Status of the ALICE TPC upgrade and beam-time prospects

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31th of October, 2014

Outline

- Requirements for the upgraded ALICE TPC
- Ion Back Flow & Energy resolution
- Large prototype(s)
  - Construction
- Discharge probabilities
- Test program at the SPS

New requirements for the ALICE TPC

New LHC conditions:

- Increased rate in PbPb collisions of 50 kHz $\Rightarrow$ Pileup of 5 events (8000 interactions) in the drift volume at every time
- Gated readout not longer feasible

$\Rightarrow$ Readout chambers with GEMs intended

Requirements:

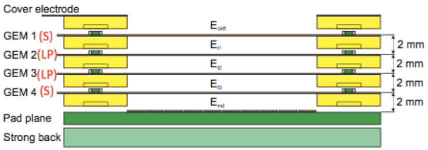
- **I**on **B**back **F**low $< 1\%$
- $\sigma_{\mathrm{E}}/E < 12\%$ for $^{55}\mathrm{Fe}$
- Gain of 2000 in $\mathrm{Ne/CO_2/N_2}$ (90:10:5)

Ion Back Flow & Energy resolution

Baseline settings

Presented in the TDR:

- Quadruple GEM stack with **S**tandard (140 µm) and **L**arge **P**itch (280 µm) GEMs
- Configuration: S-LP-LP-S
- IBF ~ 0.7 and $\sigma_{\mathrm{E}}/E \sim 12\%$



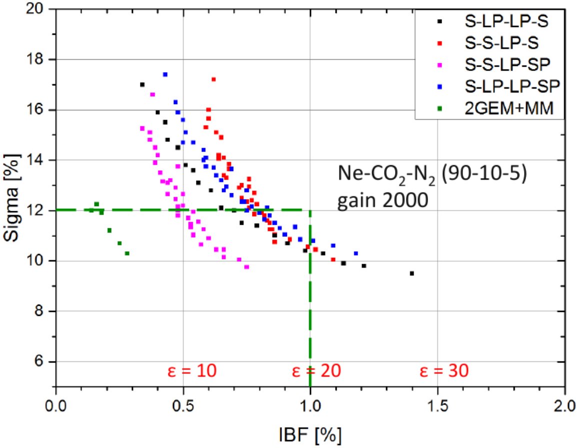
Reminder:

- $\epsilon = \frac{\#\text{ions escaping the amplification stage}}{\#\text{primary ionisations}}$
- $\textbf{I}\text{on } \textbf{B}\text{ack } \textbf{F}\text{low} = \frac{1+\epsilon}{\text{effective gain}}$

IBF vs energy resolution

Different settings examined:

- Combinations of: *SP* (90 µm), *S*, *MP* (200 µm) *and LP GEMs*
- 2GEMs + MM (the given points in the plot are preliminary)

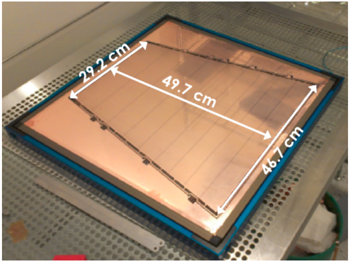


As presented at the LCC Meeting on the 23.10.2014

Large size prototypes

Large size Inner Readout Chamber prototypes

- Utilises existing alu-bodies/pad planes
- GEMs (singel mask etching technique) are mounted on top



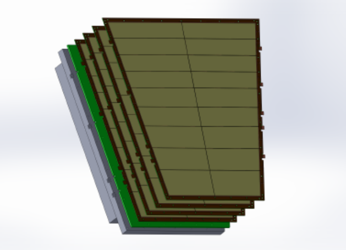
3GEM prototype

- 3 standard GEMs
- Tested at CERN PS in 2012
- $\mathrm{d}E/\mathrm{d}x \sim 10.5\%$ for 1 GeV pions was observed $\Rightarrow$ compatible with the present MWPCs

IROC prototypes – 2nd generation

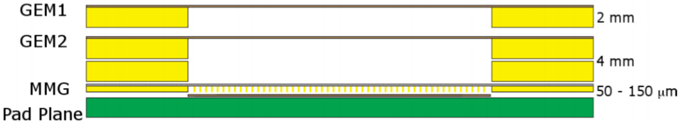
GEM IROC prototype

- Quadruple GEM stack (S-LP-LP-S) with 4 single mask GEMs
- Finished in August



Hybrid 2GEM + MM prototype

- 2 standard GEMS with one Micromegas
- Under contruction at CERN



Further planing

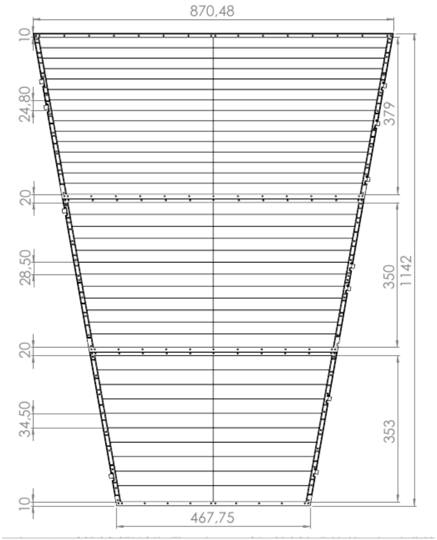
Testbeam campaings:

- PS: $\mathrm{d}E/\mathrm{d}x$ resolution
- SPS: Stability measurements

Outer ReadOut Chamber prototype

- Construction
- Testing & QA

Production start of the readout chambers



Discharge studies

Discharge studies – 1/2

Motivation:

- Minimise possible dead time due to discharges/avoid damage of the detector
- Tripple GEM stack $\rightarrow$ optimised to have a low discharge probability
- But: Quadruple GEM stack introduces again a higher discharge probability
- Discharge probability of 10^{-9} (α) and 10^{-12} (β) (compared to other LHC detectors)

Studies so far:

- Performed with $10 \times 10\,\mathrm{cm}^2$ GEMs
- Brag-peak adjusted to radiation source and gas $\rightarrow$ Ionisation takes place close to the GEM stack

Discharge studies – 2/2

Sources and rates

$^{241}\mathrm{Am} \sim 11\,\mathrm{kHz}$; $^{239}\mathrm{Pu} +^{241}\mathrm{Am} +^{244}\mathrm{Cm} \sim 600\,\mathrm{Hz}$; $^{90}\mathrm{Sr} \sim 60\,\mathrm{kHz}$

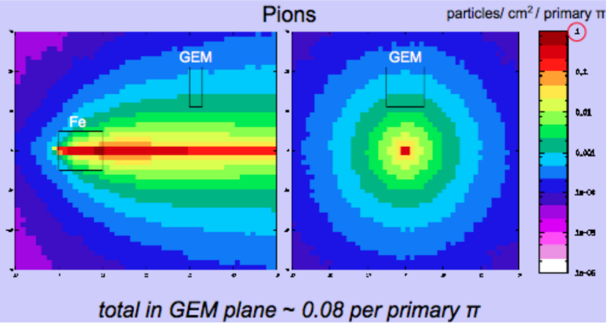
source	gain		
	2000	3000	5000
α	$< 2 \times 10^{-8}$	$< 9 \times 10^{-8}$	
α	$< 1.5 \times 10^{-10}$		
α	$< 3.1 \times 10^{-9}$	$< 2 \times 10^{-8}$	$(1.8 \pm 1.1) \times 10^{-8}$
β			$< 3 \times 10^{-12}$

- 2GEM + MM - preliminary: $\sim 10^{-8}$ $\rightarrow$ studies ongoing
- Further tests needed $\Rightarrow$ SPS

Stability tests at the SPS

Test campaing at the SPS – 1/2

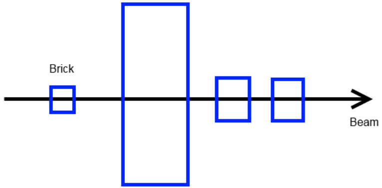
- Place the prototype with the readout plane into the beam
- Shower off the beam with a (Fe) brick
- Examine the performance of the large prototype while exposed to a high rate of MIPs



(FLUKA simulations for CBM (FAIR) by A. Senger)

Test campaing at the SPS – 2/2

Assume 10^8 pions per spill with a duty cycle of 15 s and an efficiency $\epsilon = 0.8$, then:



After a Fe brick:

- Protons: $\sim \frac{0.002\mathrm{p}}{\mathrm{cm}^2}$ per primary pion
- Pions: $\sim \frac{0.01\pi}{\mathrm{cm}^2}$ per primary pion
- $4.5 \times 10^{11} \frac{\pi}{10\times10\,\mathrm{cm}^2\mathrm{day}}$ and $10^{11} \frac{\mathrm{p}}{10\times10\,\mathrm{cm}^2\mathrm{day}}$

$\Rightarrow$ The expected rate should allow to collect enough statistic to measure the discharge probability with some precision (given optimal beam conditions)

Summary & Outlook

Quadruple GEM stack characteristics:

- IBF & σ_{E}/E: Research ongoing, promising settings already found
- $\mathrm{d}E/\mathrm{d}x$ will soon be examined at the PS
- Further discharge studies on the way (SPS)

Production

- Already gained some experience from the IROC prototype production
- OROC production on the way
- Planning for mass production started

Backup

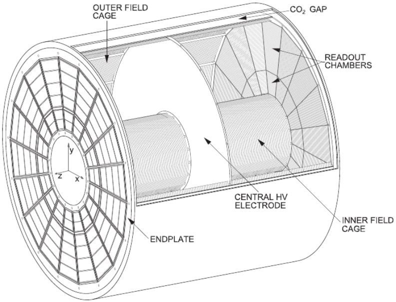
References & Further Reading

- TDR *ALICE Collaboration, "Technical Design Report for the Upgrade of the ALICE Time Projection Chamber" – ALICE-TDR-016, 2014*
- LHCC *H. Appelshaeuser, "Status of TPC Upgrade" – LHCC referees meeting, September 2014*
- Chilo *Private communication Chilo Garabatos Cuadrado*
- Peskov *Private communication Vladimir Peskov*
- Gasik *Private communication Piotr Gasik*

Challenges for the upgrade of the ALICE TPC – 1/2

Current setup of the TPC

- $2\times2.5\,\mathrm{m}$ drift length
- Current gas mixture: $\mathrm{Ar/CO_2}$ (90:10)
- Readout with MWPC
- Gating grid



General requirements for the upgrade:

- Performance in terms of momentum and $\mathrm{d}E/\mathrm{d}x$ resolution should stay the same
- Readout should be able to cope with the higher rates

IBF vs energy resolution

Best results with quadruple GEM stacks:

configuration	IBF	σ_{E}/E
S-LP-LP-S	0.7%	12%
S-S-LP-S	0.8%	12%
S-S-LP-SP	0.5%	12%
S-LP-LP-SP	0.8%	12%
S-S-S-S	<1%	>12%
S-S-SP-S	<1%	>12%
LP-S-LP-S	<1%	>12%
SP-S-LP-S	0.4%	>12%
SP-S-LP-S	0.4%	?
SP-S-LP-SP	?	?
MP-S-LP-SP	?	?

- Baseline settings
- Settings with too bad performance
- Best setting so far

Tests on many different sites ongoing:

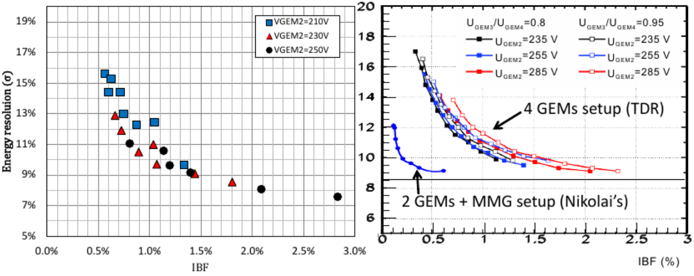
- CERN: 4GEM/2GEM+MM
- Frankfurt: 4GEM
- Yale: 2GEM + MM
- Bonn/Munich: 4GEM/3GEM/2GEM + MM

GEM1-MM scan (2GEM+MM)

■ ΔV_{GEM2}=210V ▲ ΔV_{GEM2}=230V ● ΔV_{GEM2}=250V

Gas : Ne/CO_2 (90/10), drift = 8mm, strong ^{55}Fe (placed at center of 8pads)

E_d=0.4kV/cm, E_{t1}=3.0kV/cm, E_{t2}=0.08kV/cm



ΔV_{GEM1}=200∼270V, ΔV_{GEM1}=210, 230, 250V

Gain ~2000

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Taken from: Measurements with 2GEMs + MM in Ne/CO2 at CERN, Kohei Terasaki et. al.

Chamber production

- GEM production: CERN and possibly TECH-ETCH (USA)
- QA: Search for defects/HV tests, HD scan, gain uniformity test
- Framing – Useful commercial systems for big foils wanted

- Assembling of the GEM stack
- Testing of the gain uniformity of the whole system
- Different steps at different sites

	#chambers	#foils	size
IROC	36	144	$47 \times 50\,\text{cm}^2$
OROC	36	144	$87 \times 38\,\text{cm}^2$
		144	$72 \times 35\,\text{cm}^2$
		144	$59 \times 35\,\text{cm}^2$

Further issues

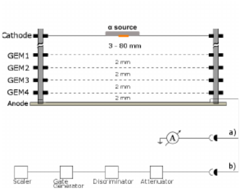
- Development of new FECs

Discharge studies with a quadruple GEM stack

A Large Ion Collider Experiment

ALICE

Discharge studies – update



SOURCE	S-LP-LP-S				
	IBF = 0.6 % σ_E/E = 12 % G = 1000	IBF = 0.6 % σ_E/E = 12 % G = 2000	IBF =0.6% σ_E/E=12% G =3300	IBF =0.6 % σ_E/E =12 % G =4000	IBF =0.6 % σ_E/E =12 % G =5000
^{241}Am *rate = 11 kHz* *drift gap = 80 mm*	$< 1.1\times10^{-8}$	$< 1.5\times10^{-10}$	$< 7.1\times10^{-10}$		
^{239}Pu + ^{241}Am + ^{244}Cm *rate = 600 Hz* *drift gap = 37 mm*		$< 3.1\times10^{-9}$		$\approx 5\times10^{-9}$	$(1.8 \pm 1.1)\times10^{-8}$

Taken from: "Status of TPC Upgrade", Harald Appelshaeuser, LHCC referees meeting, September 2014

Discharge studies with 2GEM+MM

Summary of discharge studies

Alternative solution: 2 GEM + MM

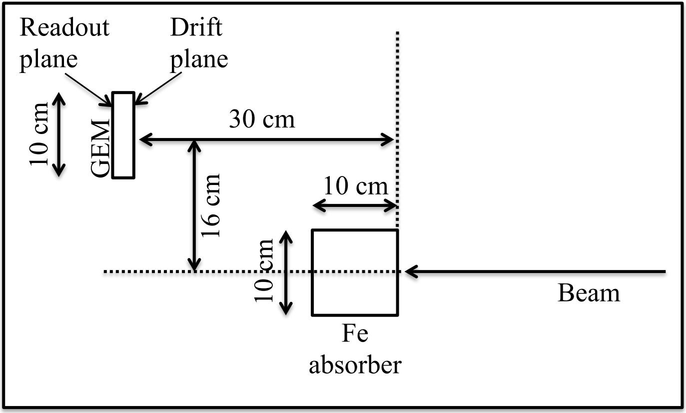
MMG, V	dV, GEM top, V	<GA>, MMG	<GA> (x e3)	Statistics	Number of sparks (MMG)	Number of sparks (GEM)
460	230	500	1.9	1.06 e8	0	0
475	225	656	2.05	1.15 e8	0	0
485	220	838	2.15	1.2 e8	0	0
505	220	1315	3.37	5. e4	25	0
E drift = 0.4 kV/cm; Barometric pressure went down						
465	230	~ 598	~ 2.3	1.08 e8	20	0
475	225	~ 754	~ 2.35	~ 1. e7	~ 2.5	0
E drift = 0.3 kV/cm; Barometric pressure went down (during the Run)						
475	225	~ 760 ~ 805	~ 2.35 ~ 2.5	3. e7 2. e7	0 3	0 0
Ne+CO2+C2H4 (90-10-10), E drift = 0.4 kV/cm						
510	270 (245 mid GEM)	~ 670	~ 2.1	4.6 e7 gas done	0	0

- Results not yet conclusive -studies ongoing

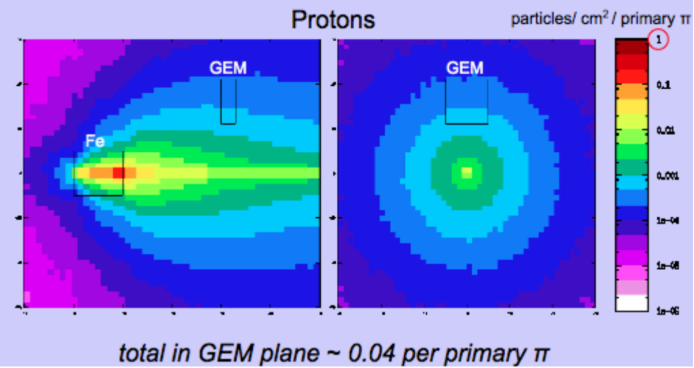
Taken from: "The ALICE TPC Upgrade: R&D", Chilo Garabatos, ALICE Week

FLUKA simulations – 1/2

Setup for FLUKA simulations:



FLUKA simulations – 2/2



(FLUKA simulations for CBM (FAIR) by A. Senger)