Some possible EIC barrel tracking options and R&D efforts (for the discussion and critics)

N. Smirnov
Physics Department, Yale University
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- It was discussed and stressed that there are problems with the option "TPC at EIC".

- First of all there is no “TPC team”, and only hope is a “second detector” option with additionally guy’s participation.

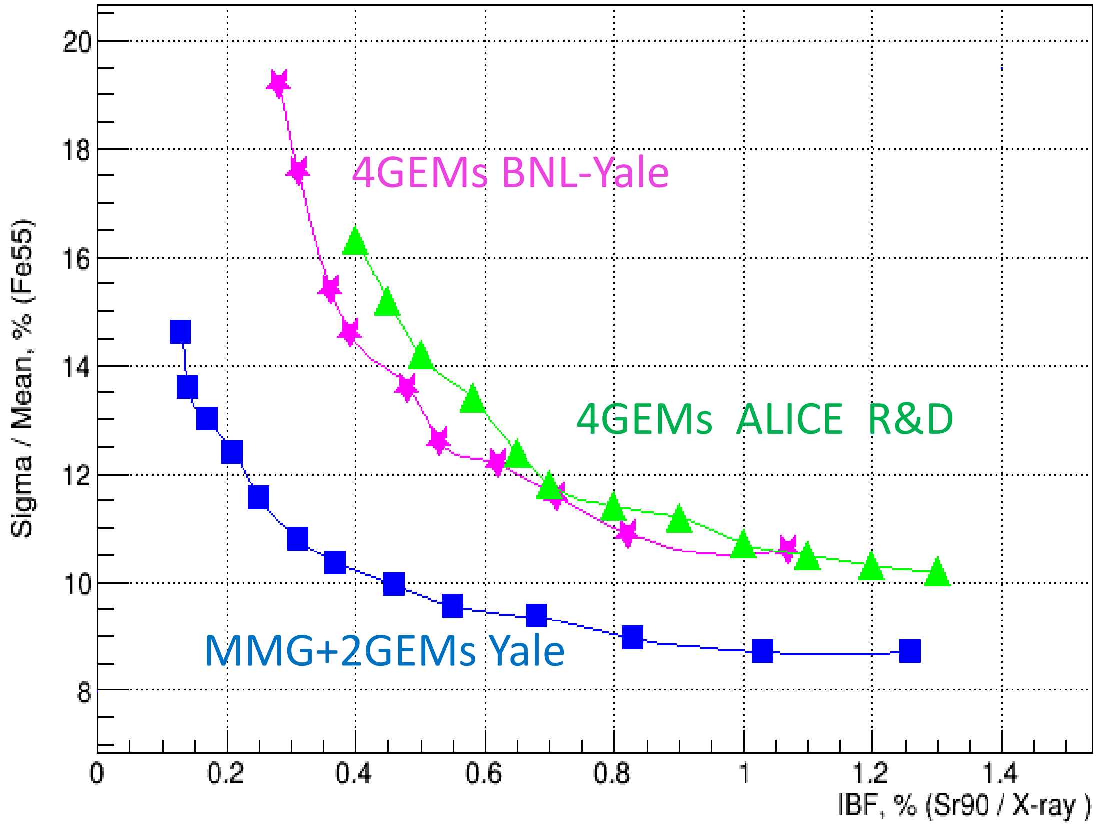
- Demands for EIC TPC parameters are good known: fast electron and ion drift speed, low transvers diffusion and minimize IBF with good energy resolution.

- It means:
  - Gas mixture with Ne+CF4, but as small as possible CF4 percentage in a gas mixture to minimize “F – problem”.
  - 4 GEMs setup does not good enough (special sPHENIX approach).
  - Solution: MMG + 2 GEMs and Ne+CF4(10%)+CH4(10%). It allows to get IBF ~0.2% with E-resolution ~12%. Additionally it much more robust from the stability point of view.
  - See R&D and GARFIELD results (next 3 pages).

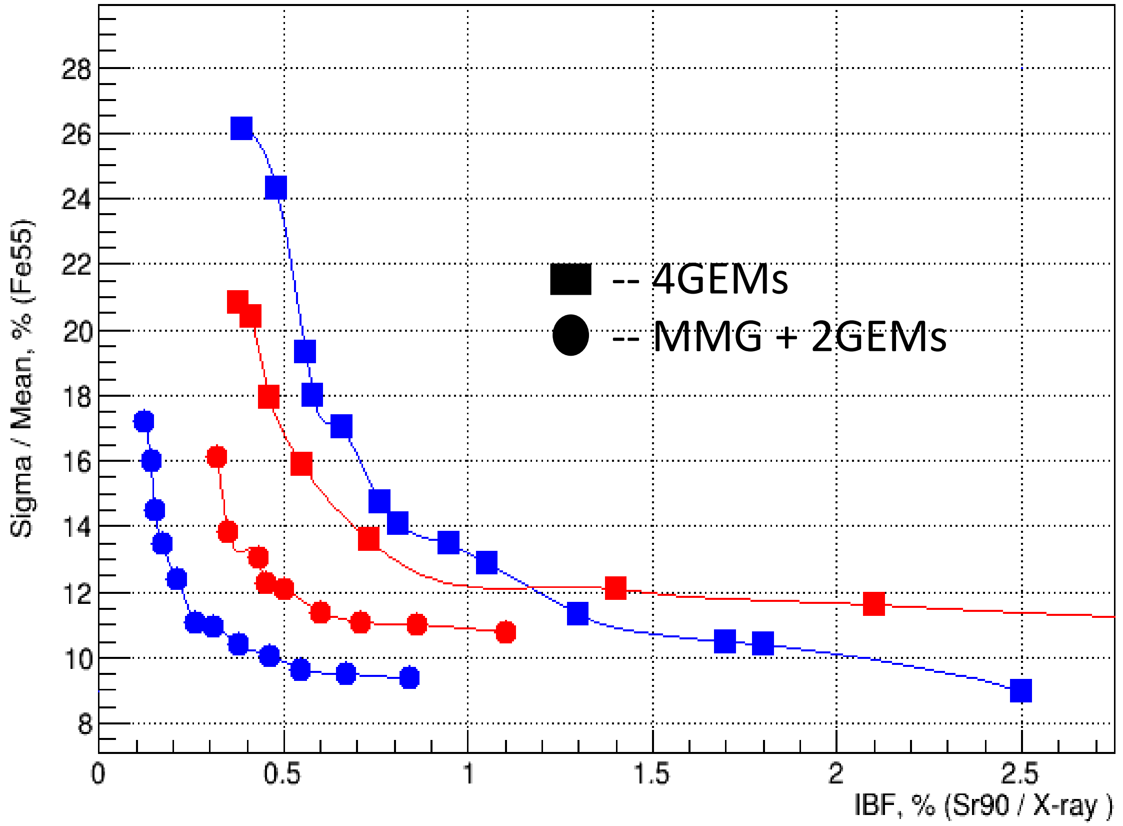
- Selected these options for Gas mixture and read-out, and with the Gain ~ 2000 it is possible to minimize space charge distortions and to get space resolution parameters that are very close to values using in today TPC simulation, and needed dE/dX performance. We are going to demonstrate such results as only the test beam activities can be a reality.

Some examples to compare 4GEMs and MMG+2GEMs setups performance

Ne (90) + CO2(10) + N2(5)



P10 + CF4(10%), Ne+CF4(105)+CH4(10%)

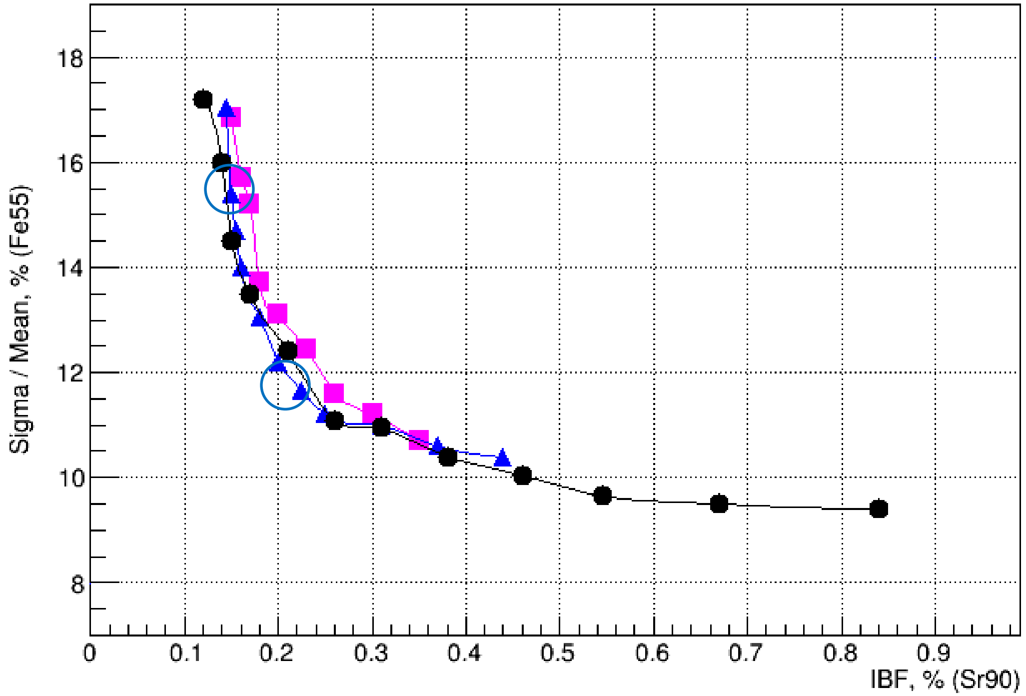


More results can be found: NIM A 834 (2016) 149

TPC R&D, MMG+2GEMs. Ne+CH4(10%)+CF4(10%) More details.

E drift – 0.4 kV/cm, E transfer – 2.0 kV/cm, E induction – 0.075 kV/cm, Gain ~ 2000.

GARFIELD: E-field: 0.4 kV/cm, B-field: 1.5T. Electron drift speed: 8.2 cm/μs , Transverse Diffusion : 58 μm/√cm.



Black: new data with different setup (no R-protection)

For two selected voltages ◯ V MMG: 450 and 480 V "stability" test was done :
Anode current : 10 nA/cm^2, 7 hours, no sparks

Using setup with R-protection the MMG mesh HV PS reaction on MMG sparks were tested
(Am^{241} source, V mesh ~ 670 V, C10 gas mixture).
In a case of spark (rate ~1/20s) HV drops ~ 0.4 V , recovery time ~ 600 μs (including oscilloscope capacitance)

But there is another, very unpleasant special for EIC problem – a lot of material in end cap position. It was stressed many times – the mail “goal” of EIC project is to measure electron (after collision) with the best possible precision both from Energy and tracking (angles and moment) points of view.

So, the “dead materials installation” on the electron “track” for pseudo-rapidity < -1. is not the mistake, it is a “criminal” step.

There are three options (my opinion) to solve this problem for small size TPC.

1. Use so-called Si – readout. One example was demonstrated by ILC team – TimePix with ~ 50x50 μm2 readout pixel and with 3 GEMs or Ingrid gas gain options. It is “sensitive” to primary ionization electrons – the best possible dE/dX performance, a “huge” number of hits, but data flow and cost questions. For EIC events (a few particle per interaction) the data flow can’t be a problem with zero suppression (?).

2. The same idea – but readout pad ~ 1x7 mm2 and electronics in the same Si wafer (different one to be sensitive to charge), and additional like CCD step to transfer charge from “big size” pad to “small” one (minimize the noise), plus one-two GEMs for low but gas gain and minimize small but IBF. Such option was discussed with Leo G. some time ago, and (if I am not mistaken) first initial steps were done at Berkeley Lab.

3. Consider not “standard” TPC – Cathode in a center, but two TPCs with readout in a center (pseudo – rapidity ~0). See slide with cartoons.

Yes, two TPCs option looks ugly, but it is the only way to keep TPC on the "list".
The specifics of EIC TPC (small size, high space resolution) "needs" at least factor two more material end cap density (in a comparison with previous ones) because small pad size --> more electronics --> more cooling and cables. Additionally sPHENIX selected (for some reason) small foil size --> more support ribs.

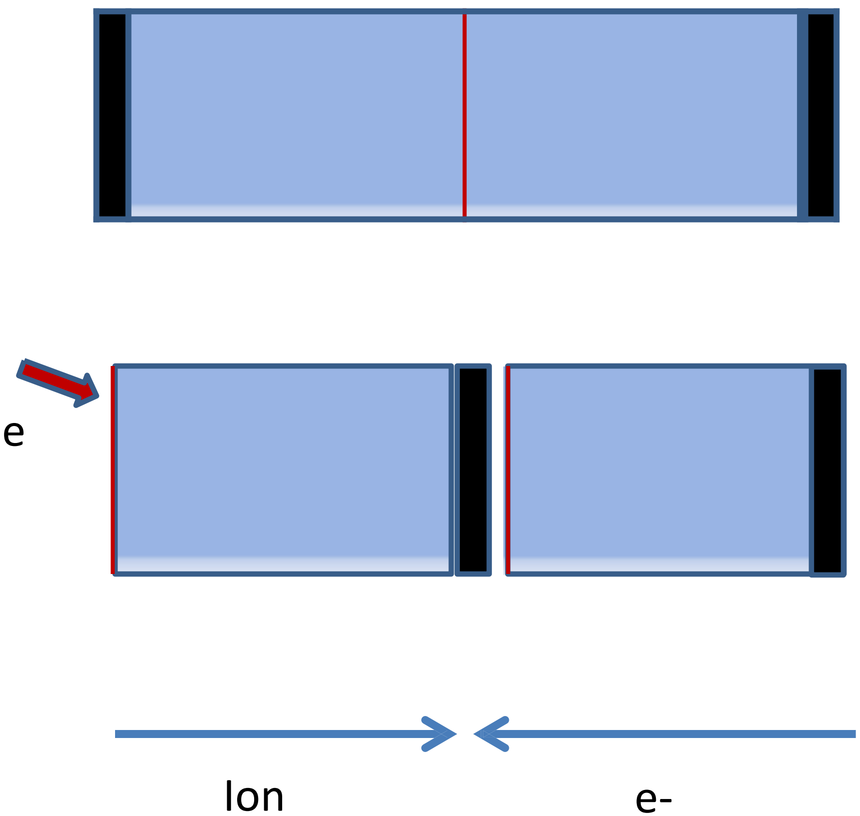
So, there is no good way for electrons to come through. But it is the "main electron direction" for EIC physics. The "dead gap" for pseudo rapidity ~0 "destroy" nothing from any EIC Physics point of view (!?).

How to use TPC but minimize material thickness for η < -1.

Gain and Read-Out structures including support stuff (“ribs”), FEEs, Cooling, Cables, Laser, …

Standard TPC

Gas barrier and Cathode



Two TPCs. Dramatically minimizes material thickness for η < -1.

But – the “rapidity hole” in an acceptance (close to η=0.)

It should not “organize” problem for any eA Physics (but – jets).

For all cables, cooling pipes, Laser fibers can be used the same position as TPC support structure.

May be there is a sense to check both option in a realistic simulation

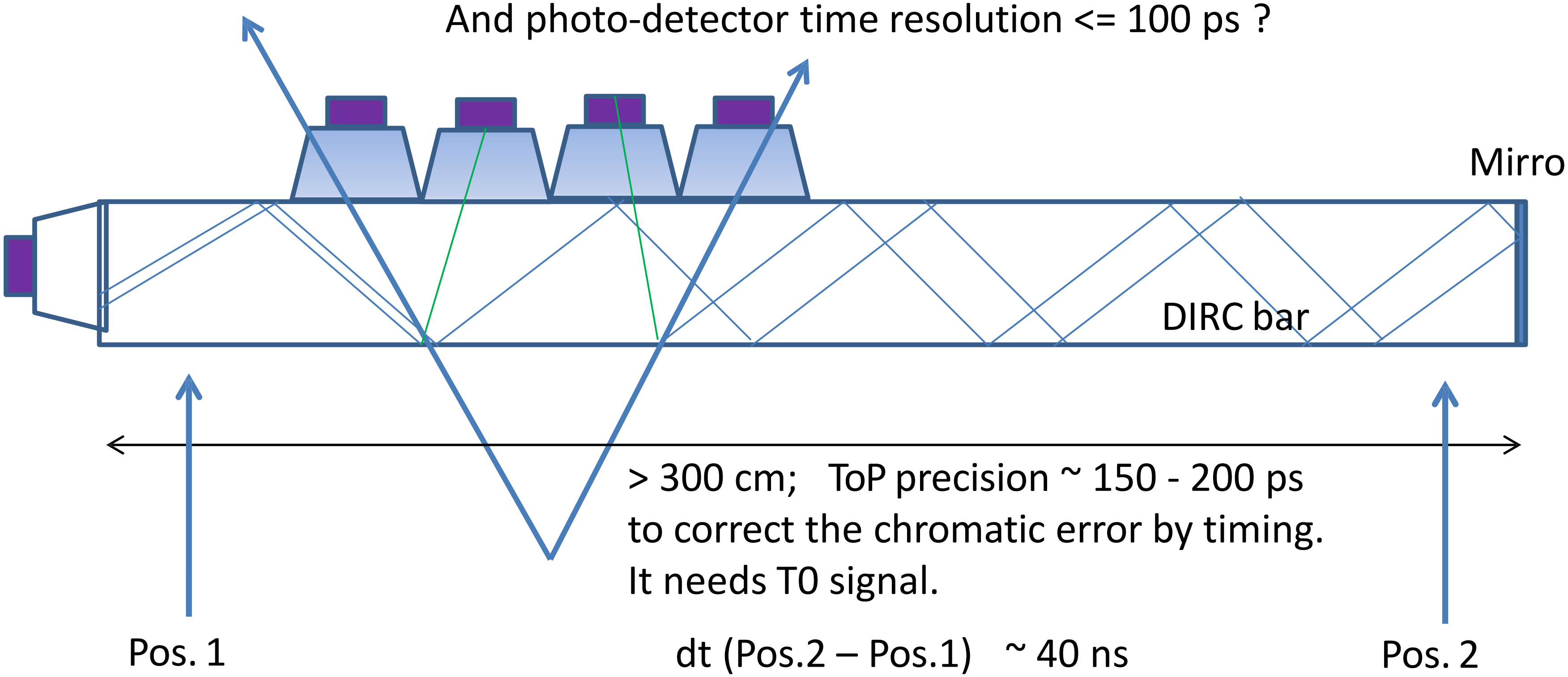
Alternative tracking option (no TPC(s) and not Si-only)
Relay on "high rate" but "low occupancy"

- The same Si-vertex setup
- Plus one (two) more Si-layer(s). Position in R should be selected in a simulation to "cover" very low momentum particle tracks finding and reconstruction.
- 6 layers MPGDs; Cylindrical shape (?), strip readout (Rϕ). 1-2 and 3-4 (in R) – in the same gas volume, reasonable close, with different (in R) drift directions (Lorentz angle), and with small strip stereo angle. {MMG detectors are practical ready for pre-production prototype construction}
- 6^{th} layer (in a front of DIRC) - in a mini Drift option to reconstruct track in a "space", and "provide" RZ coordinates for track finding and momentum reconstruction (together with Si data). It needs additional R&D to optimize the performance.
- For tracks with $|\eta| > 1.$ forward tracking detectors data should be used to combine with 2-5 hits from a barrel setup.
- "Strong" arguments should be to consider a high precision tracking detector behind DIRC (in R): competition in space with ToF detector for PiD. But there is an option – "gas PS detectors". It needs a lot of R&D, and "special" electronics.

DIRC (barrel) & ToF for PiD < 1 GeV/c particles. L > 100 cm

"DIRC looses a lot of lights": J. Va'vra

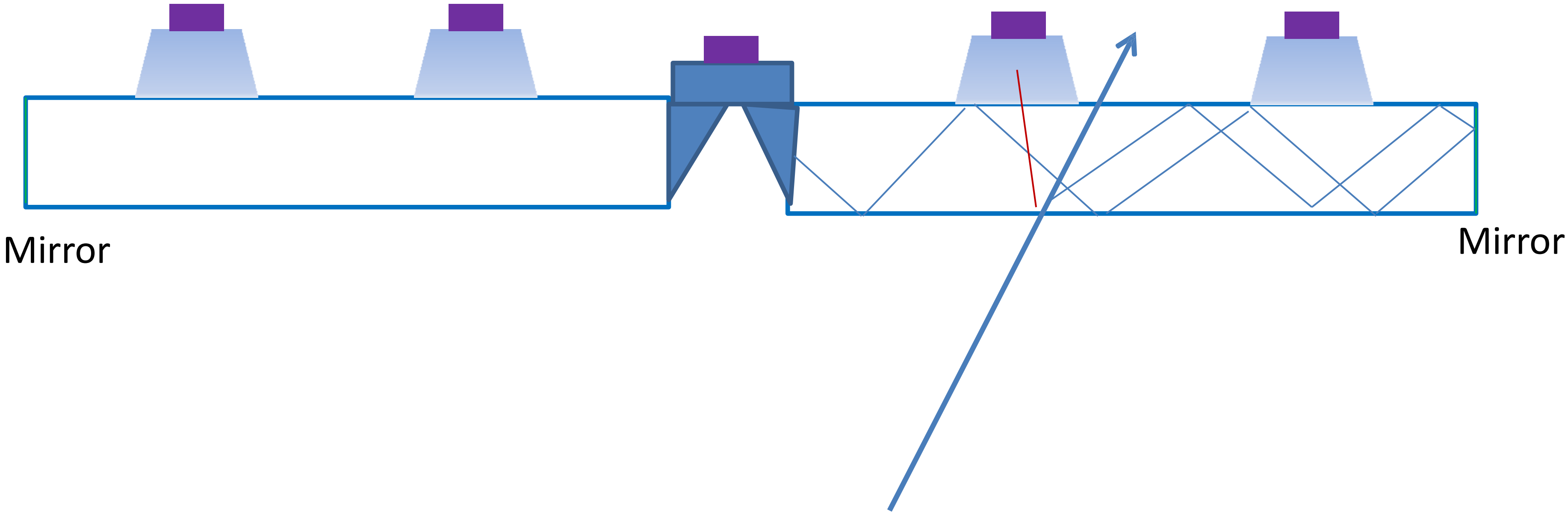
Light guides, focusing, lens (no optical contact to bar):~ 10 x 20-30 cm2 ?
And photo-detector time resolution <= 100 ps ?



> 300 cm; ToP precision ~ 150 - 200 ps
to correct the chromatic error by timing.
It needs T0 signal.

dt (Pos.2 – Pos.1) ~ 40 ns

May be two DIRC bars !?



To “solve” space problem EMC <-> DIRC, and twice faster response
But (of course) experts opinion is crucial