LP–S–SP

GEM-based alternatives for Ion Backflow suppression

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Outline

1 Motivation

2 GEM property: collection efficiency
- How to use it in our favor

3 Detector

4 Results
- V_{LP} and V_{SP} scans
- E_{T1} and E_{T2} scans
- V_{S} scan

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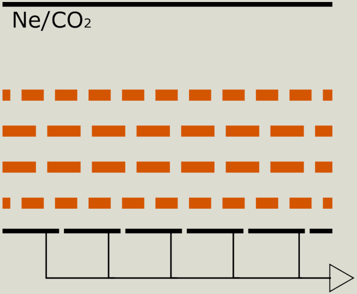
ALICE TPC Upgrade

Expected increase of event rate to 50 kHz in Run 3

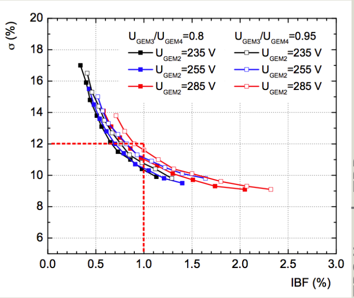
- Replacement of MWPC in readout chambers by GEMs.
- IBF < 1 % and Energy resolution (@ 5.9 keV) < 12 % madatory.

Final result after very intense and complete research program

- 4-GEM with two different types:
  - 140 μm (**S**tandard pitch)
  - 280 μm (**L**arge <u>P</u>itch)



- Sequence of GEM stack:
  - Cathode–S–LP–LP–S–Anode



TPC Upgrade TDR

Motivation

Further research has shown a very good consistency of these results.

One possible disadvantage:

- Many parameters / degrees of freedom
- challenging construction
- concept difficult to transfer to other possible experiments.

What if we could...

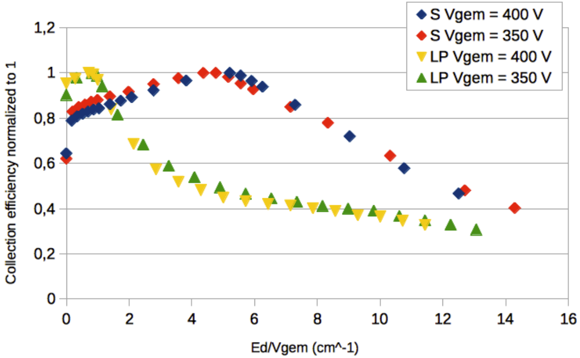
- Reduce number of GEMs.
- Use argon-based mixture (in some countries it is hard to find Neon at a reasonable cost).

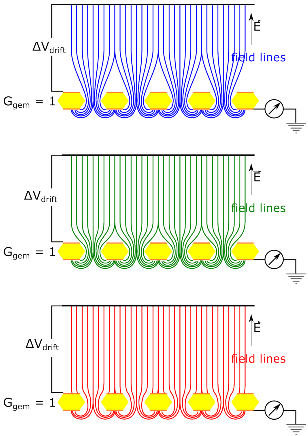
Studies done using two approaches

- Lab tests
- Simulations (on going)

Collection efficiency

Collection efficiency (normalized to 1) for pitch 140 µm and 280 µm as a function of drift field:

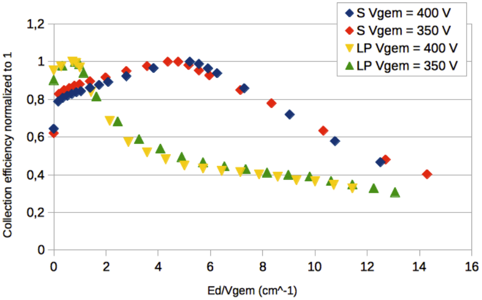




- Low field: focusing effect. Few electrons generated near the copper surface do not reach the holes.
- Maximum efficiency: all electrons are brought to the holes.
- High field: some field lines end between the holes leading to lost electrons to the copper surface of the GEM.

Collection efficiency — using it in our favor

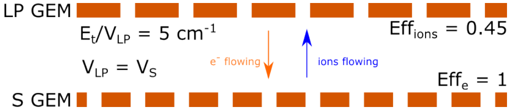
Collection efficiency (normalized to 1) for pitch 140 µm and 280 µm as a function of drift field:



Remarks:

- Curves are normalized to 1: we are interested on the point when efficiency drops — **efficiency threshold**.
- Efficiency is dependent of the ratio $E_{\text{drift}}/\Delta V_{\text{gem}}$ (not only of E_{drift}).
- The **efficiency threshold** increases as the pitch decreases.

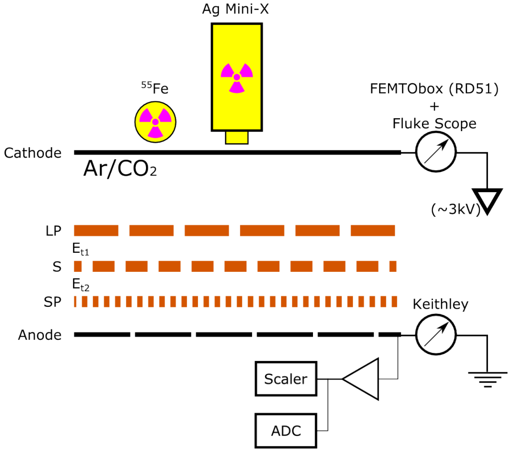
- The transfer field works as a drift for electrons and for ions in oposite directions.
- Using two different GEMs we are tuning the transfer field to have a high efficiency for electrons while keeping a low efficiency for ions.



The detector

Three GEMs with different pitch:

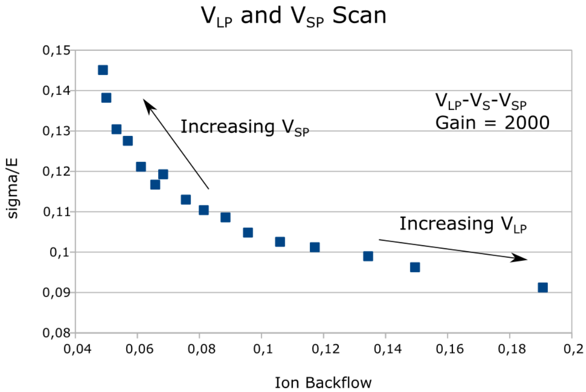
- LP (**L**arge **P**itch): 280 µm
- S (**S**tandard): 140 µm
- SP (**S**mall **P**itch): 90 µm

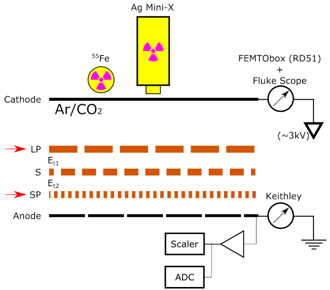


Technical details

- Ar/CO_2 (90/10) at 6 l/h
- 7 independent HV channels (CAEN VME PS)
- Spacing (drift/trans1/trans2/ind in mm): 7.2/2.2/2.2/1.6

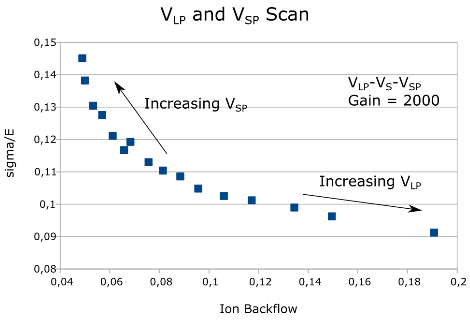
Results — V_{LP} and V_{SP} scan

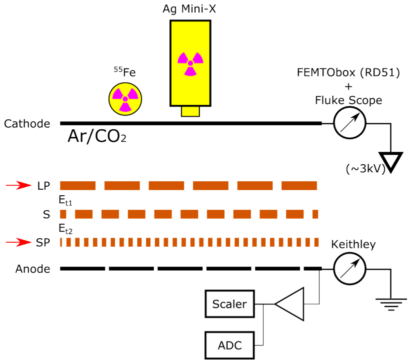




- Gain kept at 2000.
- Only voltages across LP and SP were changed:
  - Increase/decrease $V_{LP} \Rightarrow$ decrease/increase V_{SP}.
- The other voltages were not optimized. This was a scan only to cross check the system was working as expected.

Results — V_{LP} and V_{SP} scan





Making sure everything is clear:

- When LP has the largest part of the detector gain:
  - Resolution improves because one single multiplication stage right after the primary cloud has less fluctuations,
  - but more ions are entering the drift region.
- When SP has the largest part of the gain:
  - Resolution decreases because of small multiplications in two previous stages
  - IBF decreases because all these ions must cross two GEMs to reach the drift region.

Results — E_{T1} and E_{T2} scans

LP–S–SP

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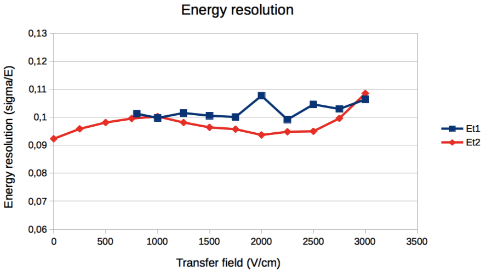

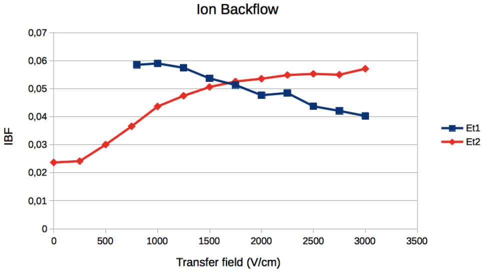

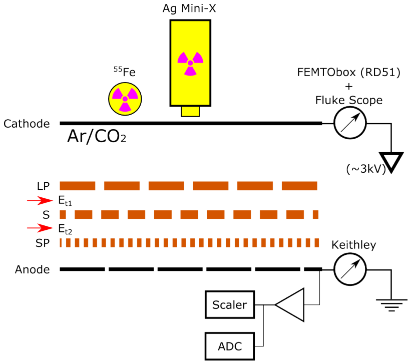

- Gain 2000 ± 50, tuned with V_S. $E_{drift} = 300\,\mathrm{V/cm}$ (to reduce V_{LP}).
- Resolution does not change much as the fields change but,
- To optimize IBF $\Rightarrow$ increase E_{T1} and decrease E_{T2}.

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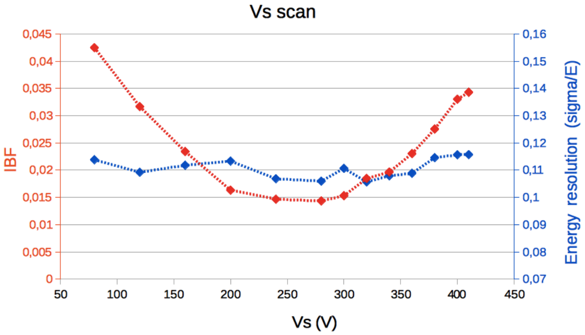
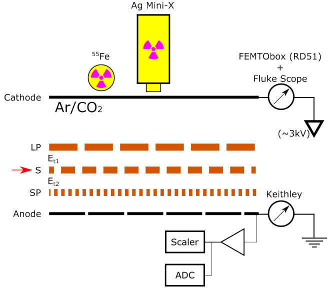


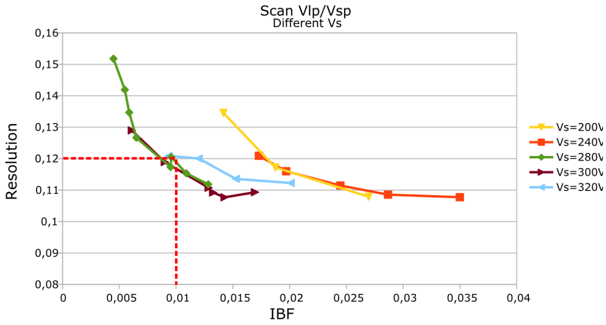


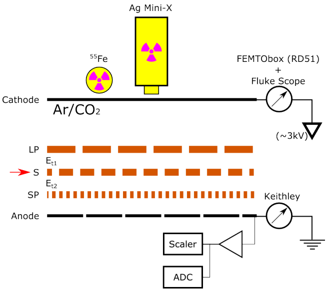
- Gain 2000 ± 50. E_{T1} and E_{T2} optimized. V_{LP}/V_{SP} kept constant (but not optimized). Remember: $E_{drift} = 300\,\mathrm{V/cm}$.
- No significant variation in resolution, but IBF has an optimal range.

IBF:

- Low V_S: V_{LP} and V_{SP} must increase to compensate the gain. More ions from LP GEM.
- High V_S (possibility): increases collection of ions from T_2 (which has low field) and all these are collected due to high E_{T1}.

Results — V_S





V_{LP}/V_{SP} scan for different V_S:

- Gain 2000 ± 50. E_{T1} and E_{T2} optimized.
- Just touched 1 % IBF/12 % resolution rectangle with Ar mixture and 3 GEMs

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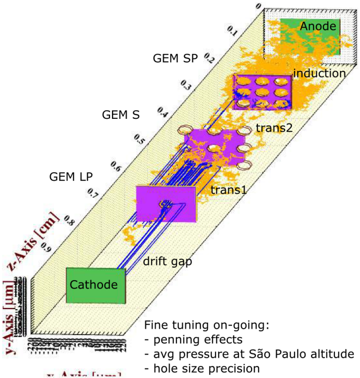
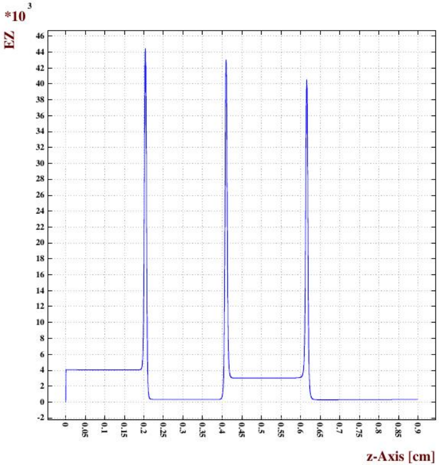
Simulation results



Fine tuning on-going:
- penning effects
- avg pressure at São Paulo altitude
- hole size precision

Collection and extraction efficiencies

	collection	extraction
GEM LP	0.73	0.29
GEM S	0.44	0.06
GEM SP	0.95	0.27



Settings and results

			E_{drift}	.3	kV/cm
V_{LP}	281	V	E_{T1}	3	kV/cm
V_S	300	V	E_{T2}	.25	kV/cm
V_{SP}	311	V	E_{ind}	4	kV/cm

Gain: 1800 (experimental: 2000)

IBF: 0.011 (experimental: 0.017).

E resolution: 0.1 (σ)

Expected vs obtained

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Expected effect of LP–S–SP geometry did not play an important role.

Expected settings from LP–S–SP

- moderate E_{T1}: to allow for a good collection efficiency of electrons in S GEM and bad collection of ions in LP.
- $E_{T2} > E_{T1}$: the small pitch of SP GEM should allow for very high E_{T2}, which would reduce ion collection in S GEM.

What we got:

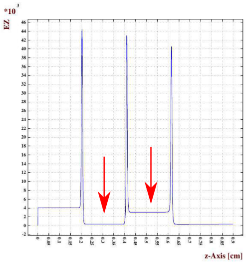
- high E_{T1}
- $E_{T2} \ll E_{T1}$
- Besides tuning V_{LP}/V_{SP}, the most important requirement is E_{T1} as large as possible and E_{T2} as small as possible.

			E_{drift}	.3	kV/cm
V_{LP}	251	V	E_{T1}	3	kV/cm←
V_S	300	V	E_{T2}	.25	kV/cm←
V_{SP}	343	V	E_{ind}	4	kV/cm

We have seen it before

LP–S–SP

			E_{drift}	.3	kV/cm
V_{LP}	251	V	E_{T1}	3	kV/cm ←
V_S	300	V	E_{T2}	.25	kV/cm ←
V_{SP}	343	V	E_{ind}	4	kV/cm

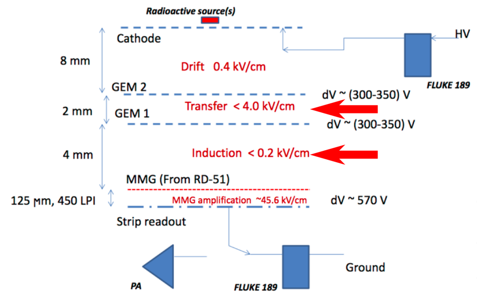


ALICE TDR base line settings (S–LP–LP–S):

(before recently changing to settings with lower ΔU_{gem})

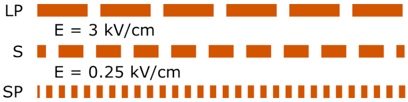
ΔU_{gem1}	270	V	E_{T1}	4	kV/cm
ΔU_{gem2}	250	V	E_{T2}	2	kV/cm ←
ΔU_{gem3}	270	V	E_{T2}	.1	kV/cm ←
ΔU_{gem4}	340	V	E_{ind}	4	kV/cm

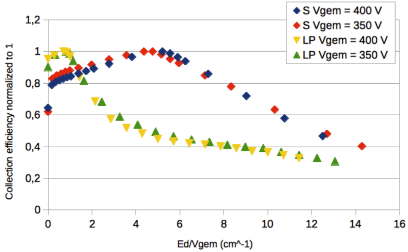
GEM+MM setup from Yale:



A closer look — LP–S–SP as example

LP–S–SP setup is shown, but this thought works for any setup.





What happens in each GEM

LP GEM Electrons efficiently extracted from holes
Ions with a low collection efficiency.

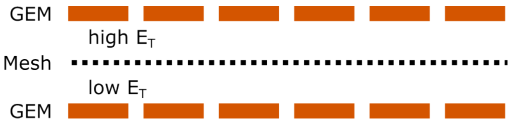
S GEM Low collection of electrons
Low extraction of electrons
Generation of ions
High extraction of ions
High collection of ions

SP GEM Good collection of electrons
Low extraction of ions.

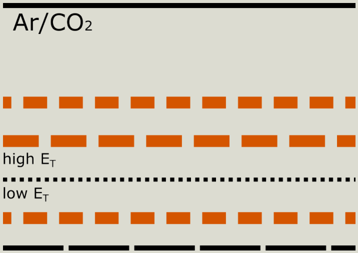
- The system 'high E_{T1}/low E_{T2}' is a very good filter for ions.
- but the S GEM is spoiling the result (do we even need it?!).

Next steps

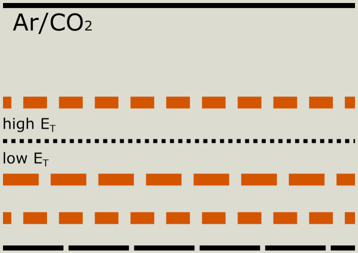
Replace GEM by a mesh, which divides transfer region in the two different zones we need:



Usage examples (inspired by ALICE setup):



Blocking ions from last GEM...



...or blocking ions from 2 GEMs.

Conclusions

- 3-GEM LP—S—SP setup achieved 1 % IBF with 12 % σ energy resolution at 5.9 keV, in Ar-based mixture at gain 2000,
- Simulations and experimental data in process of tuning and converging,
- Results understood and opened a space for new ideas.

Future work

- Test concept of using mesh to separate transfer regions in two different fields,
- accurate measurement of absolute collection and extraction efficiencies,
- study possible issues on stability against sparking,
- evaluate drawbacks in case more stages with mesh are needed (complicating the setup).

The end

Thank you

Looking forward for your comments/questions.