-4 GEM stacks
- Adjustable drift gap
- Alpha sources: ²³⁹Pu, ²⁴¹Am, ²⁴⁴Cm;

Amplitude [V]

0.0995



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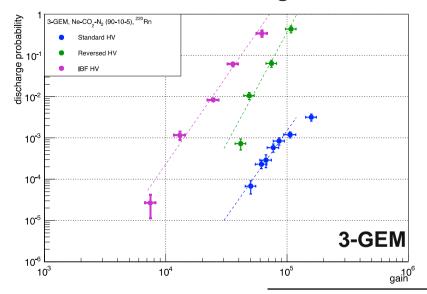
0.1015

Time [s]



DISCHARGE STUDIES

Influence of HV settings



- Different HV settings have been tested with a 3-GEM configuration
- "Standard" → "IBF"

S-S-S-S

S-S-S

Standard – optimized for stability (COMPASS)

S-LP-LP-S

- IBF → optimized for IBF
- Significant drop of stability while using IBF settings with a typical 3-GEM configuration

4-GEM configuration, optimized for energy resolution and IBF is stable also against electrical discharges

| | | 0-0-0 | 9-9-9-9 | | 3-L1 -L. | 1 -0 | |
|--|---|--------------------------|------------------------|------------------------|--------------------------------|------------------------|------------------------|
| | | 'standard' HV $G = 2000$ | IB = 2.0% G = 2000 | IB = 0.34% G = 1600 | IB = 0.34% G = 3000 | IB = 0.34% G = 5000 | IB = 0.63% G = 2000 |
| guration, | 220 Rn $E_{\alpha} = 6.4 \text{MeV}$ rate = 0.2 Hz | ~10 ⁻¹⁰ | | | < 2×10 ⁻⁶ | $< 7.6 \times 10^{-7}$ | |
| energy of the second se | 241 Am $E_{\alpha} = 5.5 \text{ MeV}$ rate = 11 kHz | | | | | | <1.5×10 ⁻¹⁰ |
| | 239 Pu+ 241 Am+ 244 Cm $E_{\alpha} = 5.2+5.5+5.8$ MeV rate = 600 Hz | , | $< 2.7 \times 10^{-9}$ | < 2.3×10 ⁻⁹ | $(3.1 \pm 0.8) \times 10^{-8}$ | | $< 3.1 \times 10^{-9}$ |
| Vienna Conferen | 90 Sr $E_{\beta} < 2.3 \text{ MeV}$ ce for instrumentation rate = 60 kHz | n 2019 18-22.02. | .2019 R. M | uenzer Goetl | he Universität | $< 3 \times 10^{-12}$ | 45 |

ION TRAPPING WITH GEMS

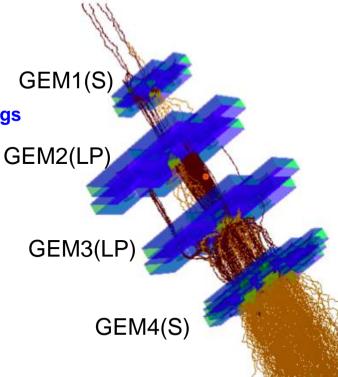
Electron transport properties for IBF optimized voltage settings

 ε_{coll} = collection efficiency

 $\varepsilon_{\text{extr}}$ = extraction efficiency

M = gas multiplication factor

 $G_{eff} = \epsilon_{coll} \times M \times \epsilon_{extr} = effective gain$



| | $\mathcal{E}_{	ext{coll}}$ | $n_{ m e,in}$ | M | $n_{\mathrm{e-ion}}$ | $arepsilon_{ m extr}$ | $n_{ m e,out}$ | G | $n_{\mathrm{ion,back}}$ | fraction of total IBF (sim.) | fraction of total IBF (meas.) |
|-----------|----------------------------|---------------|-----------|----------------------|-----------------------|----------------------|---------|---|------------------------------|-------------------------------|
| GEM1 (S) | 1 | 1 | 14 | 13 | 0.65 | 9.1 | 9.1 | 3.6 (28%) | 40% | 31% |
| GEM2 (LP) | 0.2 | 1.8 | 8 | 12.7 | 0.55 | 8 | 0.88 | 3.3 (26%) | 37% | 34% |
| GEM3 (LP) | 0.25 | 2 | 53 | 104 | 0.12 | 12.7 | 1.6 | 1.3 (1.3%) | 14% | 11% |
| GEM4 (S) | 1 | 12.7 | 240 | 3053 | 0.6 | 1830 | 144 | 0.84 (0.03%) | 9% | 24% |
| Total | Vienr | na Confei | rence for | Instruggen | tation 20 | 191830 ²² | 04.8969 | R. \(\(\(\(\) \) (\(\) (\(\) \) (\(\) (\(\) \) | the Universität | 46 |

ION TRAPPING WITH GEMS

Electron transport properties for IBF optimized voltage settings

 $\varepsilon_{\text{coll}}$ = collection efficiency

 $\varepsilon_{\text{extr}}$ = extraction efficiency

M = gas multiplication factor

 $G_{eff} = \epsilon_{coll} \times M \times \epsilon_{extr} = effective gain$

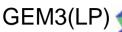
n_{e-ion} = number of produced e-ions pairs

 $n_{ion,back}$ = number of ions drifting back into the drift volume (ϵ)

$$IB = (1+\varepsilon)/G_{\text{eff}}$$



GEM1(S)





| | $oldsymbol{arepsilon}_{	ext{coll}}$ | $n_{ m e,in}$ | M | $n_{\mathrm{e-ion}}$ | $oldsymbol{arepsilon}_{	ext{extr}}$ | $n_{ m e,out}$ | G | $n_{\mathrm{ion,back}}$ | fraction of total IBF (sim.) | fraction of total IBF (meas.) |
|-----------|-------------------------------------|---------------|----------|----------------------|-------------------------------------|----------------------------------|----------------------------|-------------------------|------------------------------|-------------------------------|
| GEM1 (S) | 1 | 1 | 14 | 13 | 0.65 | 9.1 | 9.1 | 3.6 (28%) | 40% | 31% |
| GEM2 (LP) | 0.2 | 1.8 | 8 | 12.7 | 0.55 | 8 | 0.88 | 3.3 (26%) | 37% | 34% |
| GEM3 (LP) | 0.25 | 2 | 53 | 104 | 0.12 | 12.7 | 1.6 | 1.3 (1.3%) | 14% | 11% |
| GEM4 (S) | 1 | 12.7 | 240 | 3053 | 0.6 | 1830 | 144 | 0.84 (0.03%) | 9% | 24% |
| Total | Vienr | na Confer | ence for | Instrugger | tation 20 Era | 19 1830 22 nkfurt / CF | .0 4.830 9 ERN | R. Mugrze %)Go | ethe Universität | 47 |

Total

ION TRAPPING WITH GEMS

Electron transport properties for IBF optimized voltage settings

 $\varepsilon_{\text{coll}}$ = collection efficiency

 $\varepsilon_{\text{extr}} = \text{extraction efficiency}$

M = gas multiplication factor

 $G_{eff} = \varepsilon_{coll} \times M \times \varepsilon_{extr} = effective gain$

n_{e-ion} = number of produced e-ions pairs

 $n_{ion,back}$ = number of ions drifting back into the drift volume (ϵ)

fraction of total IBF: simulation vs. experiment



GEM1(S)



| | $arepsilon_{ m coll}$ | $n_{ m e,in}$ | М | $n_{\mathrm{e-ion}}$ | $arepsilon_{ m extr}$ | $n_{ m e,out}$ | G | $n_{ m ion,back}$ | fraction of total IBF (sim.) | fraction of total IBF (meas.) |
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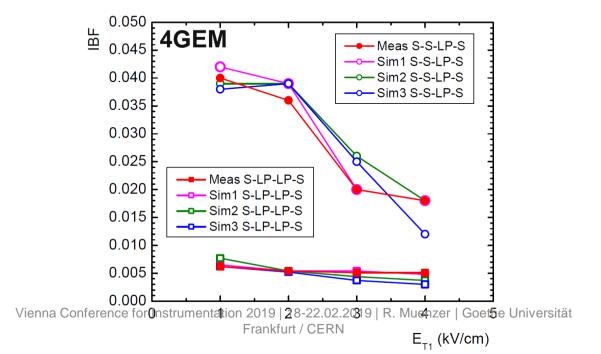
IBF SIMULATIONS

Garfield/Magboltz (Tokyo)

Systematic scan of parameter space

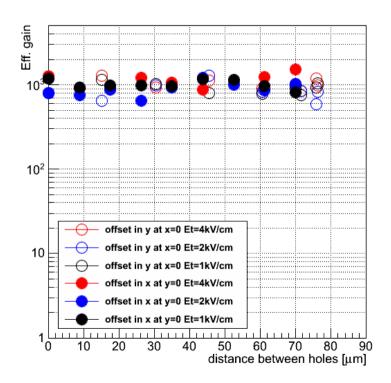
- gas composition
- 3- and 4-GEM configuration, different geometries
- tuning of simulations by adjusting <u>hole alignment</u>

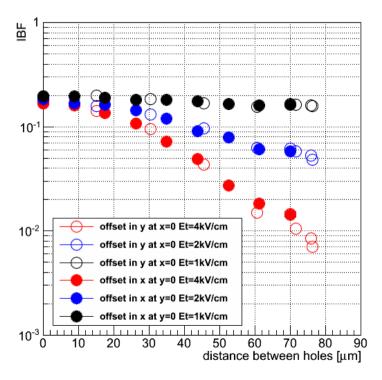
IBF quantitatively well described by simulations





HOLE ALIGNMENT



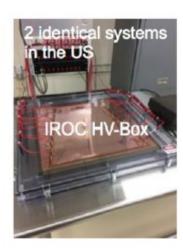


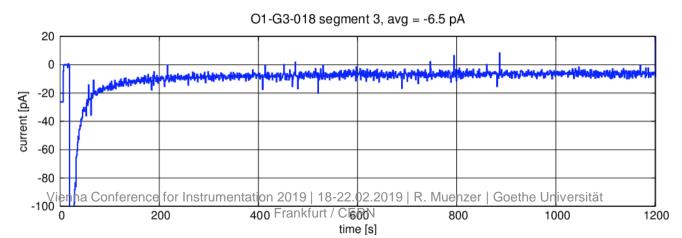
- Gas gain (left) and the IBF (right) in a 2GEM system as a function of the hole offset between two layers
- Need random misalignment: rotate foils (masks) by 90°

HV TESTS

- Apply 500 V for 15' in dry N_2 (<0.6 % absolute humidity)
- I_{leak} < 0.5 nA/segment
- All segments tested independently using multi-channel pA-meters



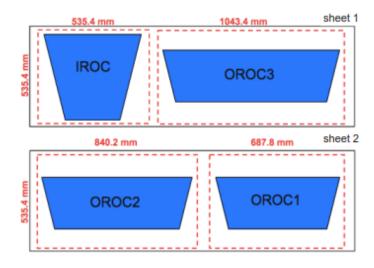






FROM GEM TO ROC

- GEM production at CERN
 - Production rate: 40-60 GEMs/month



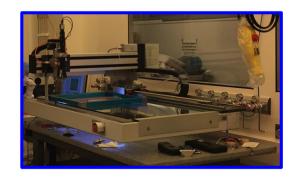
FROM GEM TO ROC

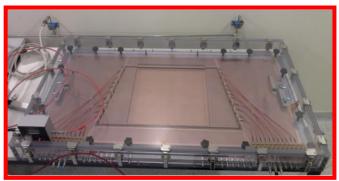
GEM production at CERN

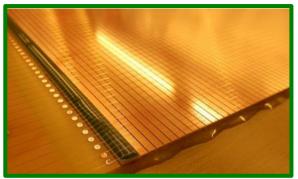
Production rate: 40-60 GFMs/month

GEM QA

- Production QA at CERN (HV test)
- Two Advanced QA centers in <u>Helsinki</u> and <u>Budapest</u>
- Advanced QA:
 - · HD Optical Scanning System,
 - HV-test system,
 - · Gain uniformity scanner
- Basic QA (HV test) at each production institute

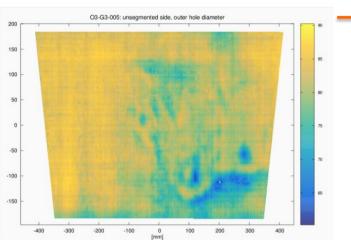




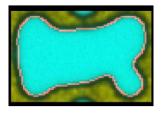


OPTICAL SCANS

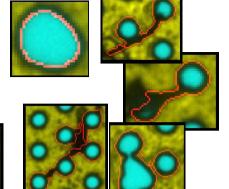
Hole size distributions

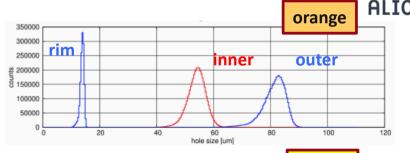


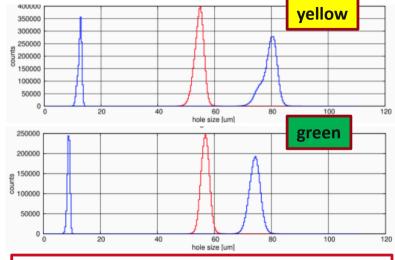
Etching defects











Green:

- uniform distribution
- mean diameter <5 um within batch average Yellow:
- distributions (not always) uniform
- mean diameter 5-10 um within batch average Orange:
- non-uniform distributions
- mean diameter >10 um within batch average

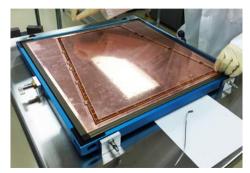
Vienna Conference for Instrumentation 2019 | 18-22.02.2019 | R. Wuenzer | Goethe Universität Frankfurt / CERN

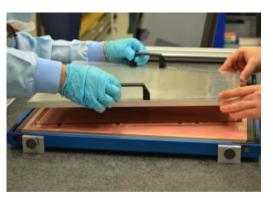
ALT CE

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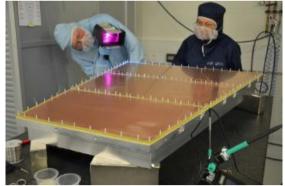


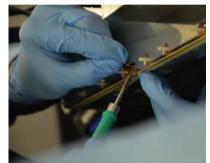


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- ROC Assembly
 - 2-3 IROCs/month (Yale)
 - 4 OROC/month (GSI, Bucharest)







FROM GEM TO ROC

GEM production at CERN

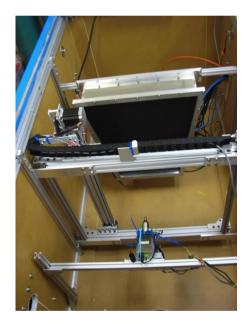
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- ROC Assembly
 - 2-3 IROCs/month (Yale)
 - 4 OROC/month (GSI, Bucharest)
- ROC Commissioning & Arrival tests

(Yale (IROC), GSI, Bucharest (OROC), CERN)

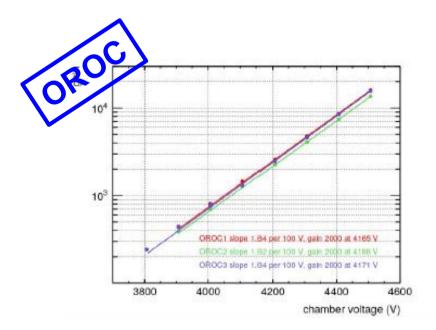


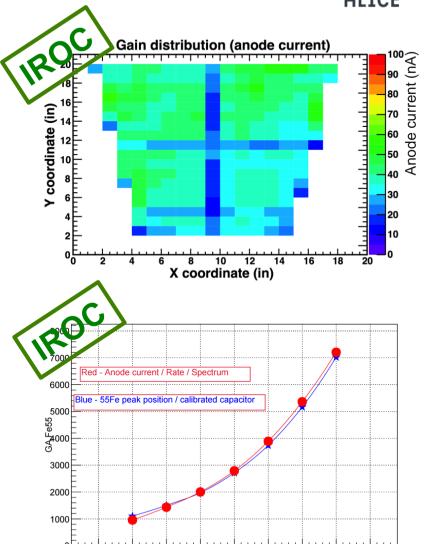


PLICE

ROC COMMISSIONING Gain

- 1. Gas tightness (< 0.5 ml/h)
- 2. Gain curve
- 3. Gain uniformity (RMS < 20 %)





4000

4050

4100

4150

4200

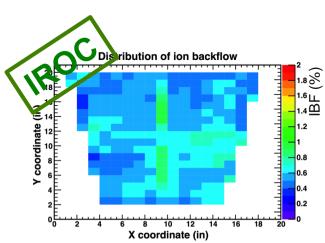
4250

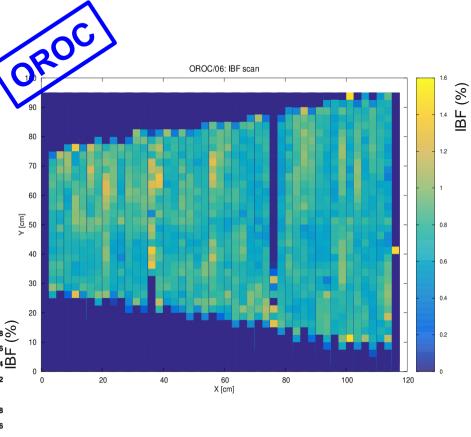
4300

ROC COMMISSIONING

Ion backflow

- 1. Gas tightness (< 0.5 ml/h)
- 2. Gain curve
- 3. Gain uniformity (RMS < 20 %)
- 4. IBF uniformity (IBF = 0.7%, RMS < 20%)



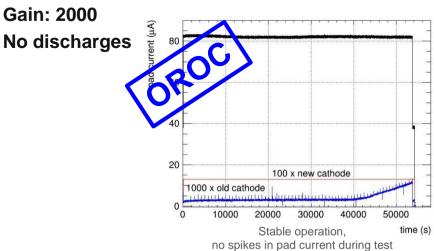


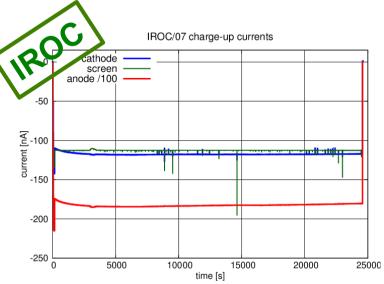
ALTCE

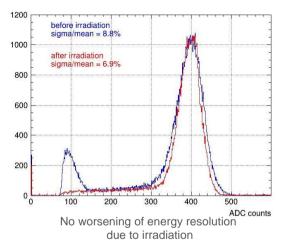
ROC COMMISSIONING

Full irradiation with X-ray

- Gas tightness (< 0.5 ml/h)
- 2 Gain curve
- 3. Gain uniformity (RMS < 20 %)
- 4. IBF uniformity (IBF = 0.7%, RMS < 20%)
- 5. Full X-ray irradiation (10 nA/cm²) for 6 h



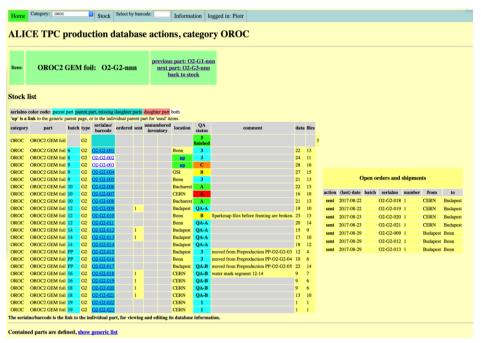




ROC PROCUTION

Database

- Powerful tool to collect all production relevant data
- Keeps track of all GEMs, components and QA results
- >7500 QA entries so far
- >5600 data files for QA
- about 400 page calls per day



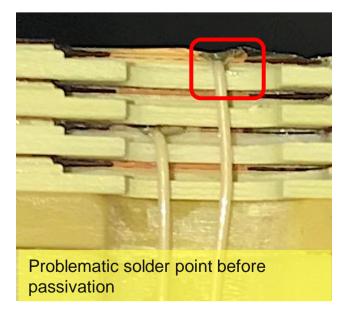
TPC FRONT END CARD



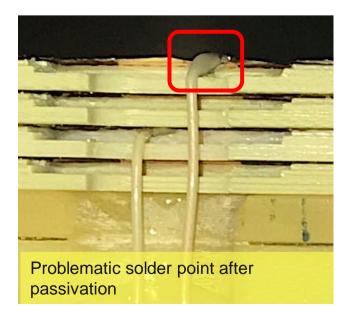
- New FE ASIC "SAMPA" (130 nm TSMC CMOS)
 - Positive or negative input
 - Programmable conversion gains and peaking times
 - Different readout modes: triggered, continuous with DSP, continuous with DSP by-pass
- For required Signal-to-Noise ratio excellent noise figure of 670e⁻ (as currently) is needed
- 5 SAMPA chips per FEC
- 3276 FECs will be installed, each with 160 channels
- System continuously digitizes signals at 5 MHz for 0.5 M TPC channels.
- All ADC values are read out: data output for 50 kHz Pb-Pb collisions ≈ 3.28 TByte/s (5 MHz sampling)
- FECs send digitized data over fiber optic links to ALICE
 Common Readout Units (CRU)



IRRADIATION RESULTS



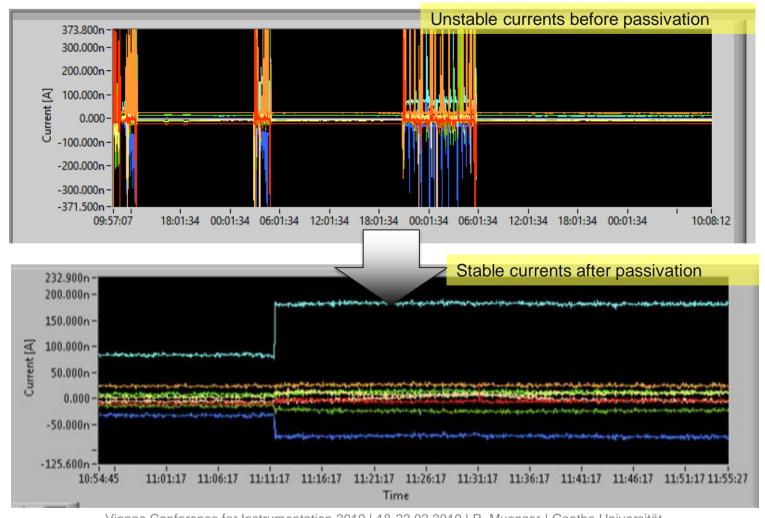




- Some ROCs show current spikes (occasional trips)
- Problem identified: solder point of HV wires to GEM foil
- Solution identified: passivation at CERN or re-soldering/passivation at production site
- New Side Illumination (SI) test to test for weak spots at production site

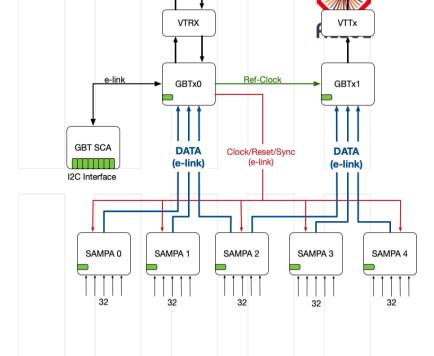


QA ISSUE: SOLDER POINTS (2)



TPC Front-End-Card (FEC)





GBTx

- 2 x GBTx chips per FEC.
- GBTx0 (master. Bi-directional link)
- GBTx1 (slave. Only TX link)
- Both GBTx use Wide-Bus mode with no FEC
- Each GBTx receives data from 2.5 SAMPs (23/28 E-Link)
- GBTx0 provides clock, Reset and SYNC via E-Links (point-to-point)

SCA

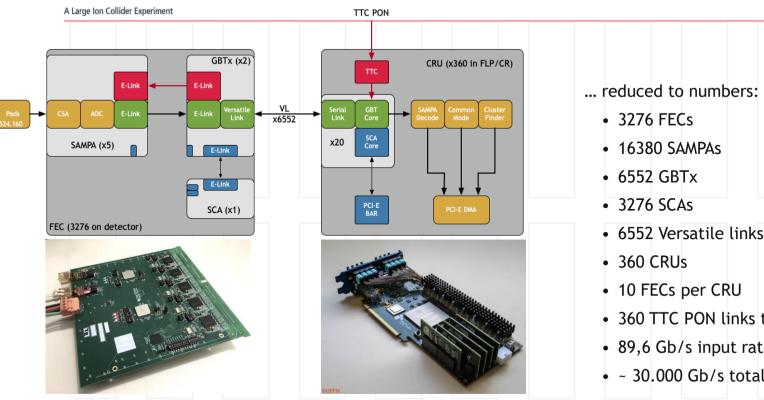
- One SCA chip per FEC:
- Configuration of GBTx0 & GBTx1 (2 x I2C)
- Configuration of SAMPAs (5 x I2C)
- SAMPA voltage regulators switching (5 x GPIO)
- T, V & I measurements via internal SCA ADC

SAMPA

- Common Front-End chip for TPC & Muon chambers
- Integrated Pre-Amp + Shaper + 10-bit ADC + DSP (not used by TPC)
- 32 channels @ 10-bit @ 5 MHz 20 MHz sampling
- 10 + 1 (ADC clock output) SLVS E-Link ports up to 320 Mb/s to interface GBTx directly
- TPC uses direct readout of the ADCs via E-Link ports and bypasses the DSP
 - 32 channels x 10-bit x 5 MHz -> 10 E-Link ports @ 160 MHz
 - ADC channel data send round-robin as raw 10-bit values. No headers, no trailers, no markers!
- Requires only 2 control signals: RESET (Align ADC clocks) + SYNC (sends data synchronisation pattern)



The complete ALICE TPC readout system...





- 360 TTC PON links to CRU
- 89,6 Gb/s input rate per CRU
- ~ 30.000 Gb/s total input rate

- Using one common readout unit (CRU) for ALICE. PCI-E40 board from LHCb (designed by CPPM)
- Located in First-Level-Processors (FLPs) of the ALICE O² Online-Offline farm in CR1 & CR2
- PCI-E Gen3 x 16 with max. 126 Gb/s user bandwidth (128 Gb/s raw, 126/128b encoding)
- TTC + Readout + Slow-Control via CRU FPGA
- Data-processing done in CRU-FPGA: Decoding, Sorting, Common-Mode Filter + Cluster-Finding