R&D and simulations on gain stability and IBF for the ALICE GEM-TPC upgrade

Taku Gunji
Center for Nuclear Study
The University of Tokyo
For the ALICE TPC Upgrade Collaboration

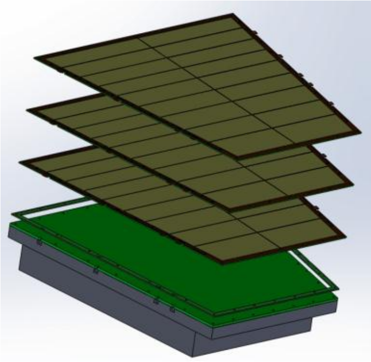
RD51 mini week at CERN, Dec. 3-5, 2012

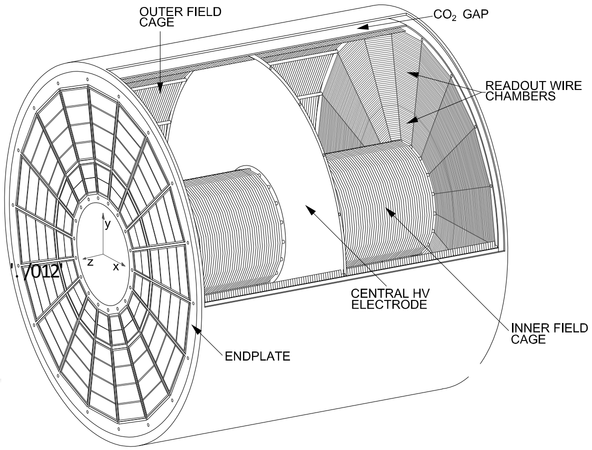
Outline

- *ALICE GEM-TPC upgrade*
- *R&D Status of gain stability*
- *R&D Status of Ion back Flow*
- *Simulation study of Ion Back Flow*
- *Summary and Outlook*

ALICE GEM-TPC Upgrade

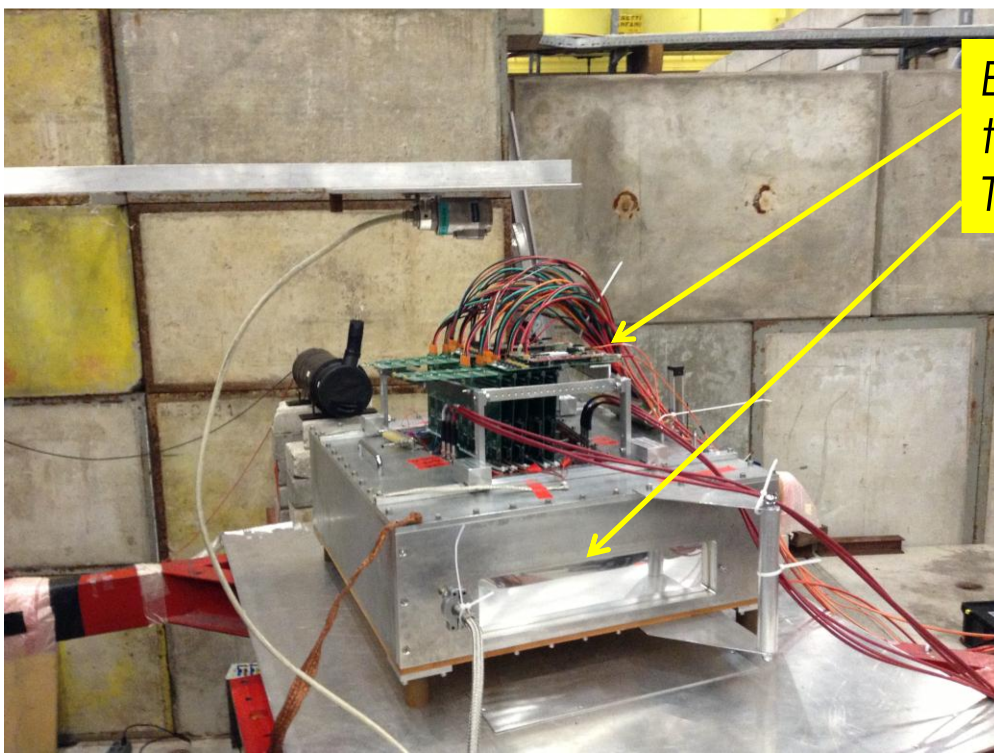
- LoI of the ALICE upgrade
  - https://cdsweb.cern.ch/record/1475243/files/LHCC-I-022.pdf
  - Endorsed by the LHCC
- High rate capability
  - Target: 2MHz in p-p and 50kHz in Pb-Pb collisions
- Plan for the ALICE-TPC upgrade
  - No gating grid and continuous readout
    - Inherited the idea from PANDA GEM-TPC [arXiv:1207.0013]
  - MWPC readout will be replaced with GEM.
  - Ne(90)/CO_2(10)
  - E_d=0.4kV/cm



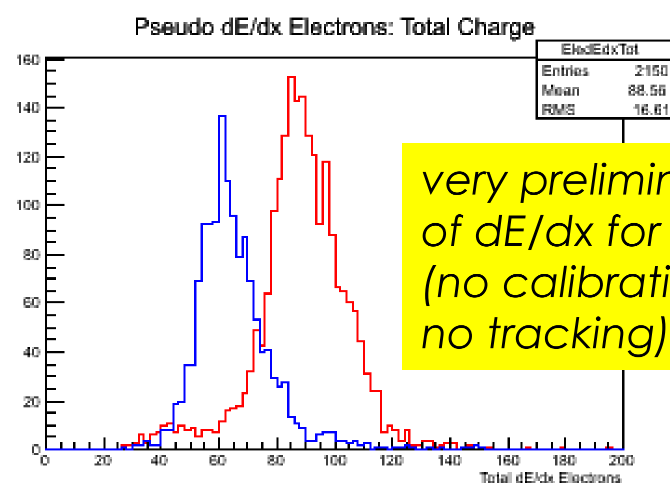


ALICE GEM-TPC Upgrade

- Major issues for the GEM-TPC upgrade
  - dE/dx resolution for the particle identification
    - ~5% for Kr by PANDA GEM-TPC.
    - Beamtest of prototype GEM-TPC at CERN PS-T10
      - ***Detailed presentation by P. Gasik***



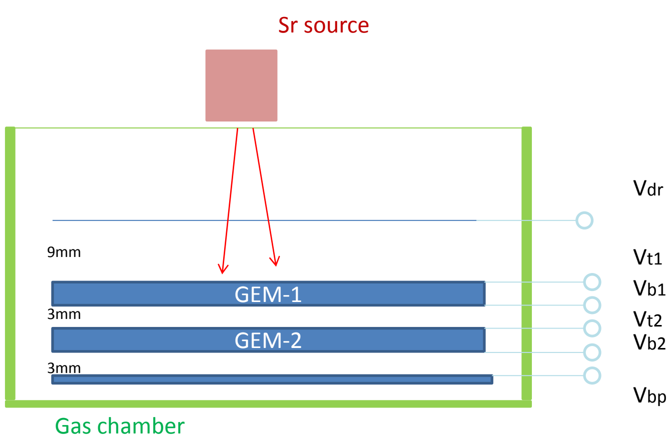
Electronics (PCA16+ALTRO: loan from the LCTPC. Thanks!!) & RCU
TPC Gas Vessel & GEM-Stack

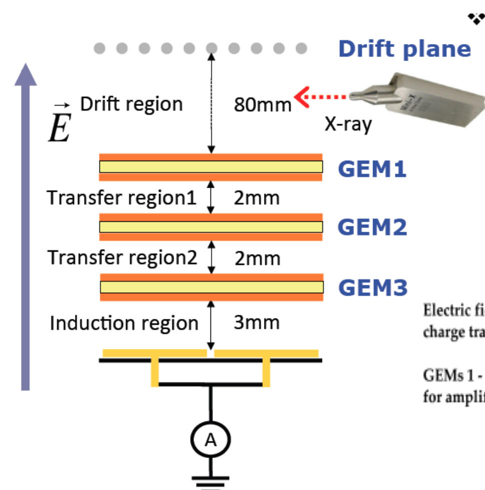


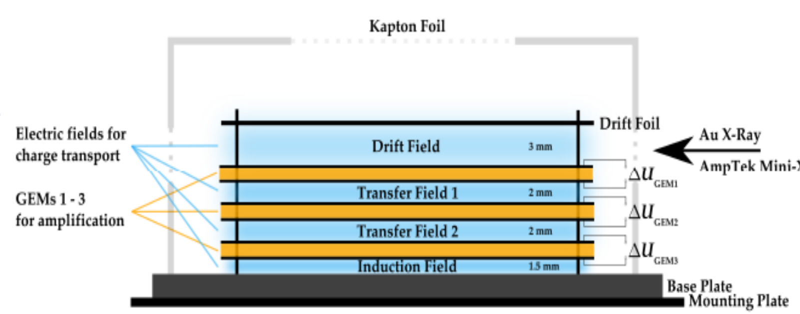
very preliminary of dE/dx for π/e (no calibration, no tracking)

ALICE GEM-TPC Upgrade

- Major issues for the GEM-TPC upgrade
  - Stability of GEM (gain, charge up, discharge, P/T)
    - Measurements in the lab.
    - Test with the prototype at ALICE cavern in 2013. (p-Pb)
  - Ion back flow to avoid space-charge distortion
    - Requirement < 0.25%
    - Test bench in CERN, Munich, and Tokyo
    - Simulations to search for the optimal solutions



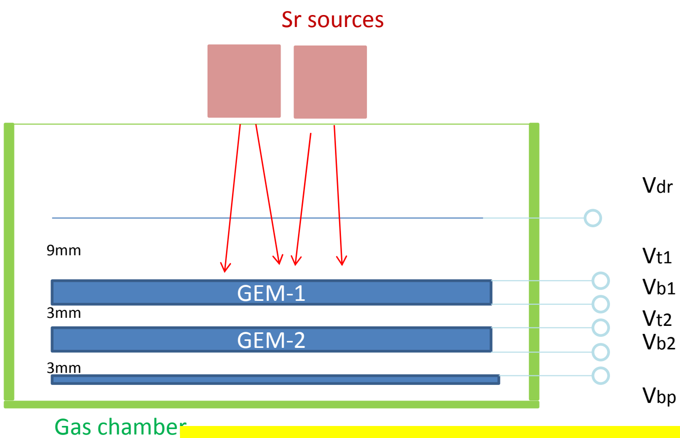




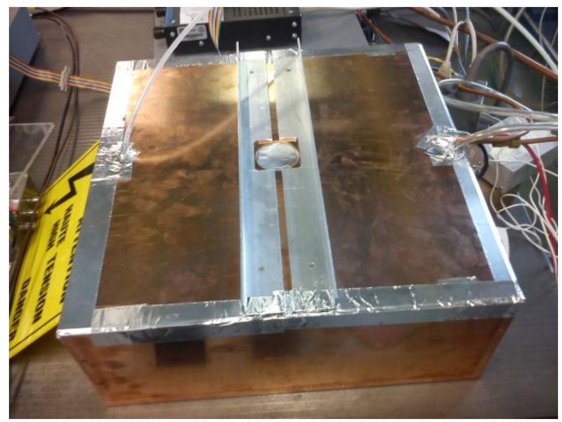
R&D of gain stability

- Measurement setup
  - Single wire chamber as reference
  - Monitor humidity

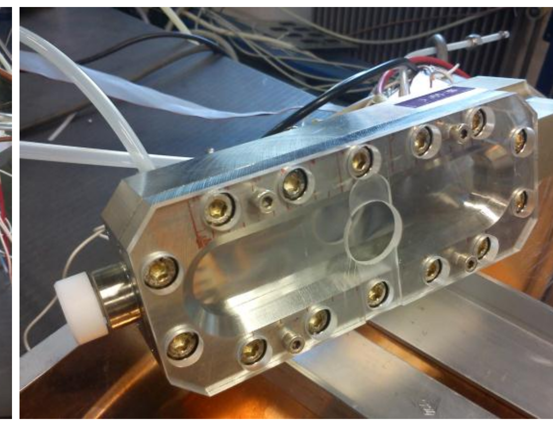
V. Peskov
J. Reinink



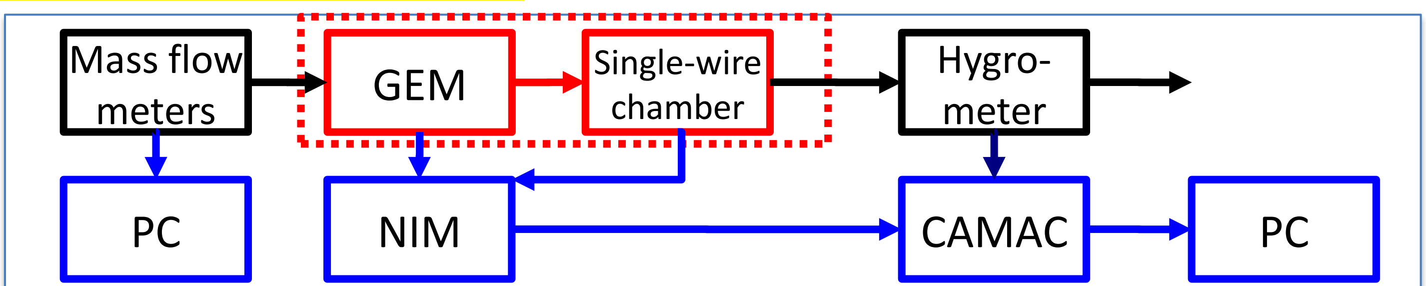
Single/double GEM
gain~900-2000
Current density ~ 2-7nA/cm^2



Sealed shielding box flushed with N_2, containing GEM

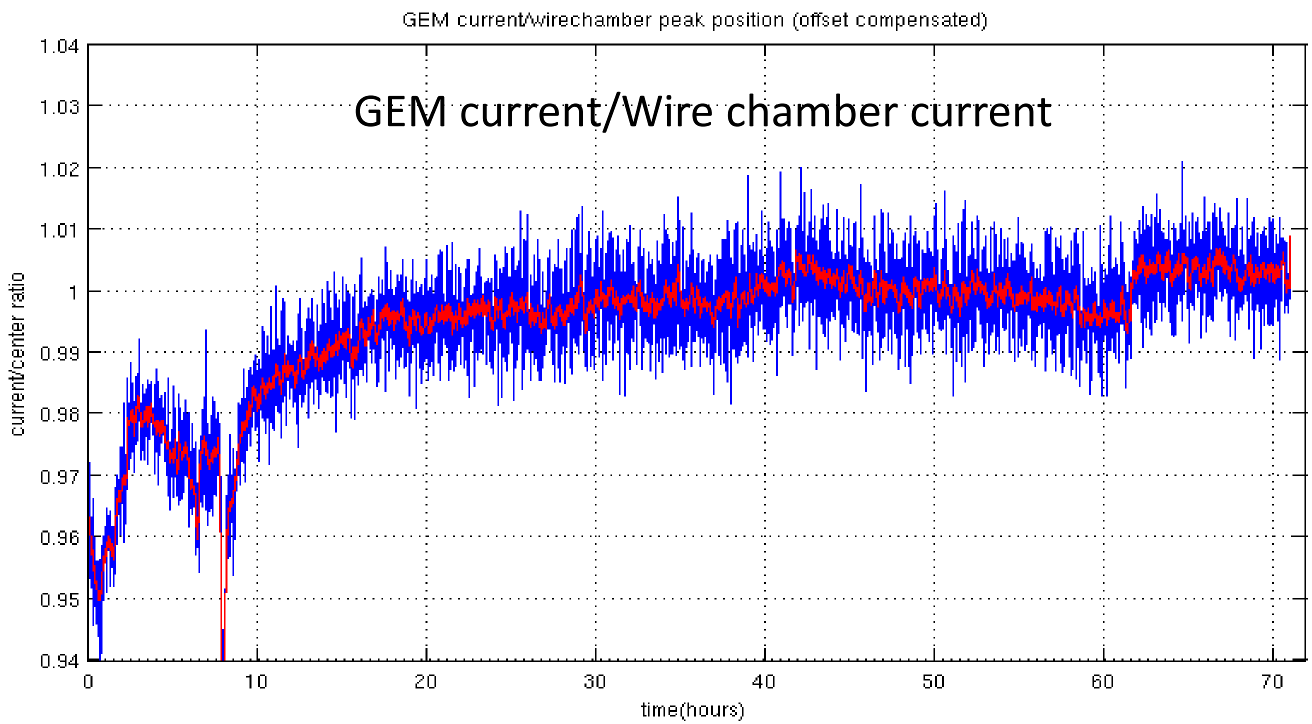


Single wire chamber used as reference



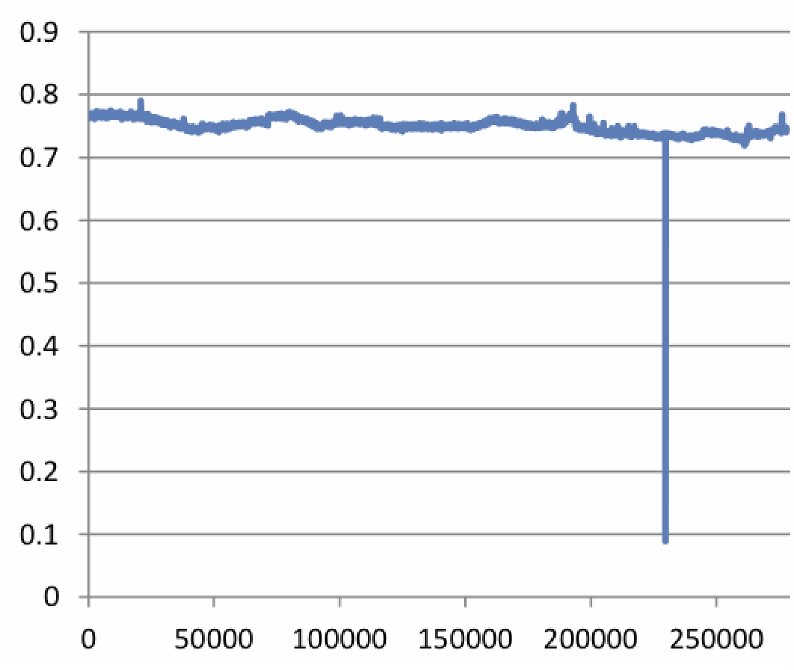
Gain stability

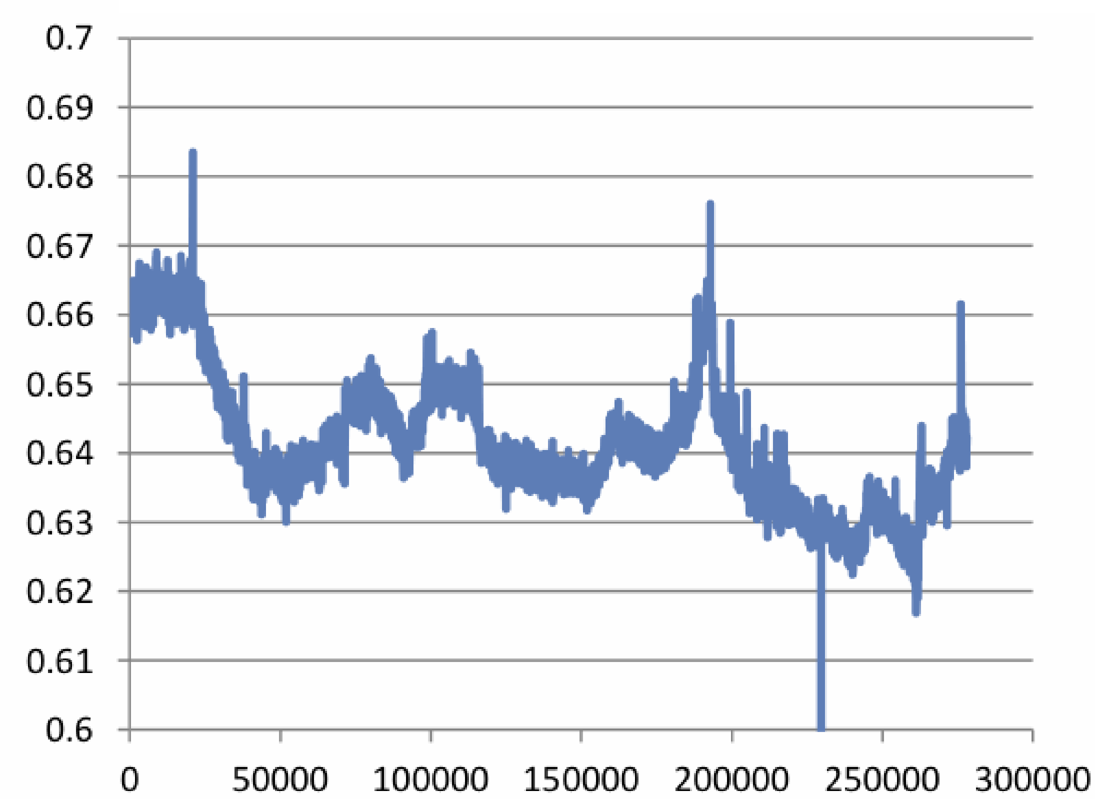
- 2 GEMs (cylindrical holes) in Ar/CO_2(10). Sr^{90} source
  - 4-5% variation of GEM and wire chamber current
    - 4-5% variation was compatible with temperature variation (T=23~24.5).
  - Gain stays stable to within 1% after a few hours
  - Humidity: 56-73 ppm. Gain~900 & current density~1.8nA/cm^2



Gain stability

- Gain~2000 & current density ~ 7nA/cm^2
  - Stability is ~3%
- Next is to measure stability with 3 GEMs under Ne/CO_2

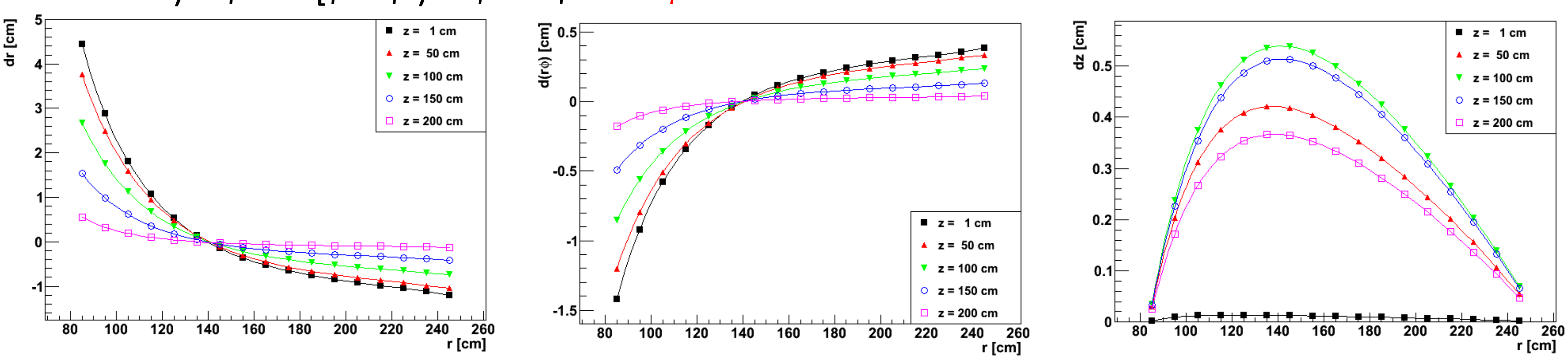




Ion back Flow

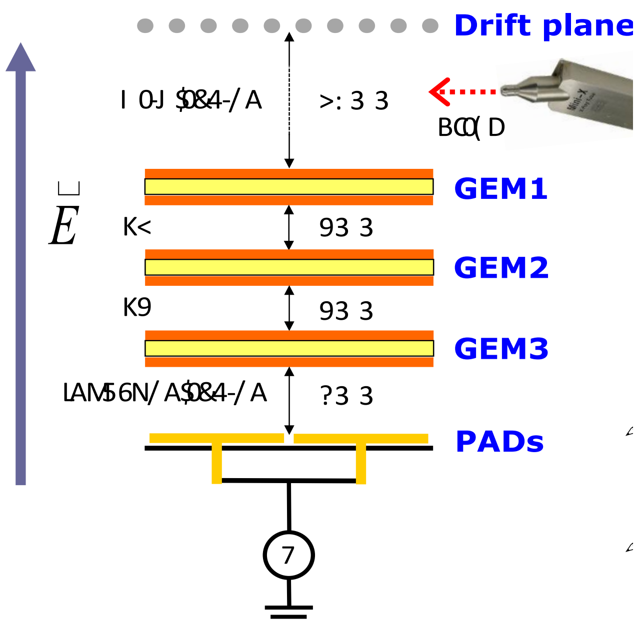
- High rate operation (50kHz), continuous readout (no gating grid), and online calibration/clustering
  - Need to minimize field distortion by back drifting ions
  - Target: IBF ~ 0.25% at gain 1000-2000
- Direction of IBF R&D
  - Use standard GEMs and optimize by asymmetric electric field
  - Use exotic GEMs (Flower GEM, Cobra GEM, MHSP)
  - Simulations to search for optimal solutions

') :>$2333[$=>$D) 7E$a=X $30MZ $

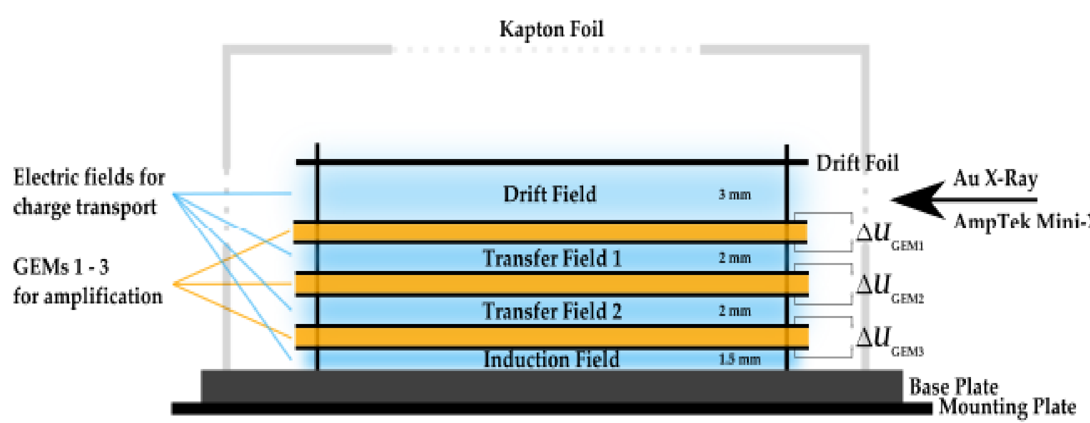


Measurement at CERN/TUM/CNS

- Systematic measurement of IBF
  - Using 3 layers of standard GEMs
  - Rate and gain dependence under various field configurations
- Setup at CERN (RD51-Lab.), TUM, and CNS
  - Various rate of X-ray gun
  - Simultaneous measurement of IBF/energy resolution (TUM/CNS)
  - Readout currents from all electrodes (TUM)

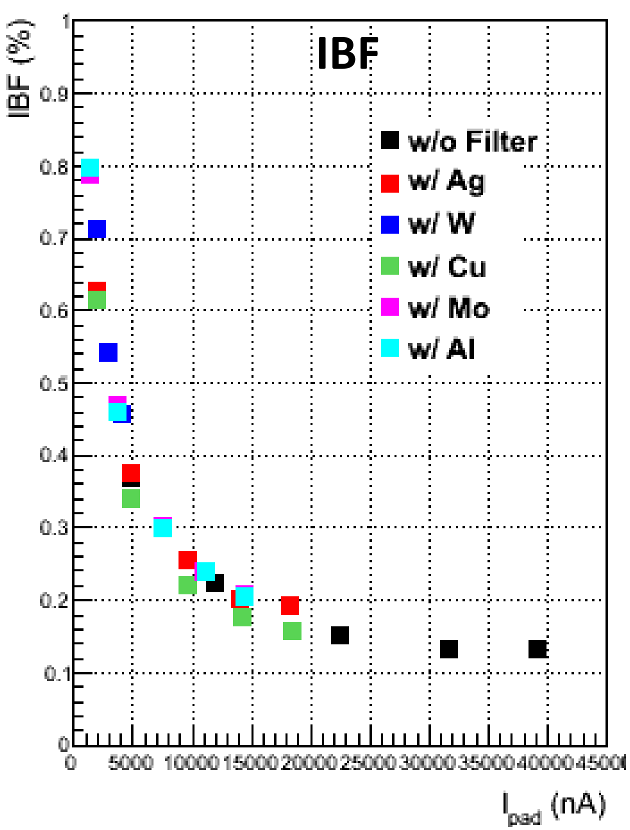


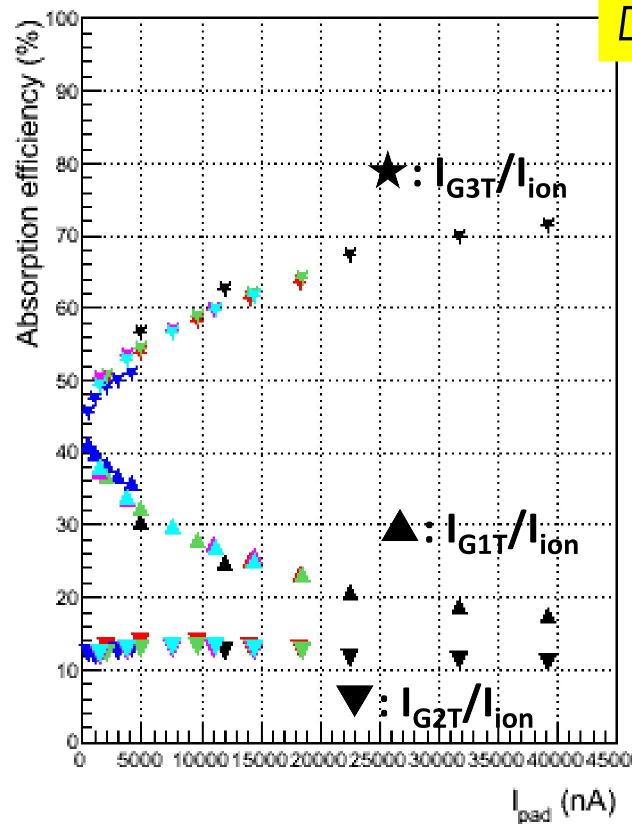
TUM: Technical University Munchen
CNS: Center for Nuclear Study, Univ. of Tokyo



Rate dependence of IBF

- Changing X-ray tube current and absorber filter
  - Covering charge density= 1000-40000nA/(10cm^2)
- Clear rate dependence on IBF (0.1%~1%)
  - Absorption of ions at GEM3 gets larger for higher rate





Due to space charge?

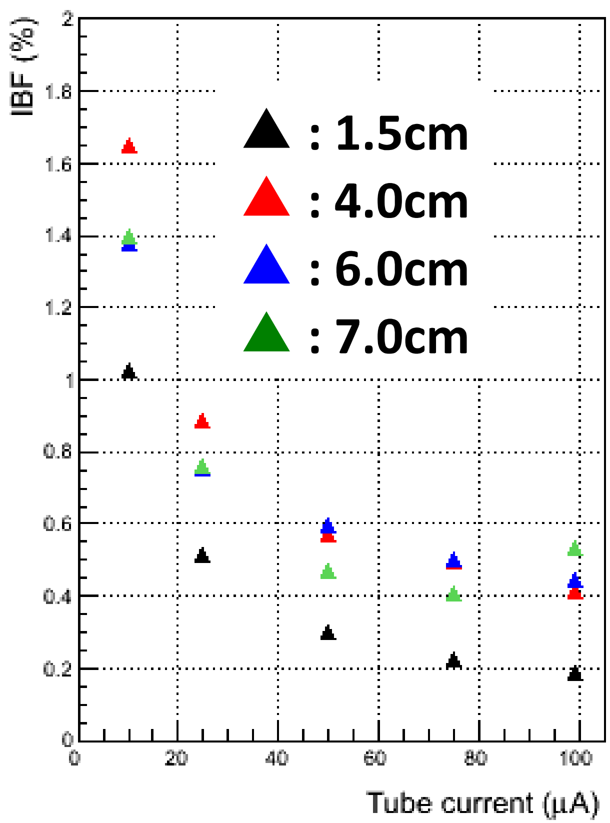
Y. Yamaguchi
C. Garabatos

Ar(70)/CO_2(30)

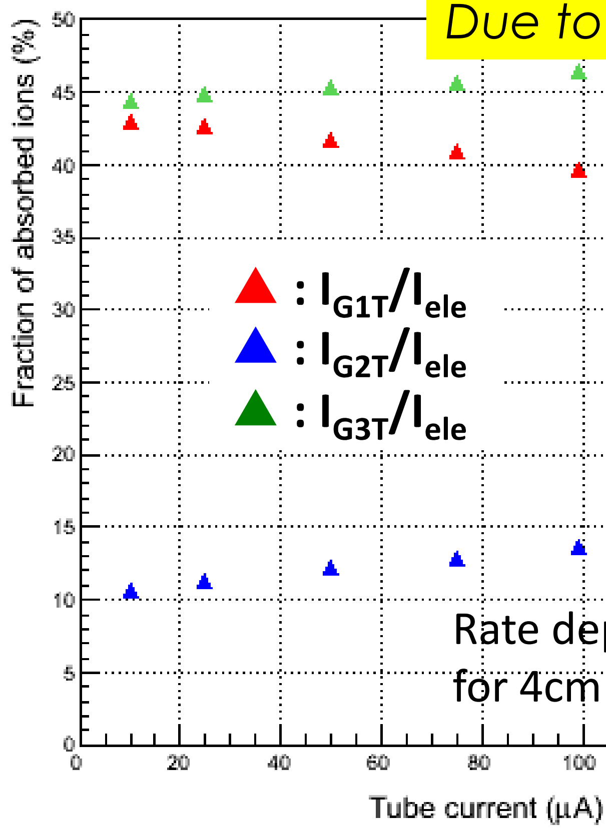
- W#D &U&JVYZ[, 2 &
- W &U&YZ[, 2 &
- W9&U&J\ YZ[, 2 &
- W) &U&YZ[, 2 &
- ZP; &U& P9&U& P<&U&] : Z
- P$1+^9\: : &

X-ray position dependence

- Changing X-ray position from top of GEM1
  - Different local charge density due to diffusion
- IBF gets better for smaller distance between X-ray and GEM1 top (→larger local charge density).



Due to space charge?

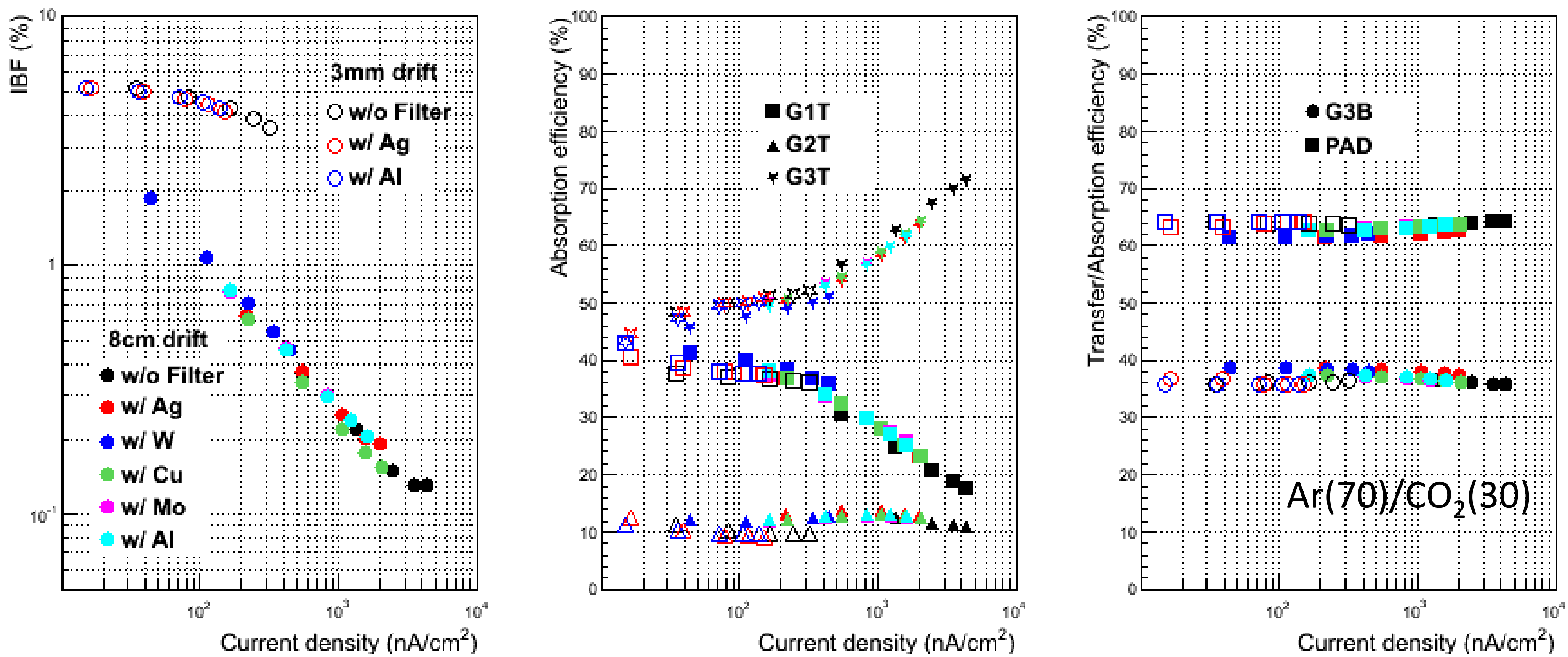


$Ar(70)/CO_2(30)$

Rate dependence for 4cm case

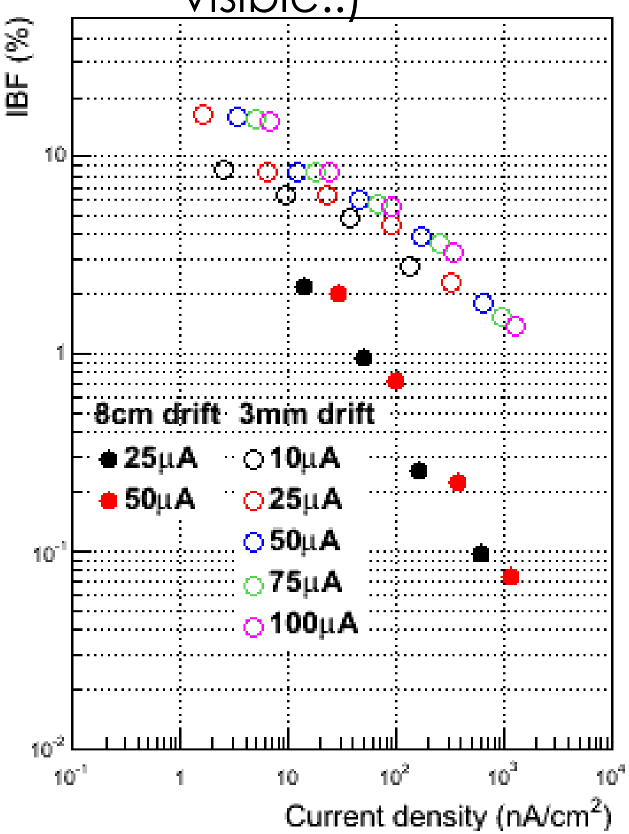
Drift space dependence

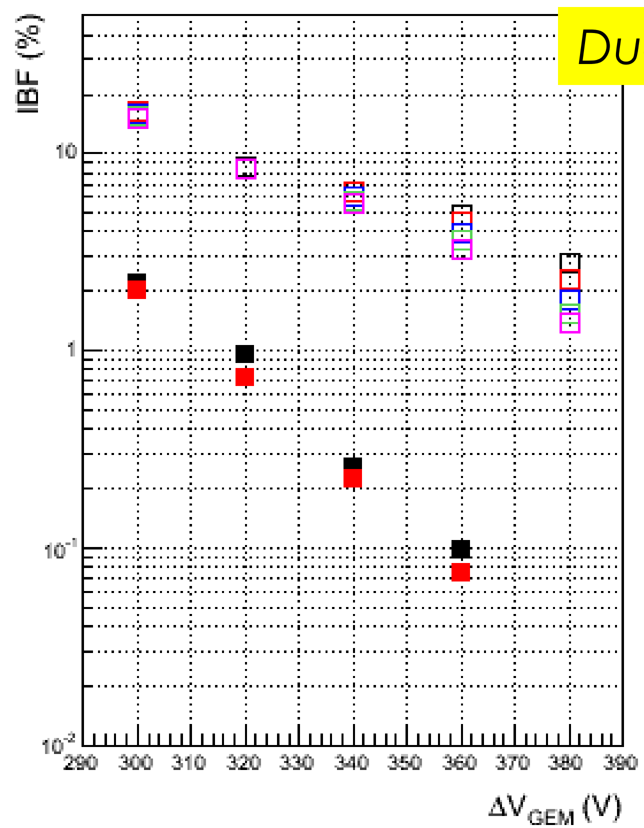
- Changing drift space from 80mm to 3mm.
  - Different interaction rate
- Clear difference in IBF due to different interaction rate.
  - IBF gets better for larger interaction rate.
  - IBF=2~5% for lower rate (not so much dependeing on rate).



V_{GEM} dependence

- V_{GEM} dependence for different drift space
- IBF depends on V_{GEM}.
  - Steeper dependence for 80mm case.
  - (even if rate dependence is small for 3mm, V_{GEM} dependence is visible..)





Due to space charge?

$Ar(70)/CO_2(30)$

- W #D &U& JVYZ [, 2
- W &U& YZ [, 2 &
- W 9 &U& J\ YZ [, 2 &
- W) &U& YZ [, 2 &

Space charge and IBF

- Simulation study by garfield simulation.
  - Presented at the last RD51 meeting on Oct. 2012.

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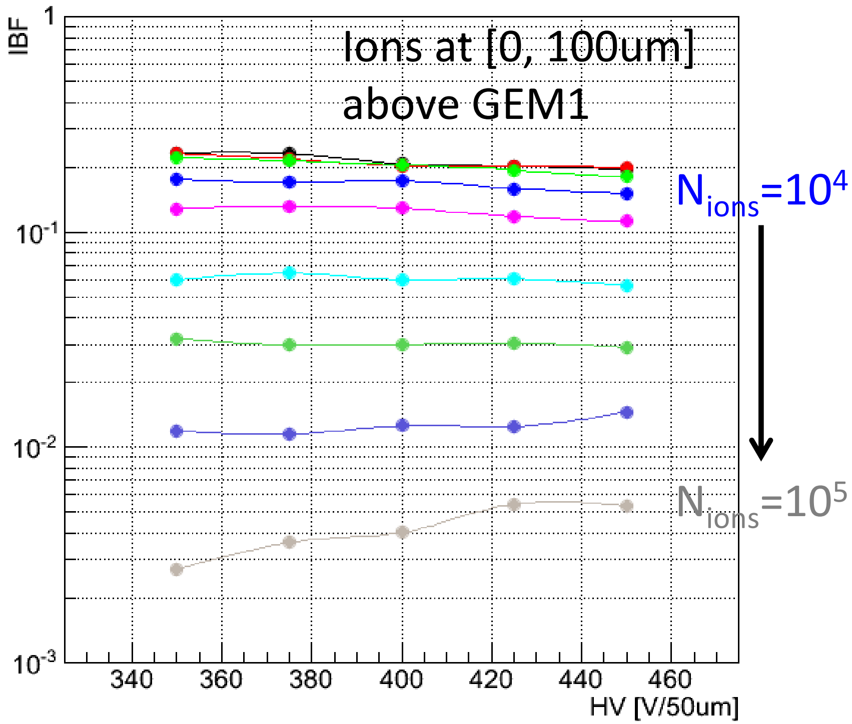
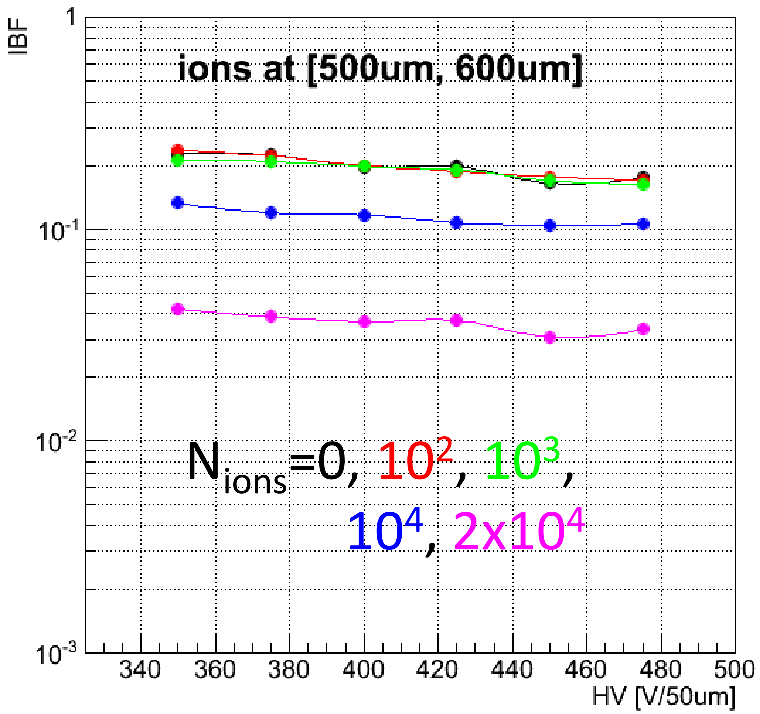
- Put many Ions above GEM1 (Ed=0.4kV/cm)
- IBF strongly depends on N_{ions} (>10^4). Space charge may play an important role for IBF.

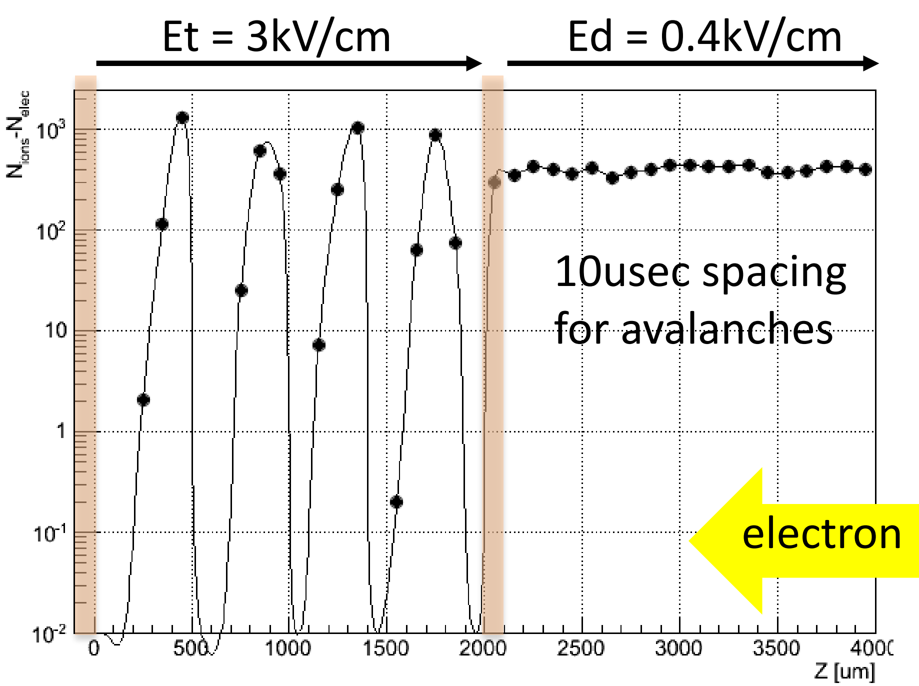


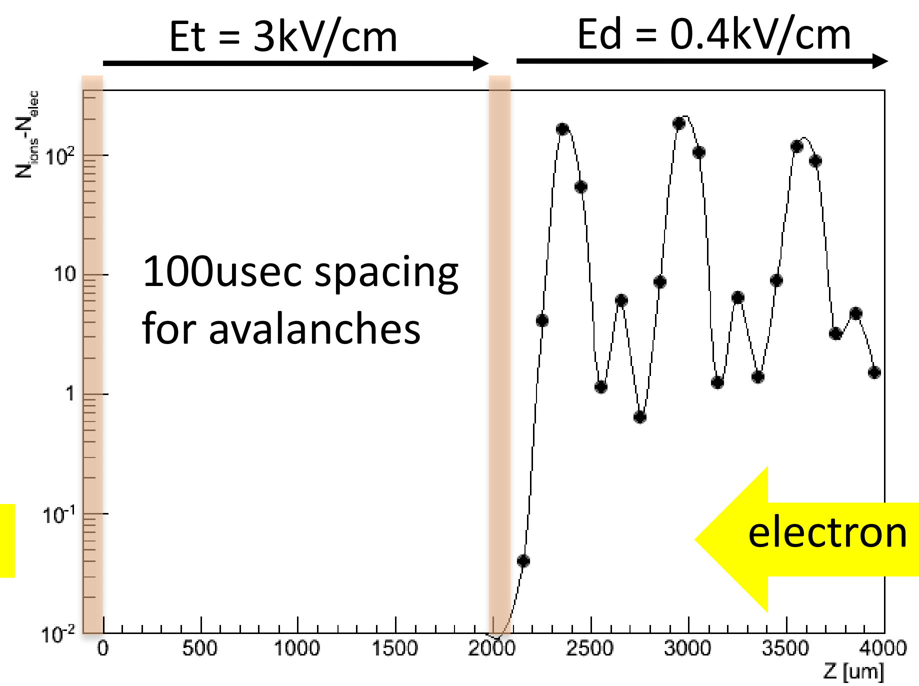


Space charge and IBF

- More dynamical simulations by garfield (2 GEMs).
  - Presented at the last RD51 meeting on Oct. 2012.
- Make spatial profiles of ions created by avalanches for 10usec (100kHz) and 100usec (10kHz) separated seeds.

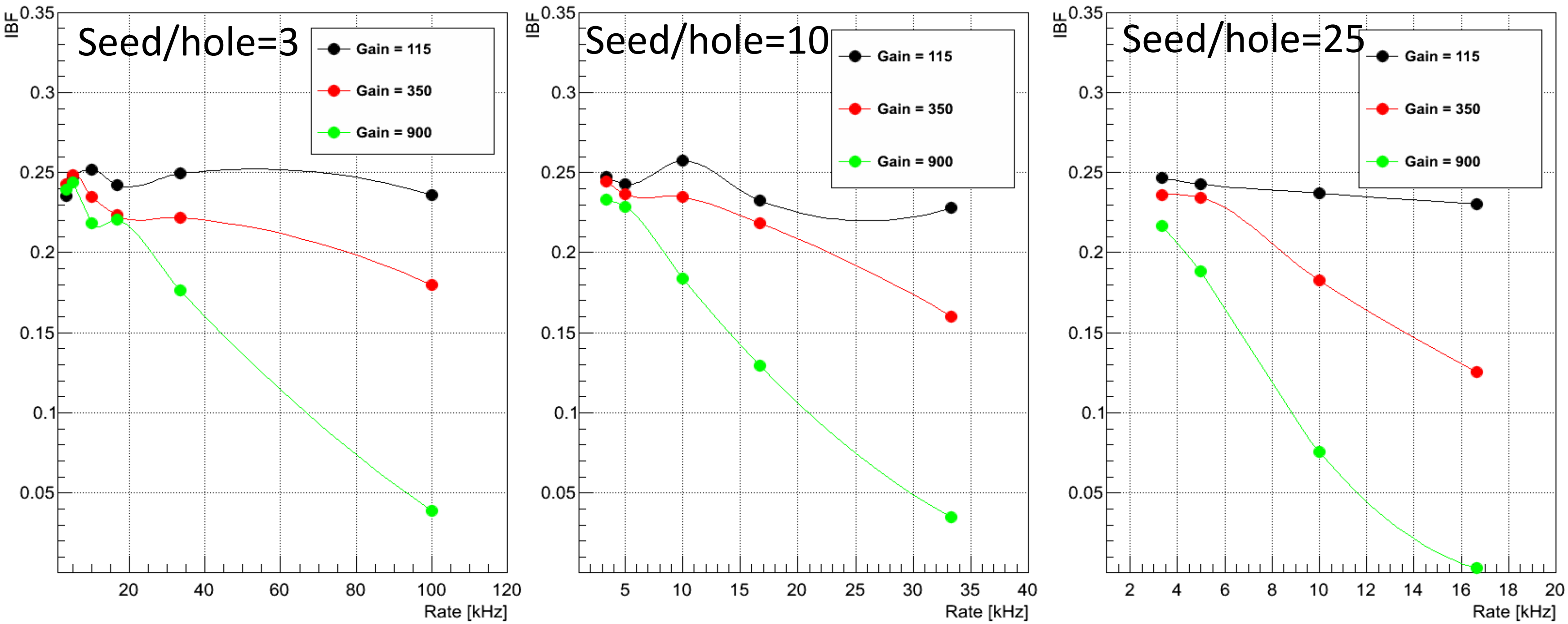
Ion profile per one seed (Ar/CO_2=70/30, Gain~1000)





Space charge and IBF

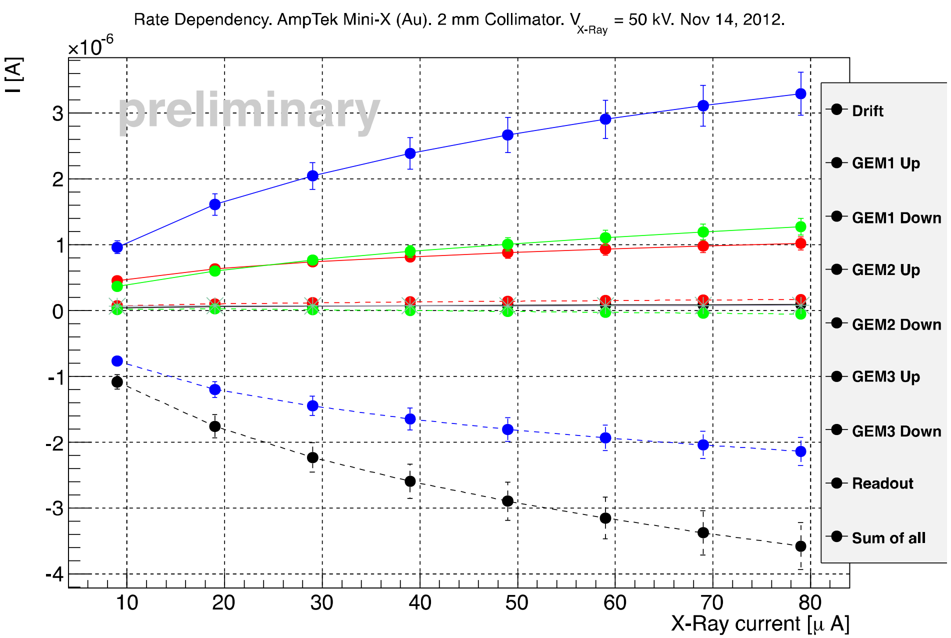
- IBF vs. rate (time separation between 2 coming seeds)
  - Rate/hole=10-50kHz in the lab. and less than 1kHz for LHC Pb-Pb 50kHz collisions
- IBF strongly depends on rate, gain, and # of seeds/hole in case of high rate operations.
  - Qualitatively consistent with the measurements.

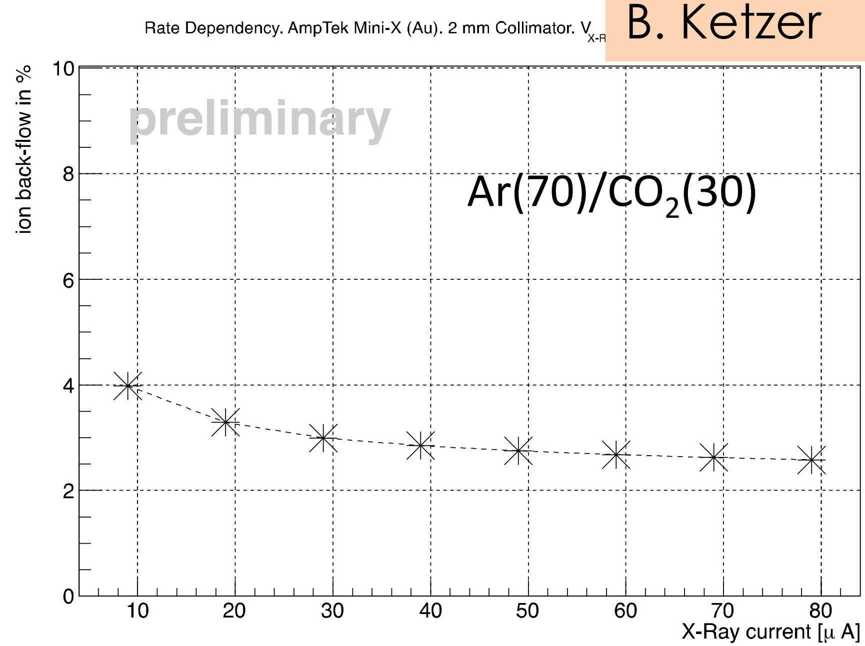


IBF from TUM (lower rate)

- Reading currents from all electrodes.
- 3mm as drift space. X-ray tube with 2mm collimator.
- Pad current ~ 5uA(<< current at CERN measurements.)
- No strong rate dependence (may be due to low rate and less space charge). IBF = 2-4%

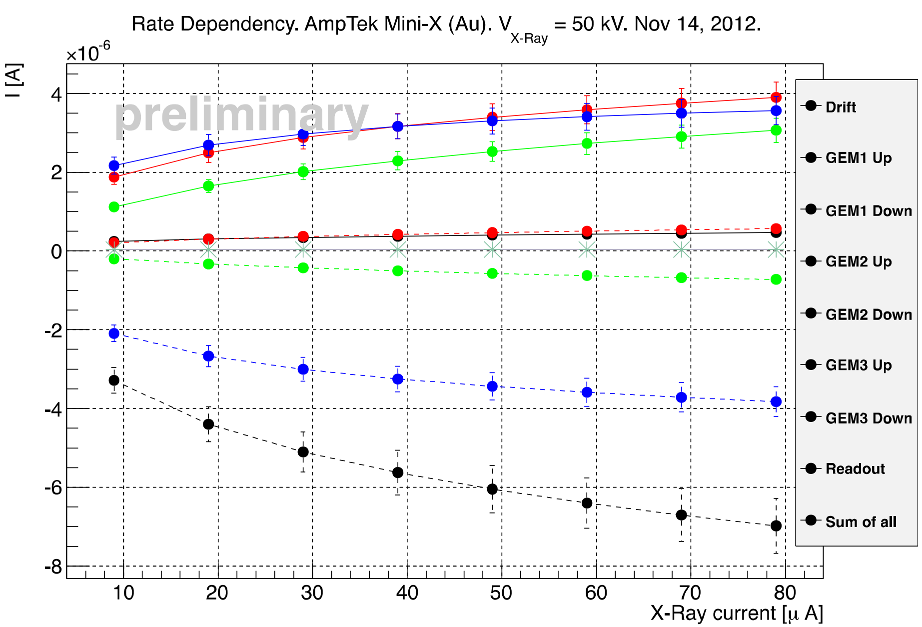
A, Honle
K. Eckstein
M. Ball
S. Dorheim
B. Ketzer

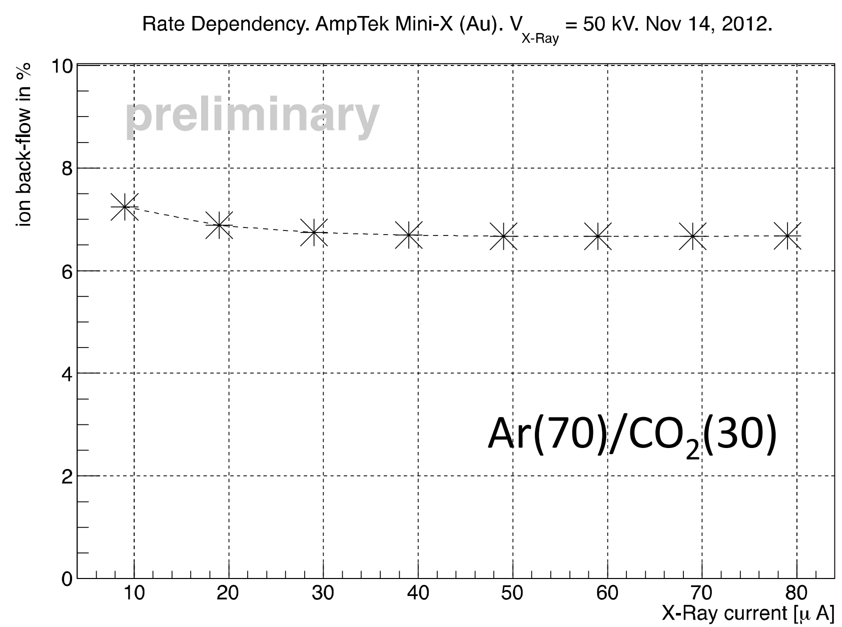




IBF from TUM (lower rate)

- Reading currents from all electrodes.
- 3mm as drift space. No collimator.
- No strong rate dependence (might be due to lower rate, much less space-charge).
- IBF = 7%

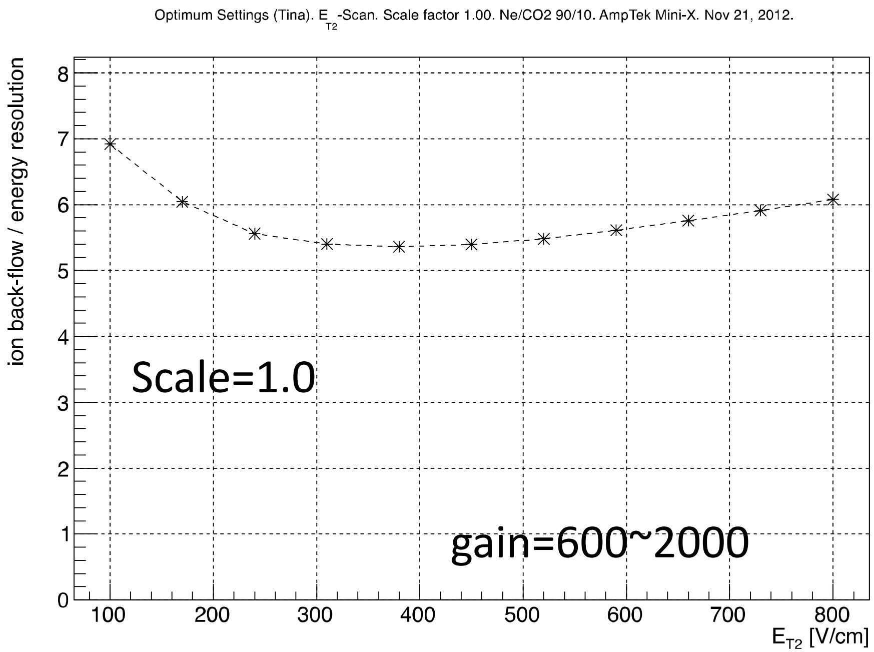


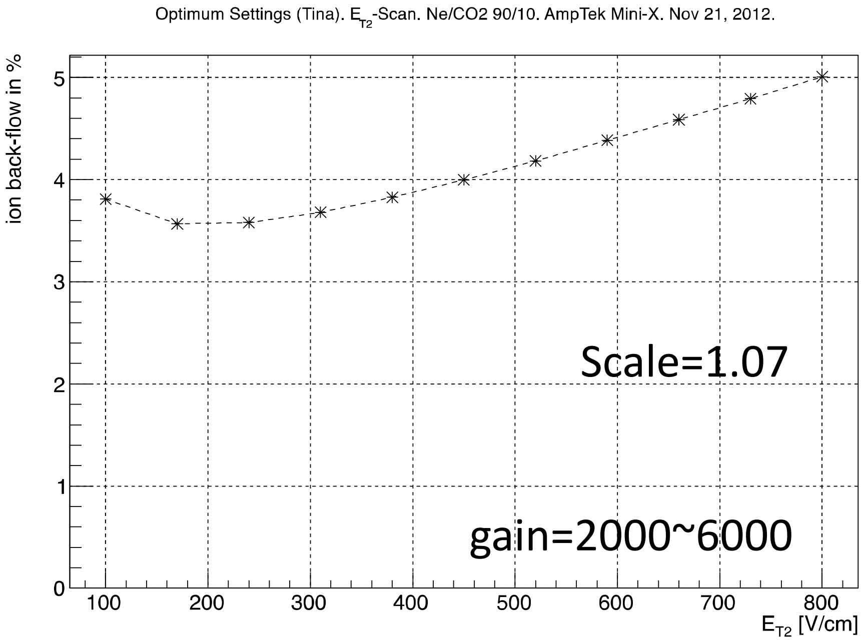


Different field configurations

- Lowering E_{T2} and high E_{T1}
  - 0.8% of IBF in Ar/CO_2 with E_{T2}=0.16kV/cm and E_{T1} = 6kV/cm (E_d=0.25kV/cm)
- IBF=3-5% for Ne/CO_2
  - E_{T1} cannot be so high.
    - Adding N_2 to achieve high E_{T1}?

GEM voltage settings		*Detector field settings*	
GEM1	225 V	E_{Drift}	$0.4\,\mathrm{kV\,cm^{-1}}$
GEM2	235 V	E_{T1}	$3.8\,\mathrm{kV\,cm^{-1}}$
GEM3	285 V	E_{T2}	$0.1\ldots0.8\,\mathrm{kV\,cm^{-1}}$
		E_{Ind}	$3.8\,\mathrm{kV\,cm^{-1}}$





IBF for various GEM configurations

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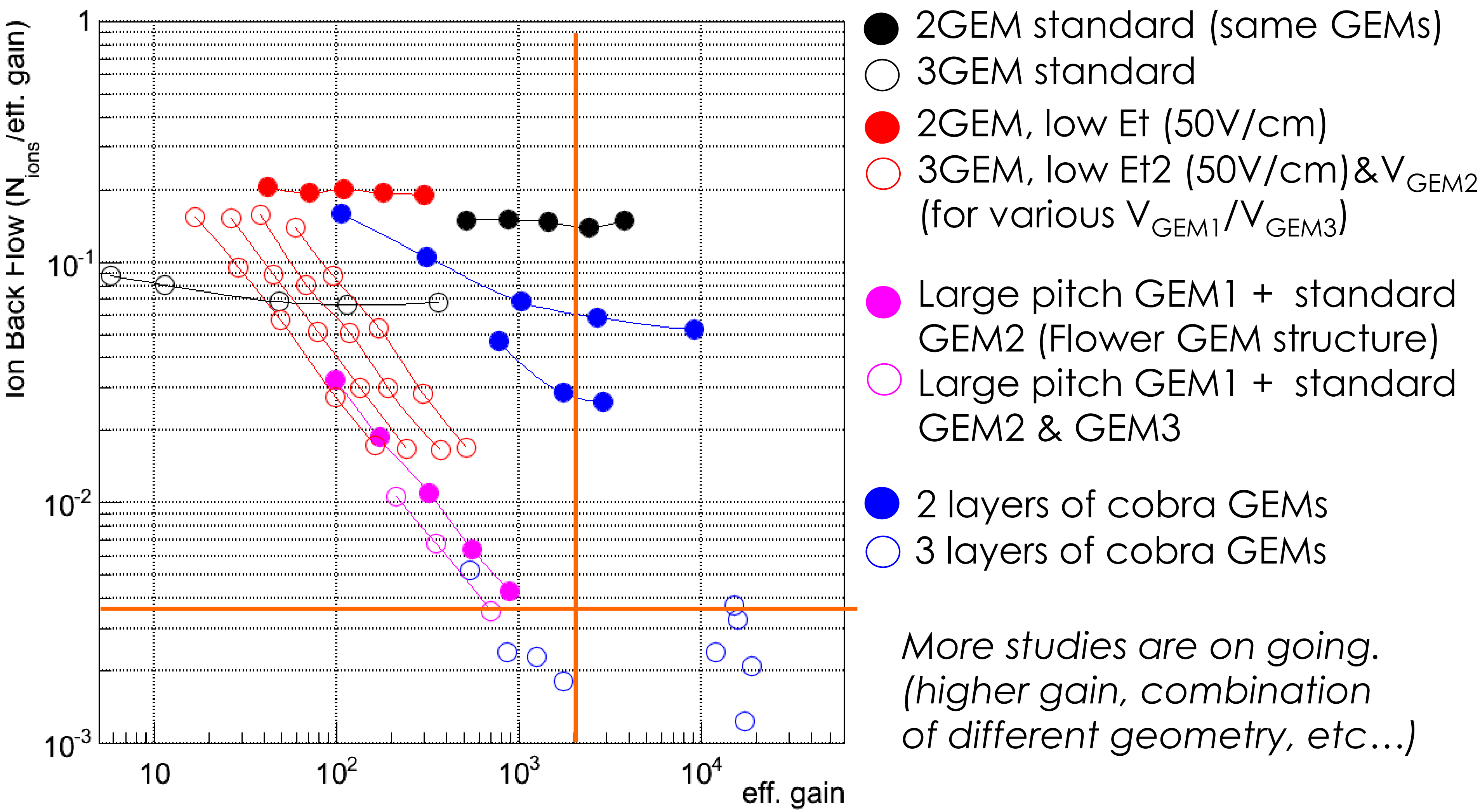
- Search for optimal solutions for IBF by simulations



More studies are on going. (higher gain, combination of different geometry, etc…)

Summary and Outlook

- R&D of gain stability and ion back flow are on-going.
- Gain stability <3% (2 GEMs, higher gain and rate)
  - Stability of 3 GEMs will be studied under Ne/CO_2.
- IBF depends on rate of X-ray, spread of seed electrons (diffusion), and gain of GEM under high rate conditions.
  - Space charge plays an important role for IBF under high rate.
  - This is (partially) confirmed by garfield simulations.
- Under low rate, IBF is 2-5% with 3 standard GEMs.
- Try to reduce IBF further:
  - More study on asymmetric field configurations
  - Use standard GEMs with different geometry (hole size, pitch)
  - Use exotic GEMs (Thick COBRA GEM, Flower GEM)
- Simulation studies are on-going.

Backup slides

R&D of gain stability