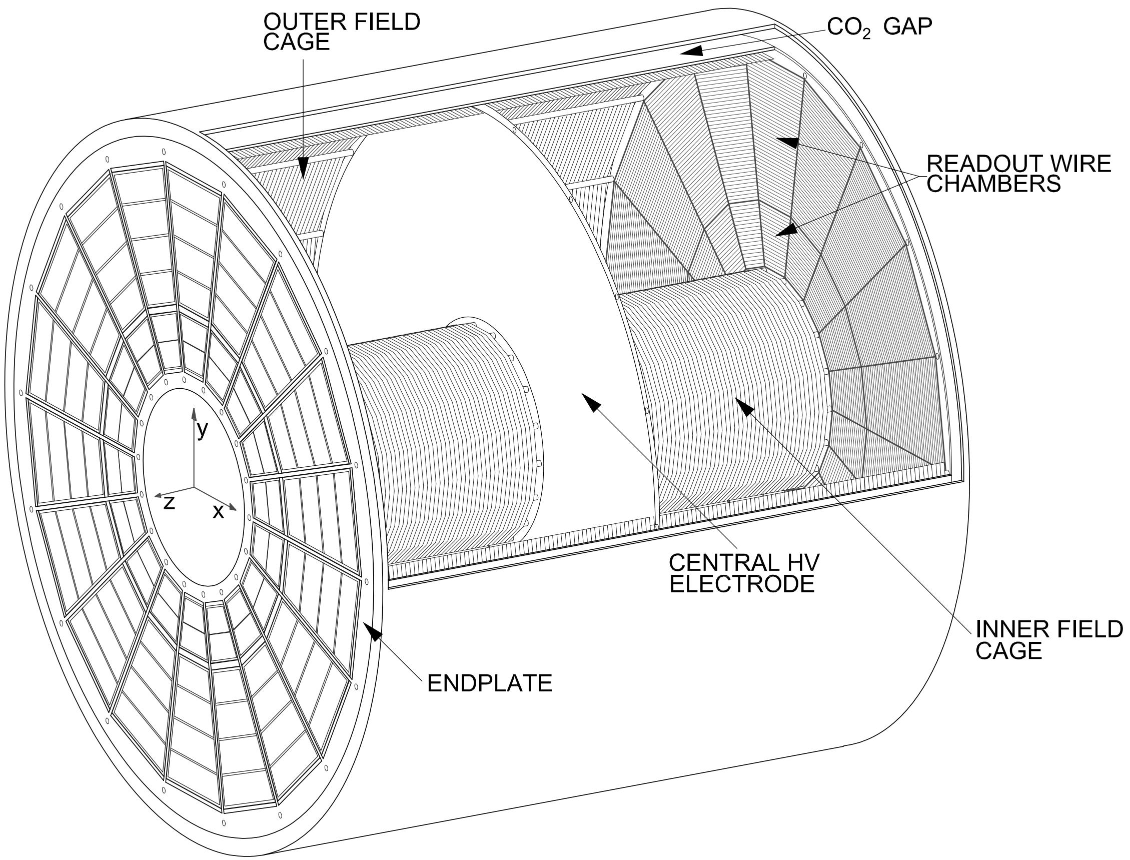
The ALICE TPC upgrade

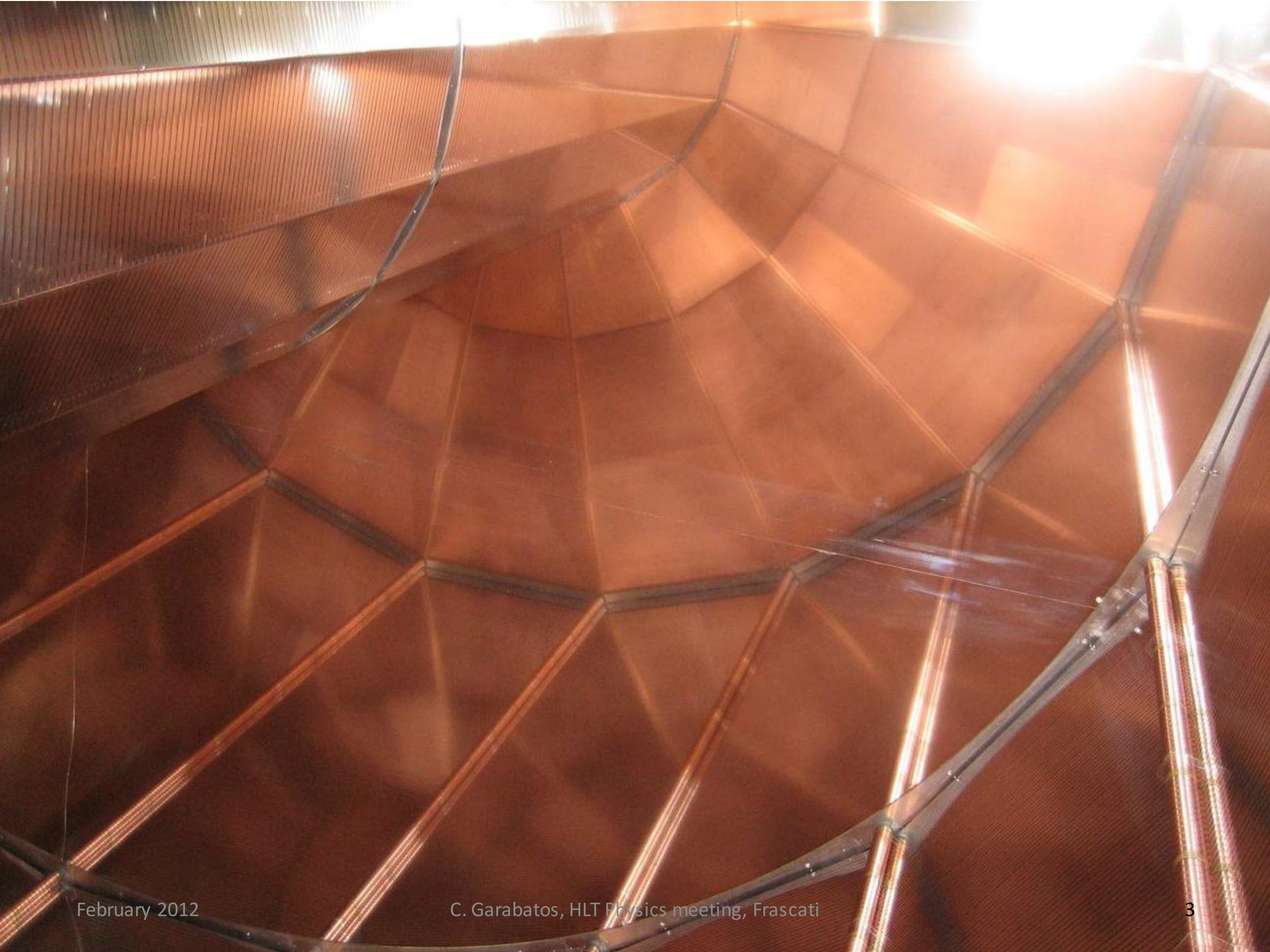
C. Garabatos, GSI

for the TPC group

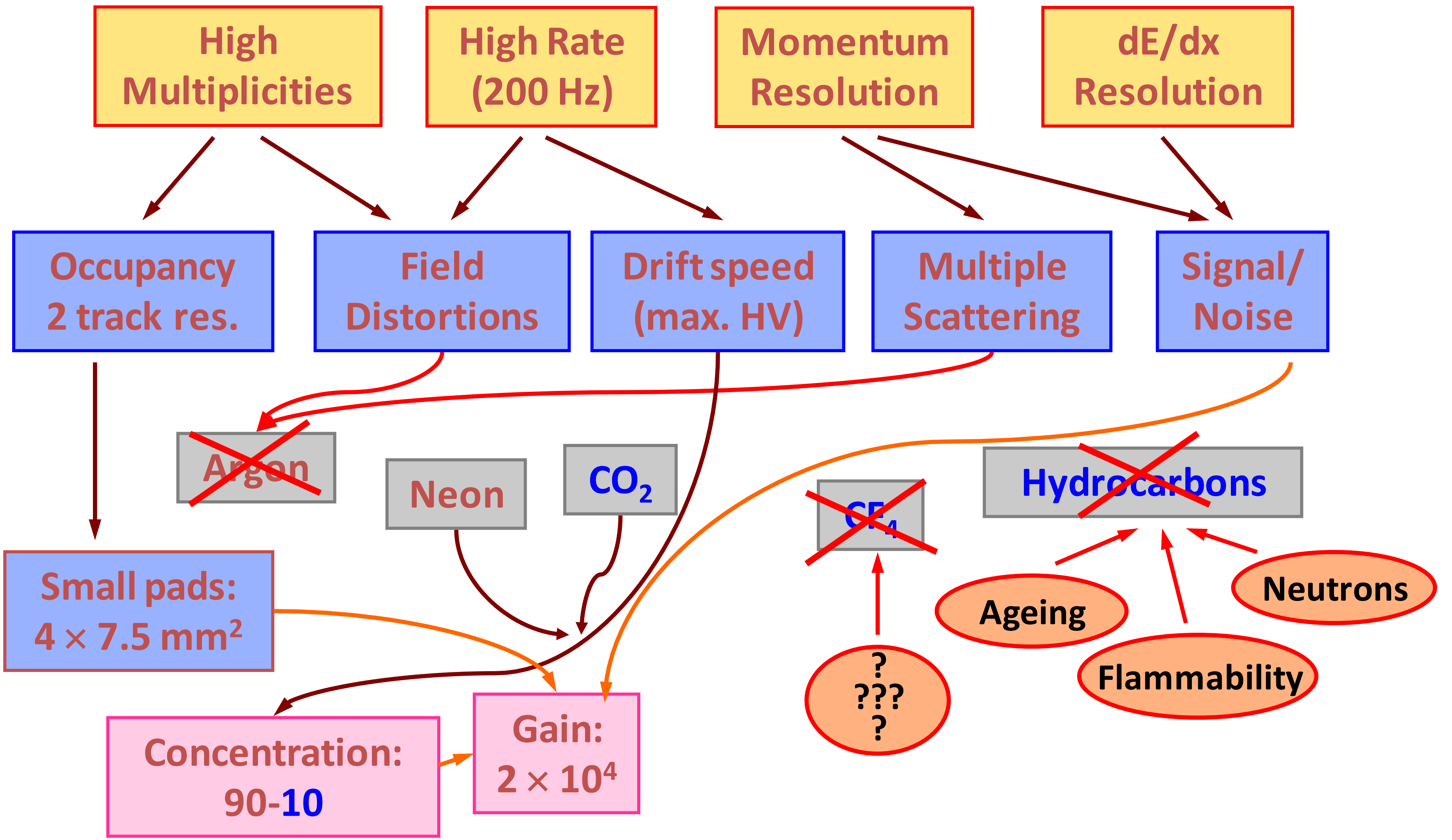
The largest TPC ever



- 5 m x 5 m
- High mechanical precision: 200 μm
- 100 kV in central electrode
- Cooling everywhere
- Wire chambers with pad readout
- Ne-CO_2(-N_2)
- Designed for dN/dy = 8000 (now 1600) and 200 Hz readout rate Pb-Pb



Challenging requirements for the gas



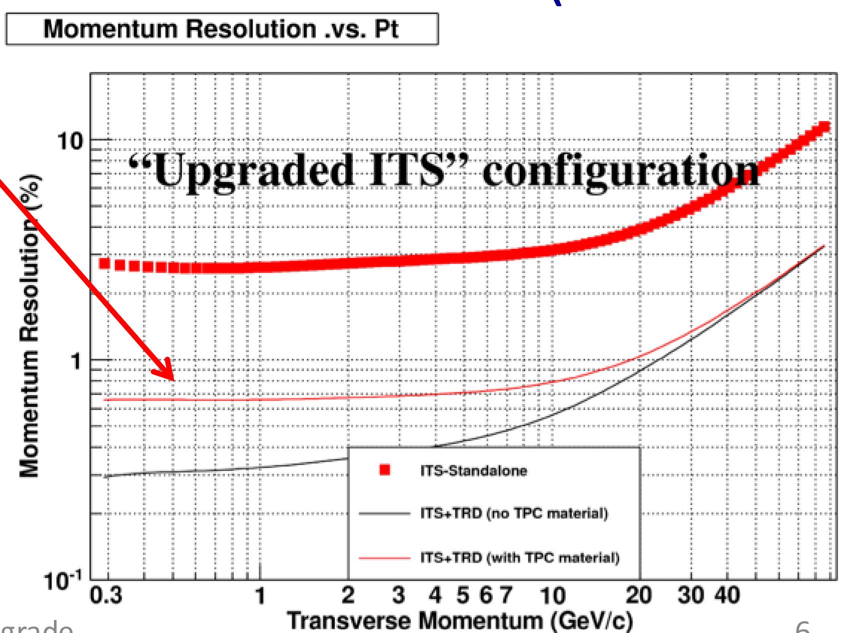
Gas dependencies: calibration challenge

Drift velocity	*90-10*	*90-10-5*
Temperature	+0.37 % / K	+0.34 % / K
Pressure	-0.15 % / mbar	-0.15 % / mbar
CO_2 concentration	-7.6 % / %CO_2	-6.4 % / %CO_2
N_2 contamination	-1 % / %N_2	-1 % / %N_2

Gain	*90-10*	*90-10-5*
Temperature	+0.9 % / K	? % / K
Pressure	-0.34 % / mbar	? % / mbar
CO_2 concentration	+67, -20 % / %CO_2	+17, -14 % / %CO_2
N_2 contamination	+34 % / %N_2	+6.3 % / %N_2

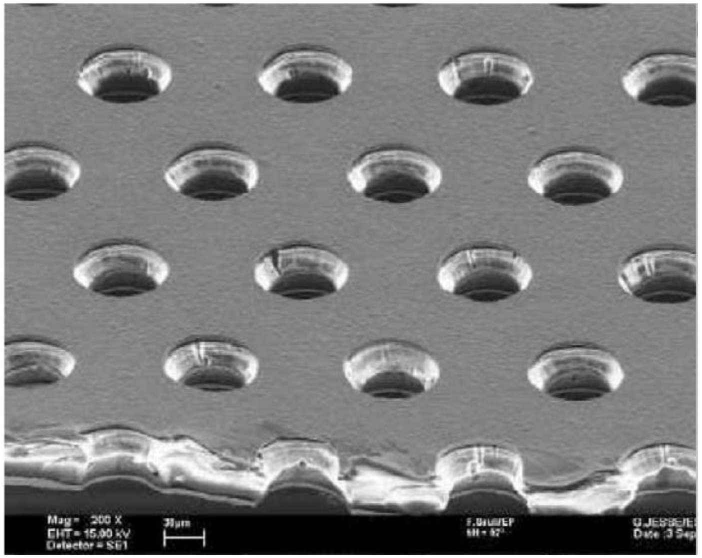
Baseline scenario: benefit from the excellent rate capability of GEMs

- Continuous –untriggered- readout of Pb-Pb collisions at 50 kHz ➔ replace wires by triple GEMs
  - to limit space-charge in drift volume
  - cope with rate
- Spatial resolution somewhat limited by space-charge, but ITS+TRD provide enough momentum resolution (3% at 80 GeV/c)
- Maintain excellent PID
- Perhaps a fast gas
- New FE electronics
  - x2 channles
- Existing FC at ≤ 100 kV



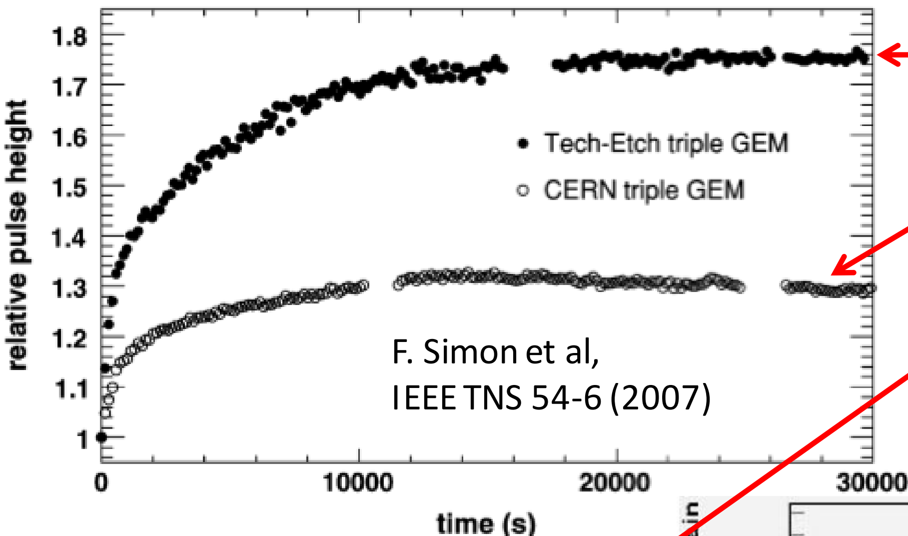
About GEMs

- 50 μm metalized polyimide foils with tiny holes at 150 μm spacing where amplification takes place
- Signal entirely produced by electrons
- Ions absorbed at the electrodes, some 0.1 % leak back into drift
- Rate >10^6 counts/mm^2
- Triple assembly
- Segmentation to avoid damaging discharges
- Produced at CERN and others
- Widely used now



Gain dependence of GEMs

- Gain increases at switch-on (30%)
- Effect depends on foil properties and rate (mins-hour)
- Slow decrease with time (hours/days)
- Slow decrease at switch-off (days)



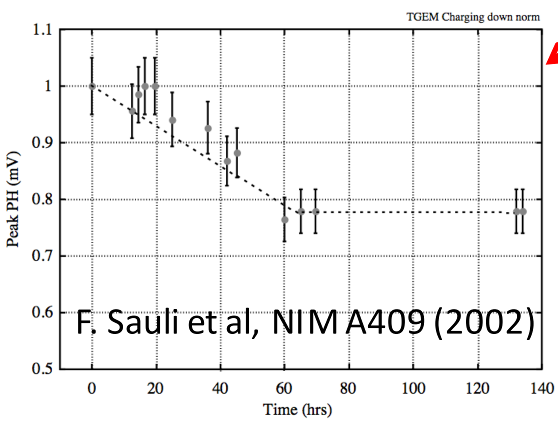
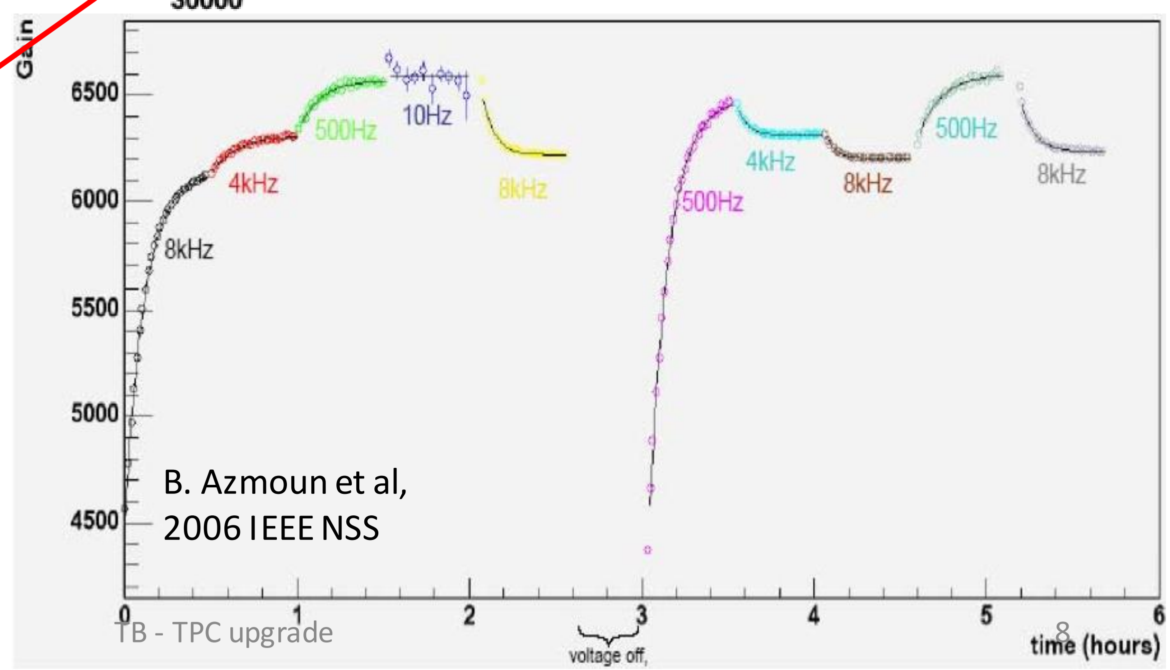


Fig. 31. Long-term charging down in absence of radiation.

☞ Calibration issue

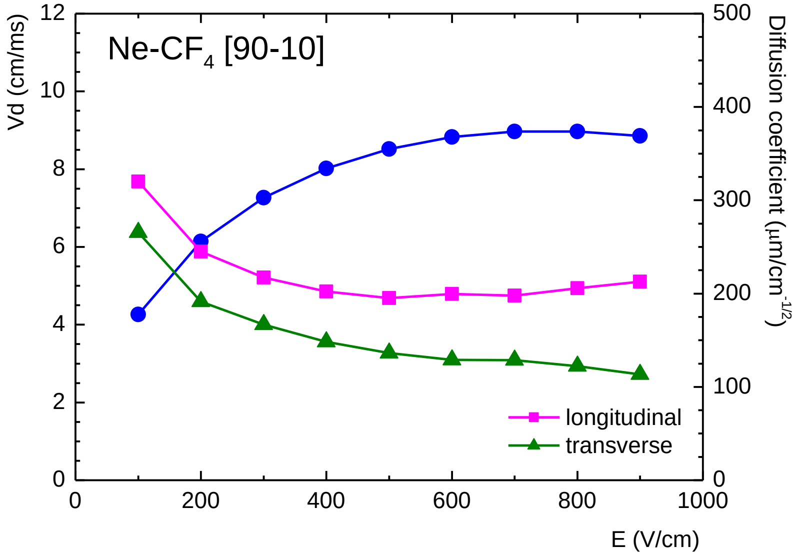
Gain depends on rate

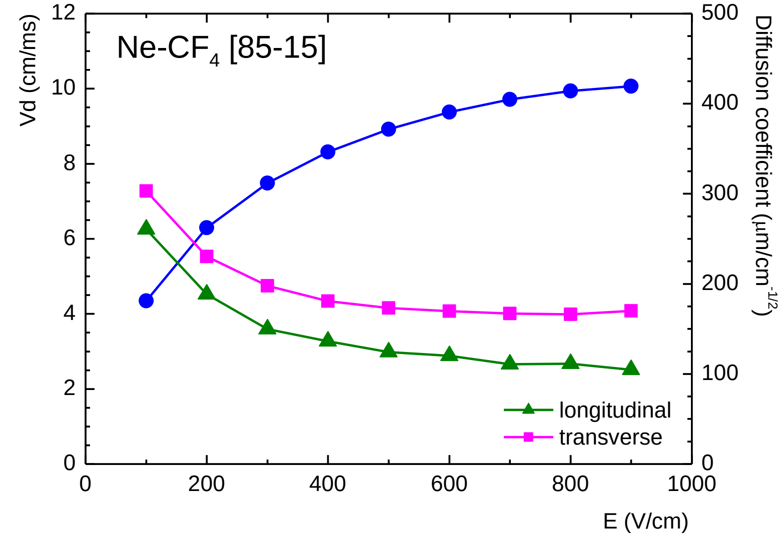


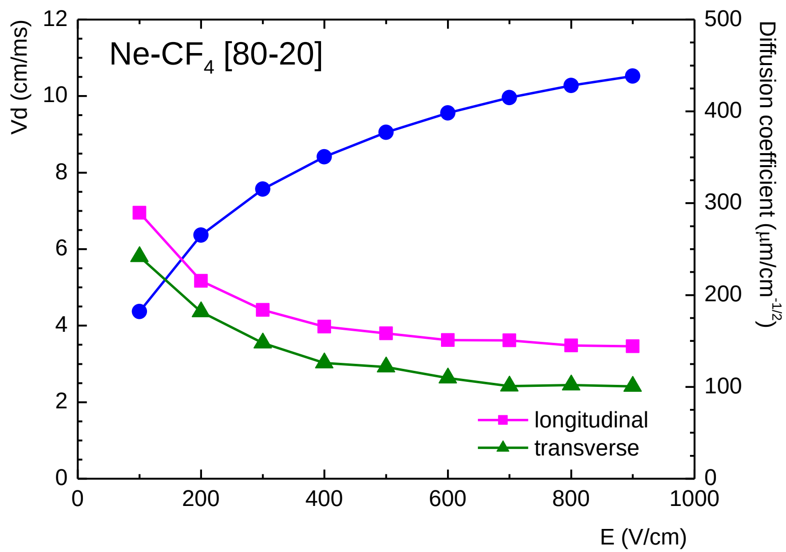
Gain dependence issue

- Charge-up times at Stable Beams in ALICE probably or order of many minutes
- Careful monitoring and calibration (offline, in baseline scenario) is needed
- R&D on minimization of polyimide charge-up and polarization/charge migration effects is needed
  - field configuration
  - water? (Brrr…, not good with CF_4)

Fast gas: Ne-CF_4?







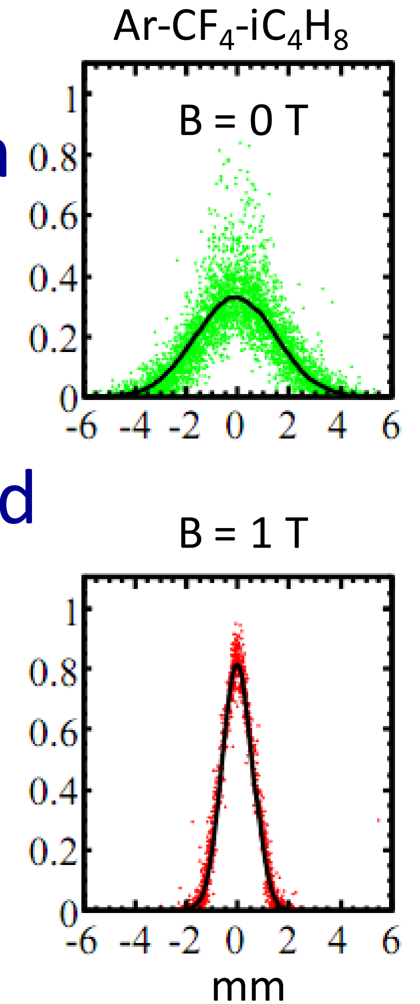
- Up to factor 3 faster than CO_2 at 400 V/cm
- Provides flexibility to choose drift field
- Unfortunately, the transverse diffusion is smaller, and the longitudinal is larger, than in CO_2 (220 µm/√cm) ➔ wrong direction

Fast gas: Ne-CF_4?

- In addition, diffusion in CF_4 shrinks with magnetic field ➔ more channels

- Mobility of ions in Ne-CF_4 not known, but taking CF_4^+ on CF_4, distortions would be 3-4 cm max., comparable with Ne-CO_2 (50 kHz Pb-Pb with 4 ions/electron leaking out) ➔ not critical

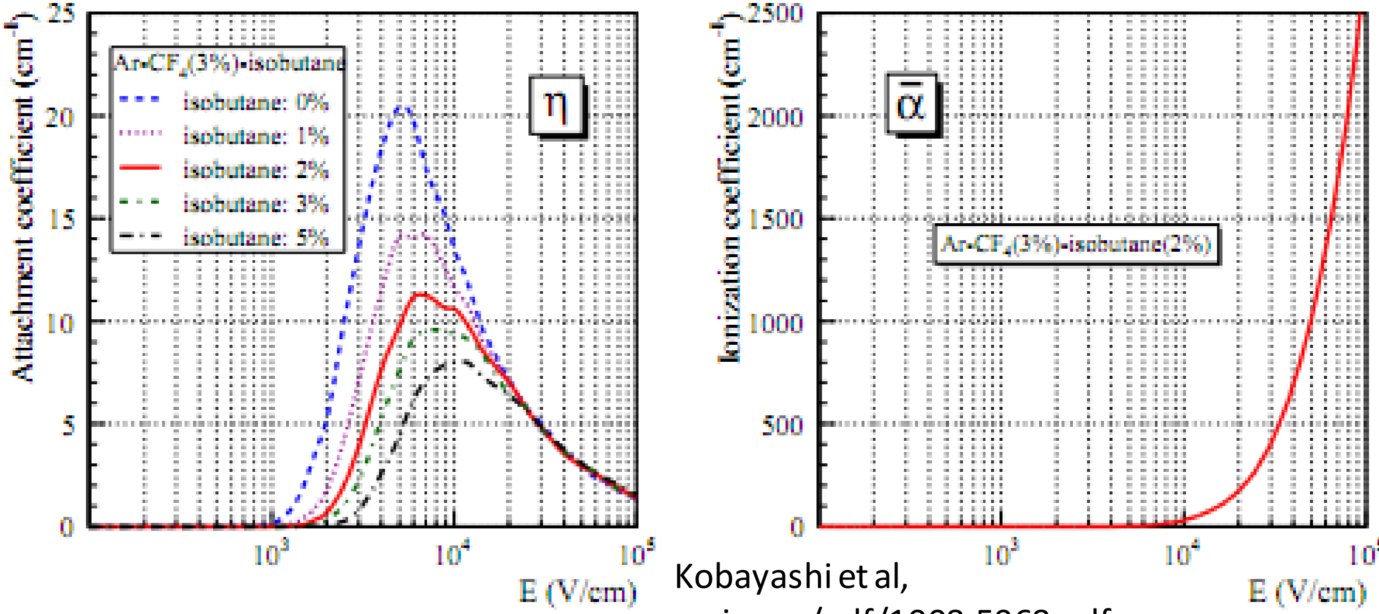
 A fast gas *only* buys us less overlapping events (5 ➔ 2), but TPC designed for dN/dy = 8000



Kobayashi et al,
arxiv.org/pdf/1008.5068.pdf

Fast gas: Ne-CF_4?

- CF_4 exhibits electron attachment near and in the amplification region, leading to further gain fluctuations



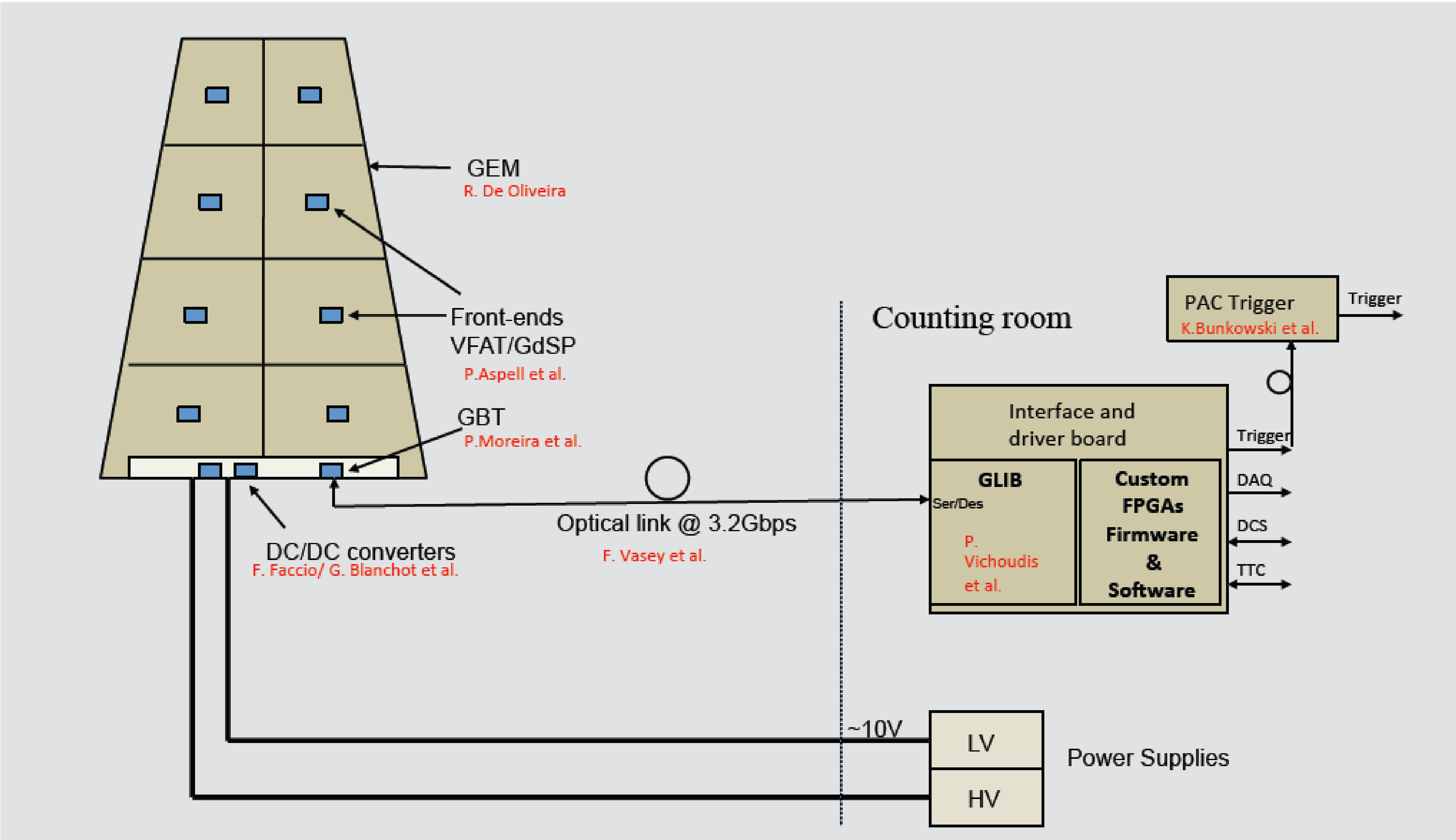
Kobayashi et al, arxiv.org/pdf/1008.5068.pdf

- In addition, the compatibility of CF_4 with all materials must be validated, and H_2O must be avoided

Estimate of number of readout channels

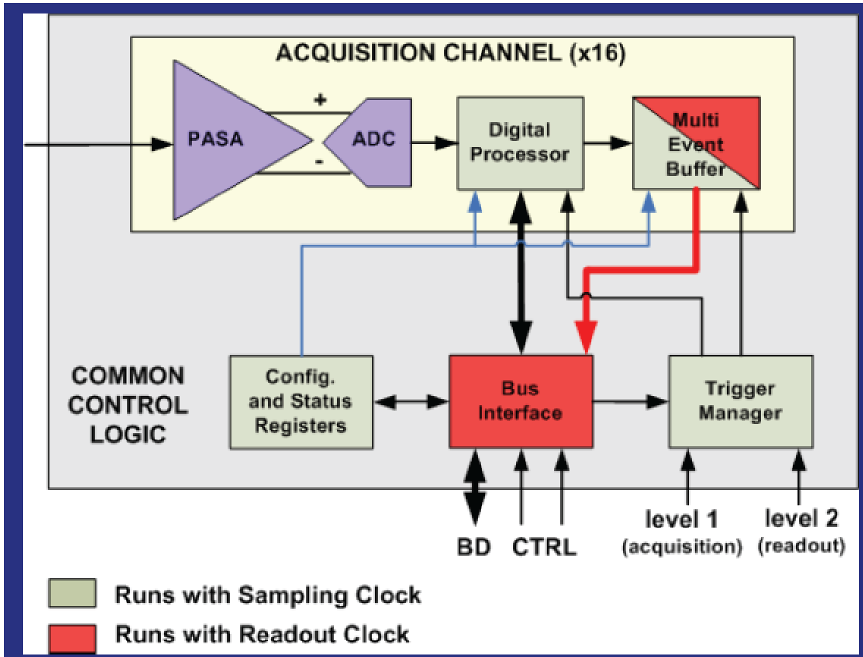
- At > 1 m drift distance, diffusion of order of ~2-4 mm
- Probably can live with 4 mm wide pads for IROCs
- Reduce the OROC pads (6 mm) to 2-3 mm
- This results in roughly a factor 2 more pads: 1-1.5 M
- Anyway, position resolution can be somewhat relaxed. PID is important

CMS High Eta Upgrade Electronics System



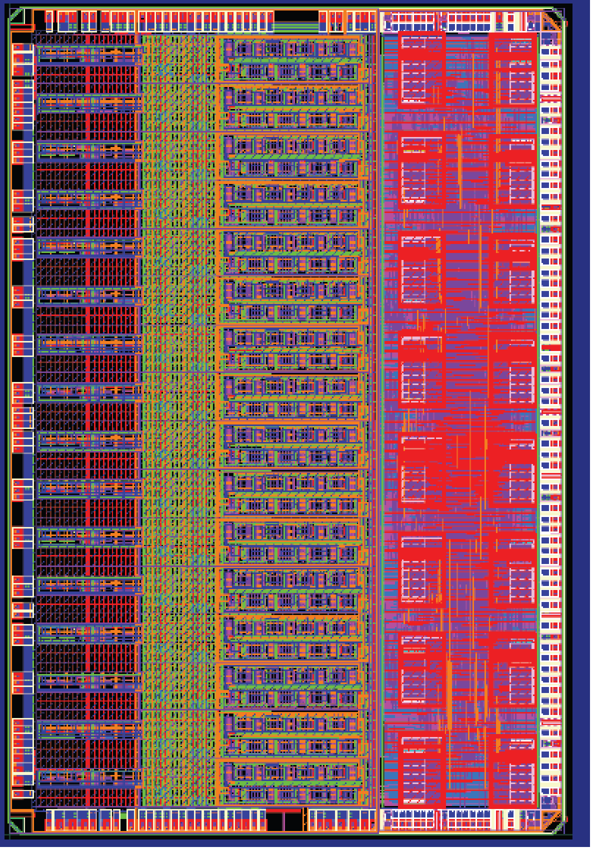
The SALTRO Demonstrator Chip

Charge amplifiers, ADC, digital processing all in one chip



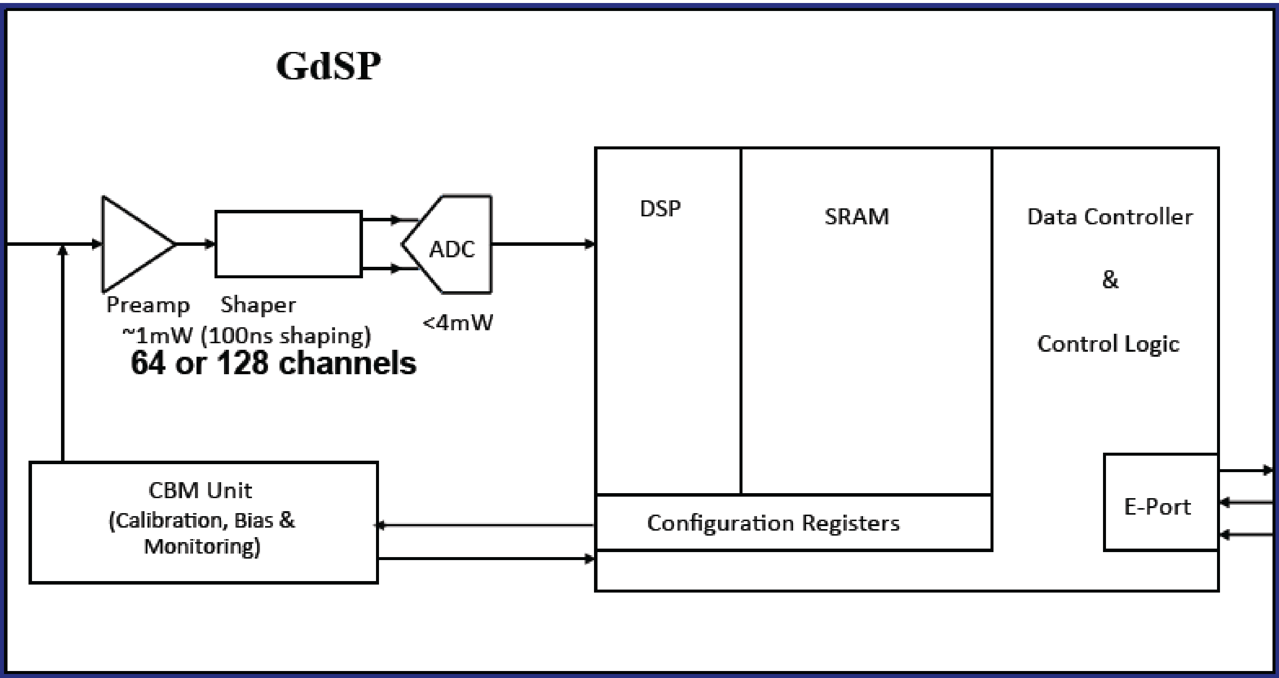
16 channel demonstrator chip designed in 2009-2010, recently received back from the foundry awaiting test.

Technology : IBM 130nm CMOS



Luciano Musa …………………. S-Altro Specs. & Architecture
Paul Aspell …………………….. Coordinator of design
Designers :
Massimiliano De Gaspari ……. Front-end + ADC
Hugo França-Santos ……….. ADC core
Eduardo Garcia ………………. Data Processing & Control

Further evolution for CMS/LCTPC (could support continuos readout)



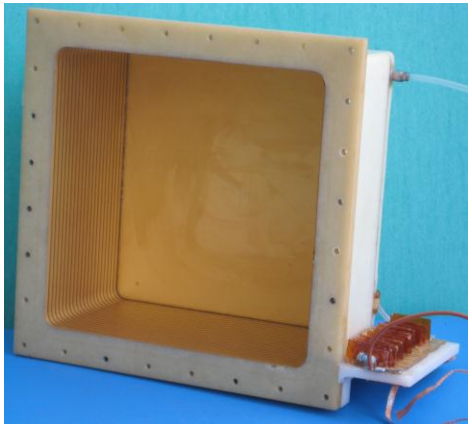
64 channels = Analog power ~ 320mW + Digital power ~ a few hundred mW. Approx. ~500mW / chip.

128 channels = Analog power 640mW + Digital power ~ some hundreds mW. Approx. ~900mW / chip.

Should be possible to get 7-8 mW/ch for everything on a 128 ch chip.

Short-term plans

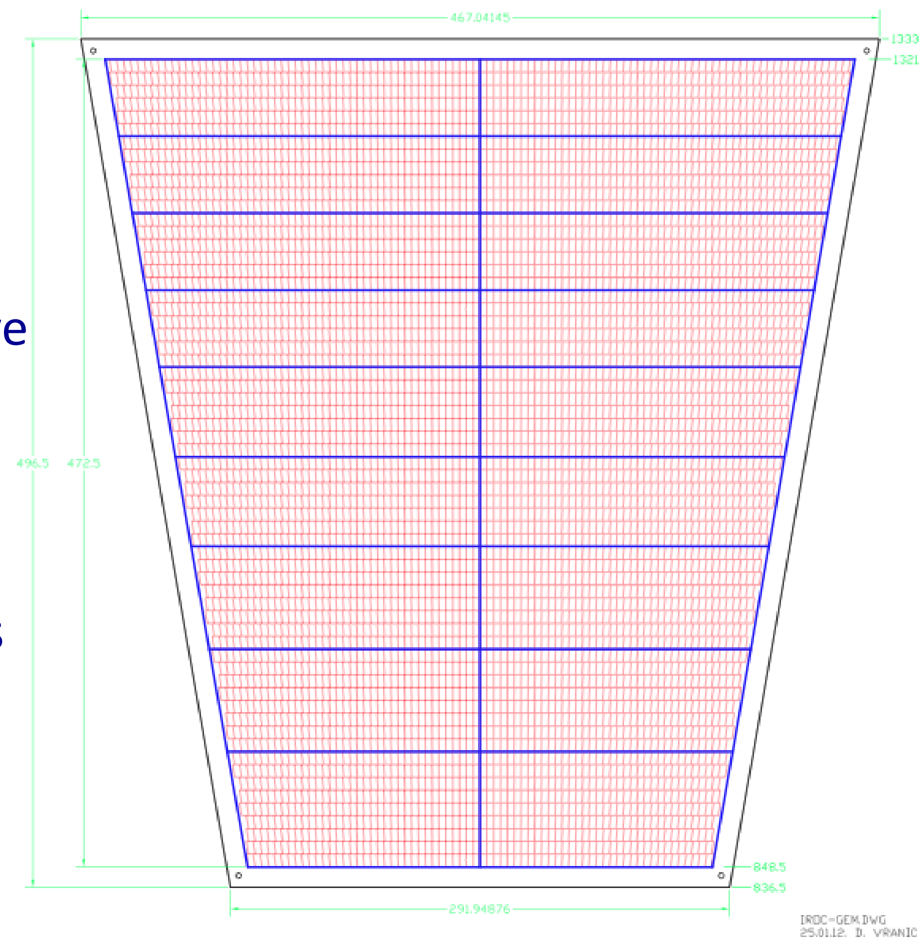
- Prepare a small set-up for laboratory measurements (with RD51)
  - ion mobility
  - ion back-flow
  - gain stability
  - gas mixtures
  - cluster size
  - field configuration
  - ageing: 0.1 C/cm^2/month Pb-Pb (100 times more!)



- Prepare an IROC with GEMs to be exposed to p-Pb in the cavern
  - main goal is to prove stability of GEMs under LHC conditions (unfortunately no Pb-Pb), including gain behavior
  - exact running conditions to be worked out now

Fit a triple GEM into a spare IROC

- GEM foils being designed by the Munich group
- No problem to produce single-mask full surface GEMs
  - perhaps thin frames in the active area are needed to prevent sag
- Enough feed-throughs in chamber support to power 6 electrodes
- Segmentation (≤100 cm^2) results into 19 segments
- FC box needs a 'last resistor' to match the drift field to the potential of 1st GEM
- 1-2 chambers will be prepared



Schedule

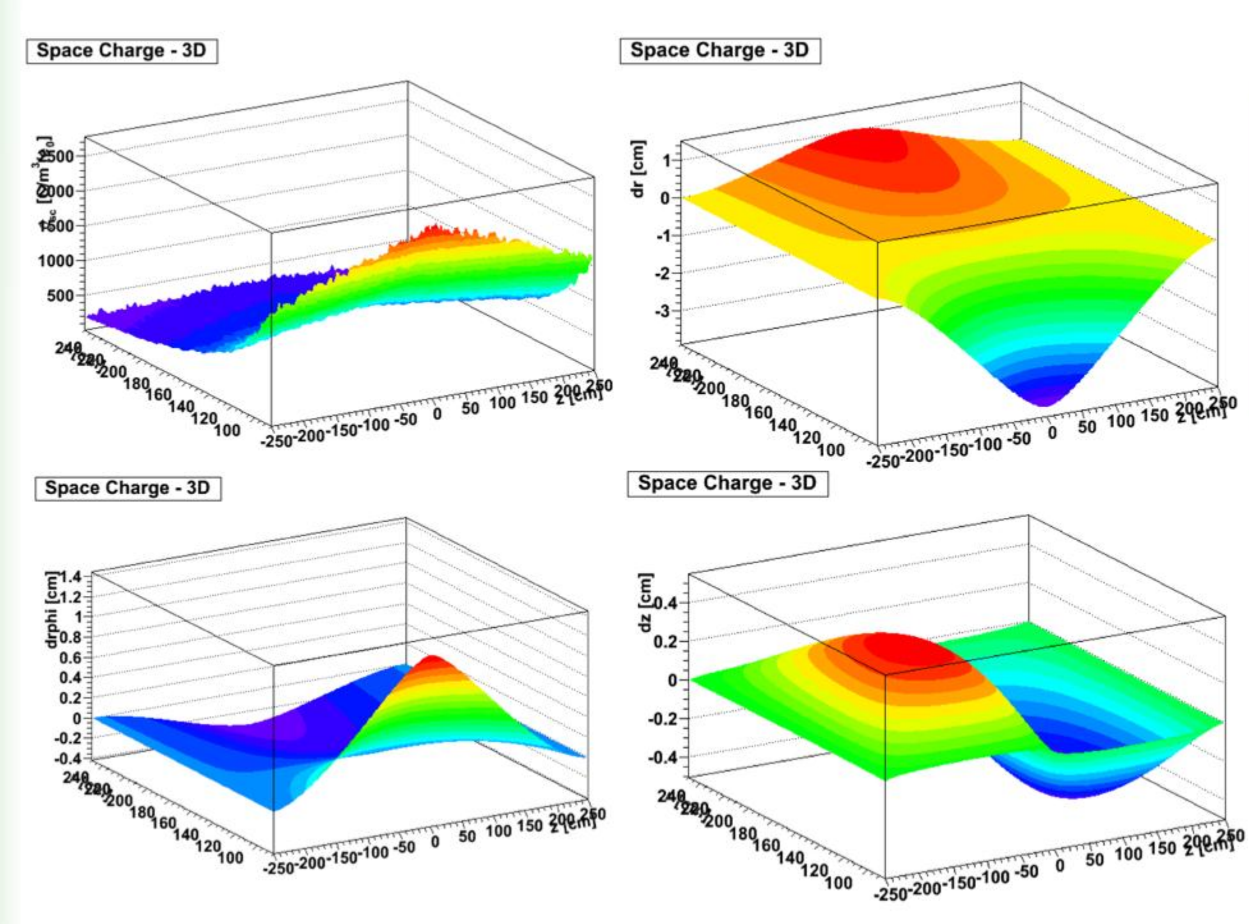
- 2012: prepare, and carry out, test in the ALICE cavern and basic R&D
  - decision to go ahead
  - define the project: chambers and readout
- 2012: build Collaboration
- 2012-2017: design, produce, test
- 2018: installation

Conclusions

- Use existing Field Cage with GEM readout and new electronics for continuous readout in Pb-Pb at 50 kHz
- Start tests now; put a prototype in the experiment
- Staying with the current, slow gas would save short-term R&D on
  - ion mobility
  - ‘PRF’
  - compatibility with materials and water
  - electron attachment
- Start search for collaborators now

BACKUP SLIDES

GEM with Ne-CO_2 – Space-charge distortions



ρ_{max} ~ 2500 C/m³/e0

Δr_{max} ~ 3.7 cm

$\Delta r\phi_{max}$ ~ 1.3 cm

Δz_{max} ~ 0.45 cm

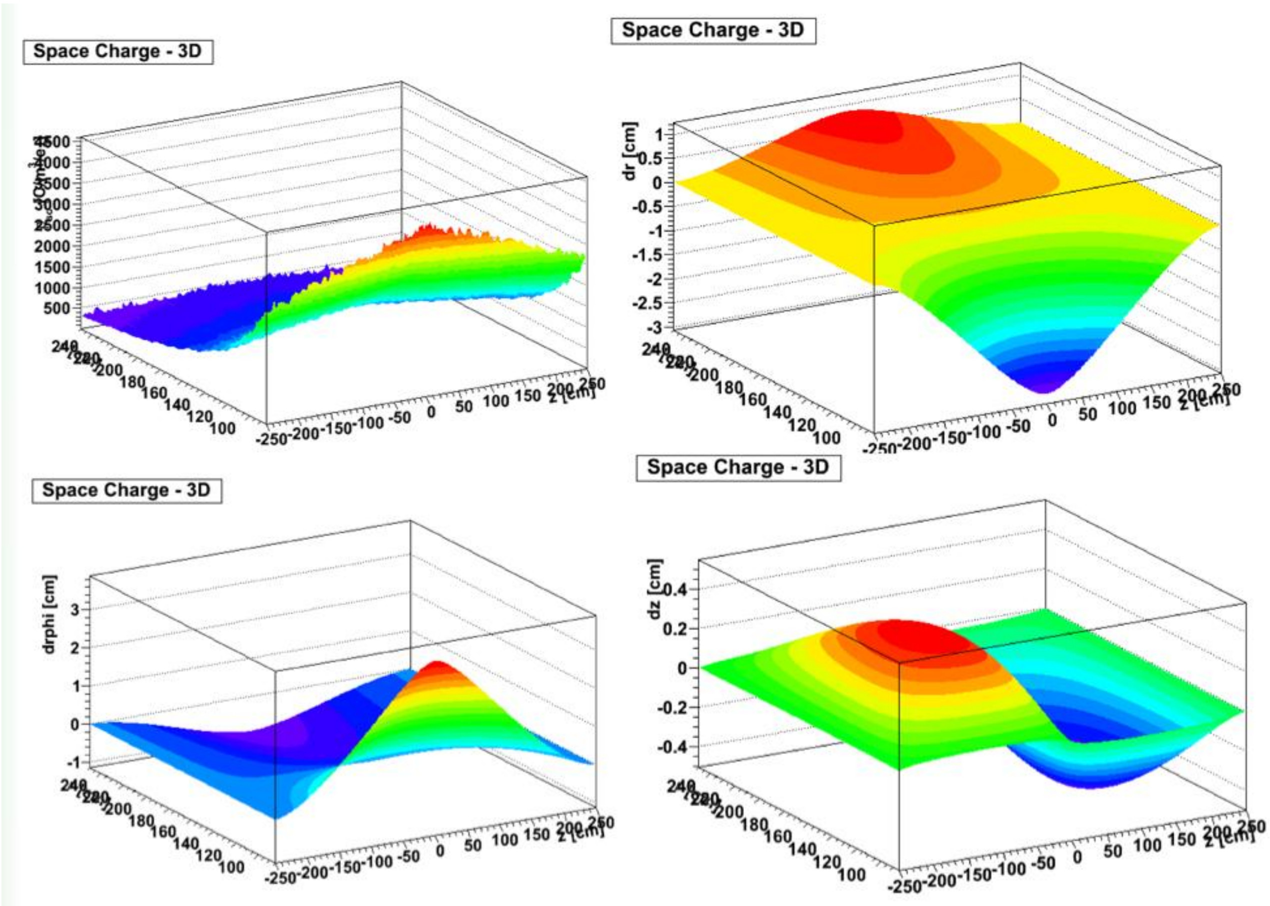
Shown is Primary ionization us Ion-Feedback from the GEMS

(Based on MC-estimate with "tuned" HIJING generator from 2011)

S. Rossegger

50 kHz Pb-Pb, 4 ions leakage per primary electron

GEM with $Ne\text{-}CF_4$ – Space-charge distortions



$\rho_{max} \sim 4000\ C/m^3/e_0$

$\Delta r_{max} \sim 2.9$ cm

$\Delta r\phi_{max} \sim 3.4$ cm

$\Delta z_{max} \sim 0.45$ cm

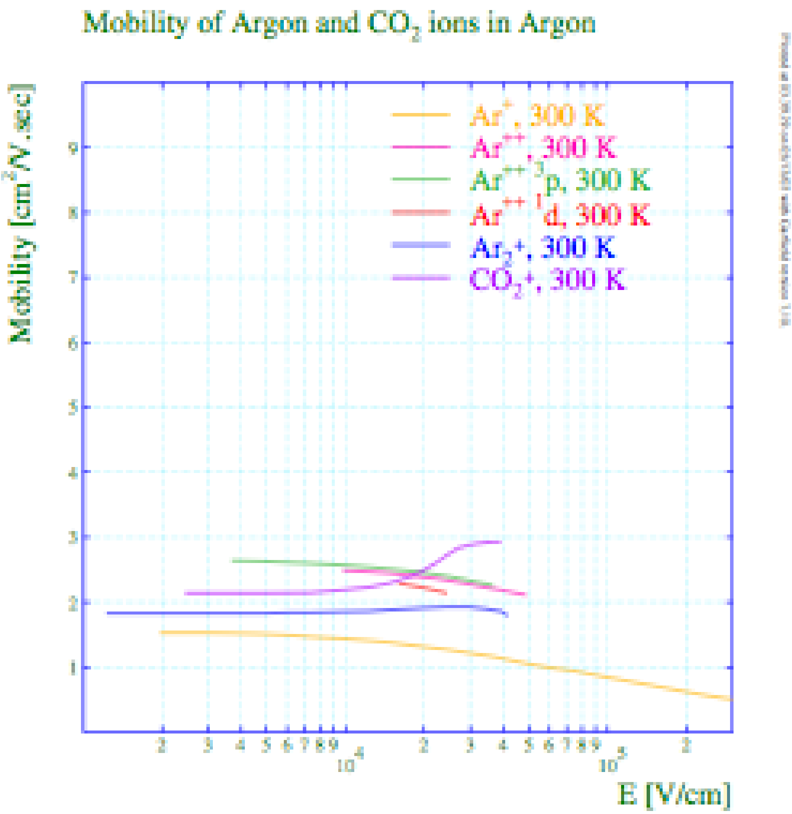
Shown is Primary ionization plus Ion-Feedback from the GEMS

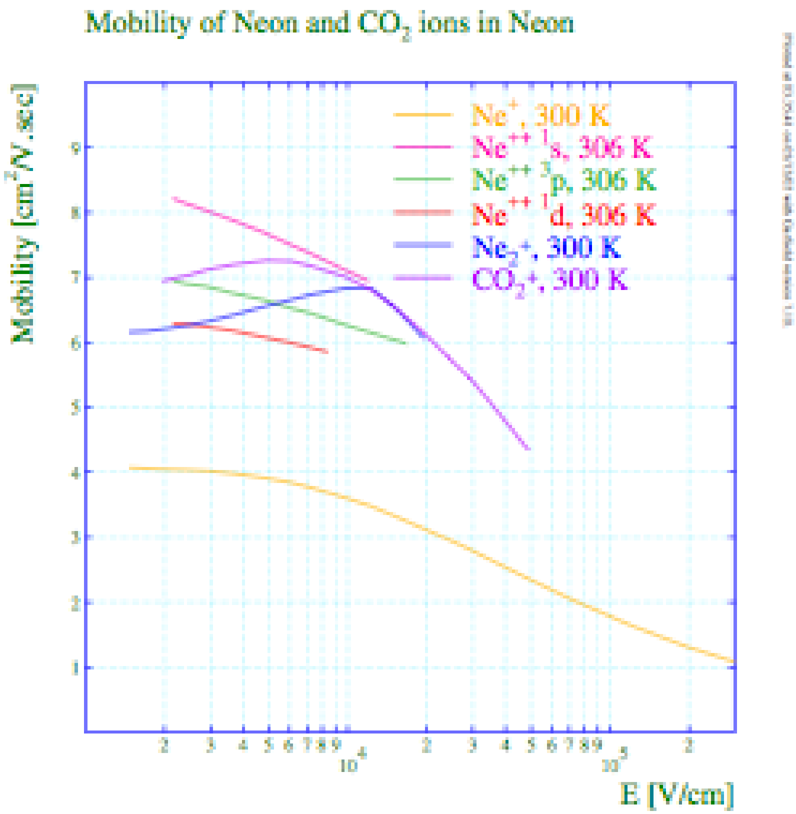
(Based on MC-estimate with "tuned" HIJING generator from 2011)

S. Rossegger

50 kHz Pb-Pb, 4 ions leakage per primary electron

Ion mobility in Ar and Ne





No information found on ion mobility of Ne-CF_4 mixtures. It must be measured