eRD21 Progress Report: EIC Background Studies and the Impact on the IR

JLab:

- Latifa Elouadrhiri
- Yulia Furletova
- Vasiliy Morozov
- Marci Stutzman
- Mark Wiseman
- Pavel Degtiarenko

BNL

- Alexander Kiselev
- Christoph Montag

ODU

- Charles Hyde
- Christine Ploen
- PostDoc Feb'19

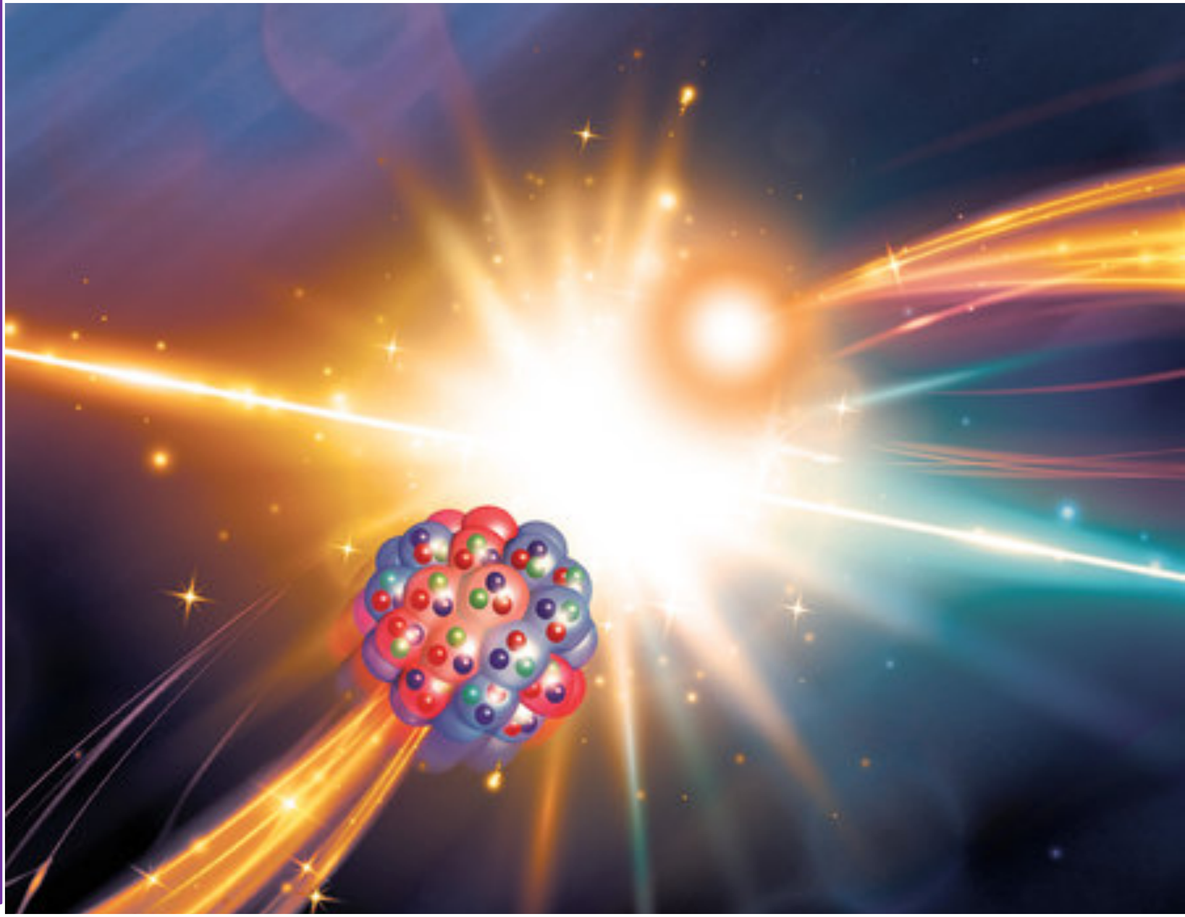
UConn

- Nikolay Markov

SLAC

- Mike Sullivan

eRD21 partial support



Generic Detector R&D for an EIC Meeting

25 Jan 2019

Activities

- Synchrotron Radiation studies from electron FFQ (Mike Sullivan)
  - Flux calculated for JLEIC66
  - Beam Pipe, Mask, updated
- Beam Gas interactions (Ion Beam)
  - Benchmarked to HERA (C. Ploen, N. Martov,)
- Realistic Vacuum profiles (M. Stutzman: JLEIC)
- Updated IR Design for JLEIC @ $\sqrt{s} = 100$ GeV (V. Morozov)
  - New Beam⊗Gas background studies in preparation (Y.Furletova, C.Ploen)
- Neutron Flux (A. Kiselev)

Synchrotron Radiation

- Radiation from electron quads
  - SLAC codes SYNC_BKG and MASKING
    - Semi Analytic, fast
  - GEANT4
    - Full Propagation, slow
- Benchmarking done

Second half of FY2019:

- Software Integration (ODU Post-doc, Y. Furletova, N. Markov, C. Ploen …)
  - Use output from SYNC_BKG and MASKING in GEMC (& other detector simulations) and propagate photons through beam pipe and detector
  - Generate detector hits, especially Central Vertex Tracker
- Beam Tail study at High Luminosity
- Synchrotron induced outgassing impact on IP vacuum (M. Stutzman, M. Sullivan)

Beam tail distributions

- The recent experience of the superKEKB accelerator and the Belle II detector argue that beam tails distributions have become and will become much more important in new high current accelerators
- The upcoming high-current designs for colliders rely on continuous electron injection in order have a very low stored beam lifetime (~10 min)
- This means the beam tail (or beam halo) distribution can be quite high and therefore generate more detector background from both SR and from lost beam particles
- This is the current ongoing study

The tails in the plots here are the ones Sullivan has been using for synchrotron radiation background calculations

Beam Tails

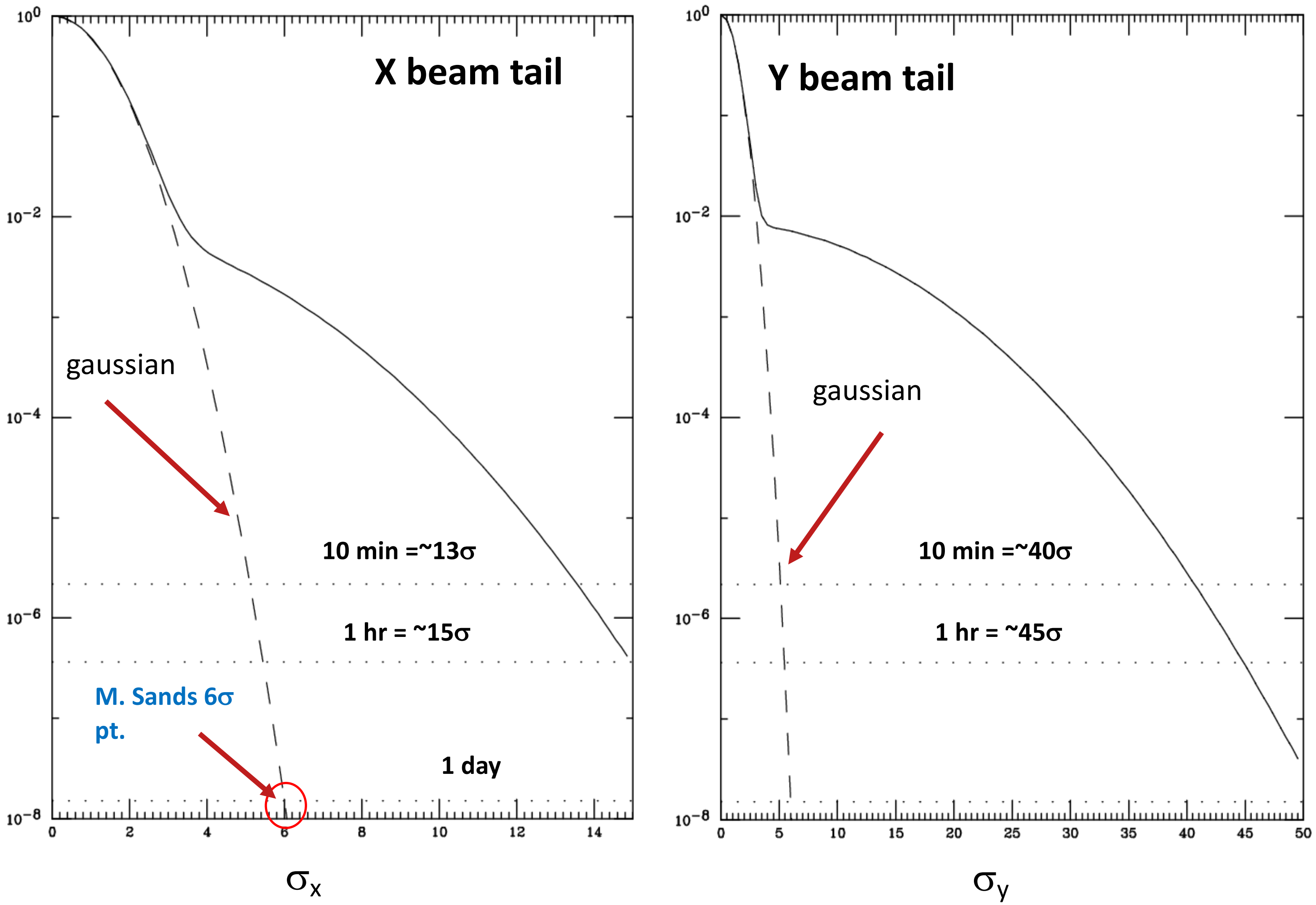
The background distribution is a 2nd lower and wider gaussian

$$e^{-\left(\frac{x^2}{2\sigma^2}\right)} + ae^{-\left(\frac{b^2x^2}{2\sigma^2}\right)}$$

Where $a = 8.5\times10^{-3}$ and
b = 0.3 for x and
0.1 for y

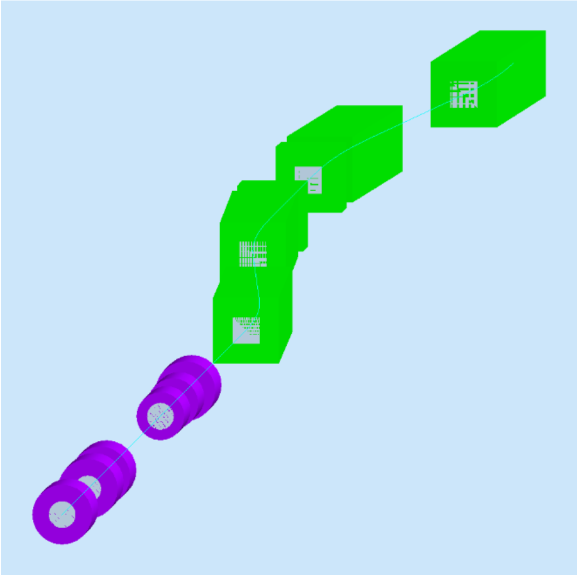
The integral of the background distribution is about 0.3% of the total.

This might be on the low side especially for a new accelerator.



Ion Beam ⊗ Residual Gas

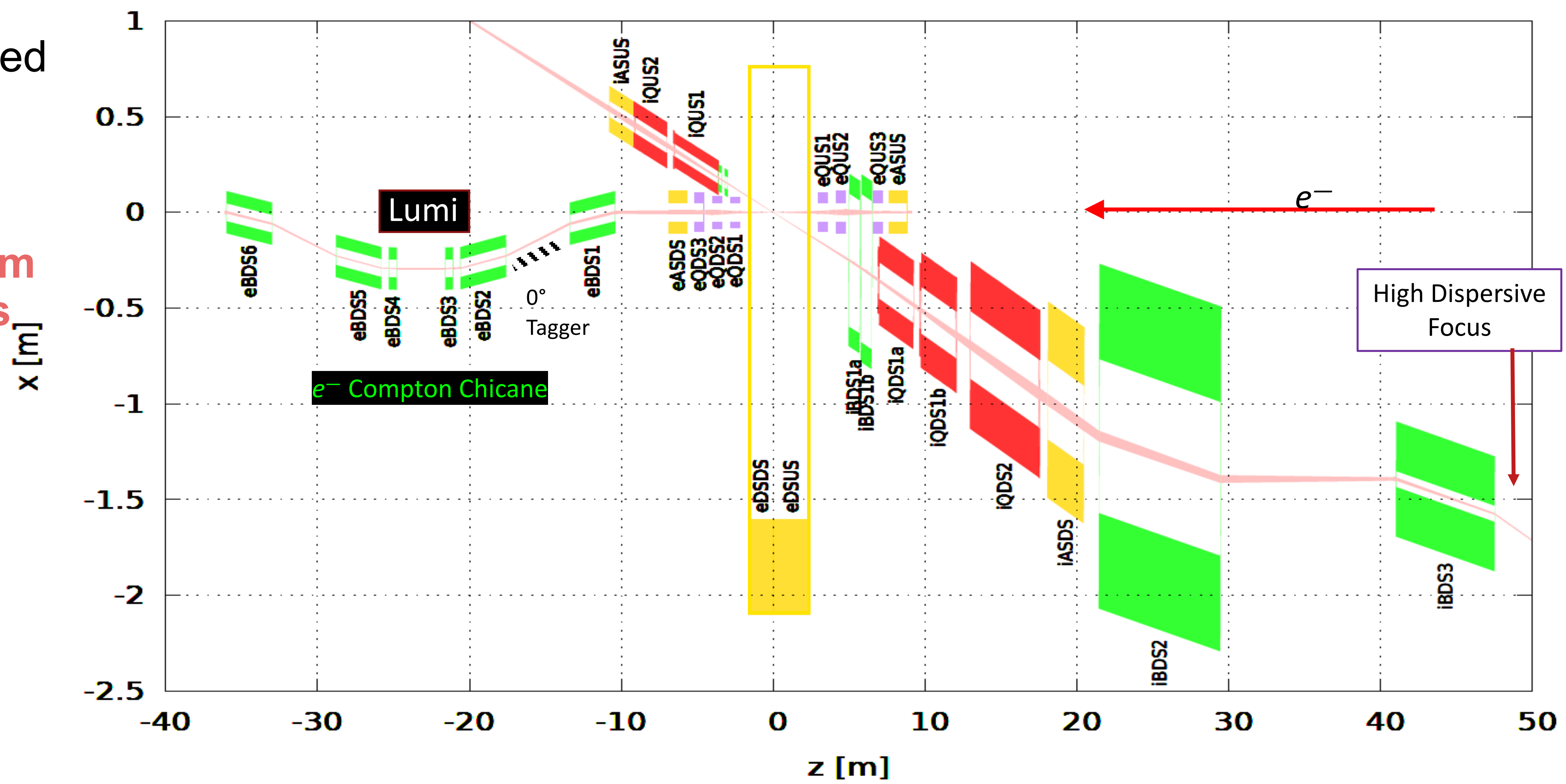
- Benchmarking to HERA done. Publication in progress.
- Fast Integration/Update of Accelerator Design to Physics Simulation
  - Idealized magnets in MAD-X from accelerator group
    - Python script converts to GEANT4 ➔ ➔ ➔
  - Engineering designs in CAD. Script converts to GEMC
- New work for second half of FY2019
  - Update studies with updated vacuum profiles
  - Update studies with new IR layout: JLEIC100
  - Use projected beam lifetimes to estimate beam halo interactions with beam pipe



OLD DOMINION UNIVERSITY

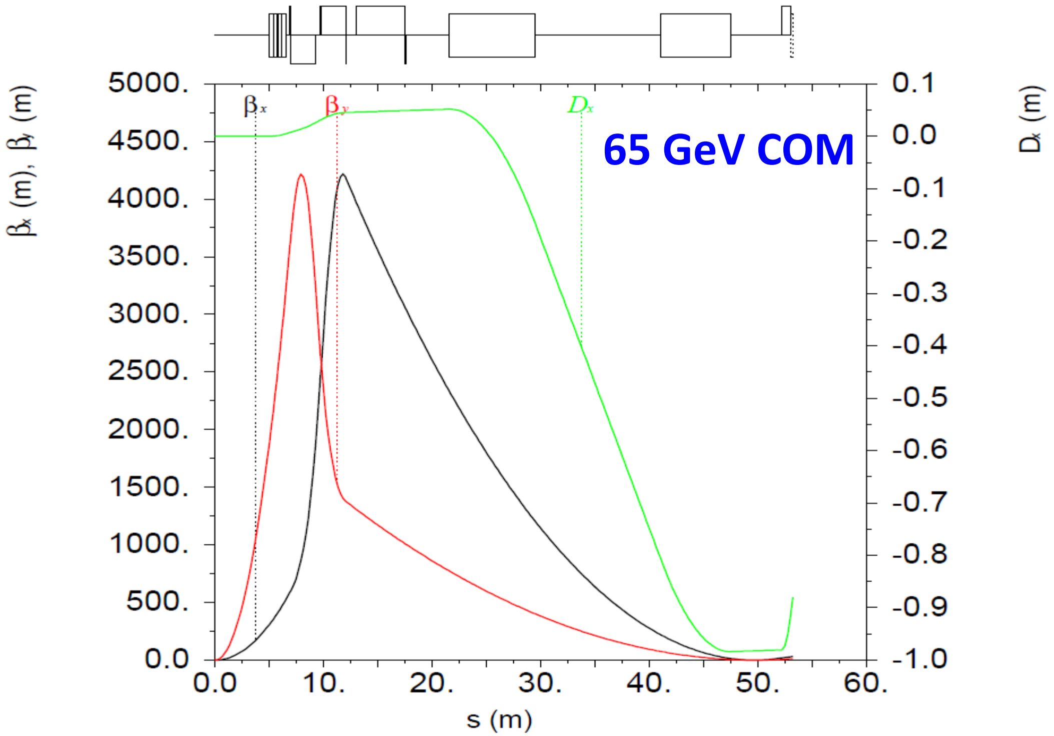
JLEIC $\sqrt{s}$ = 100 GeV IR Layout: New Baseline (12 GeV $e^- \otimes$ 200 GeV p)

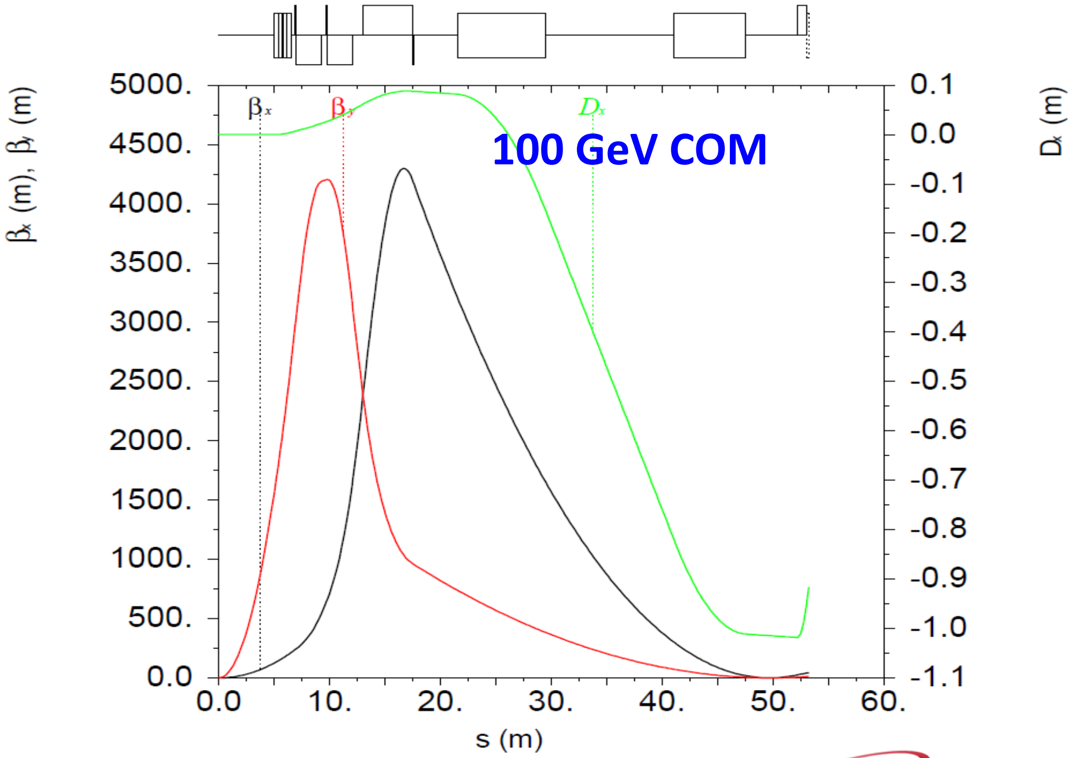
- Design implemented in GEMC detector simulation
- $\pm 10\sigma$ beam envelopes
- Dipole
- Solenoid
- iQuad
- eQuad



JLEIC 100 GeV COM Design

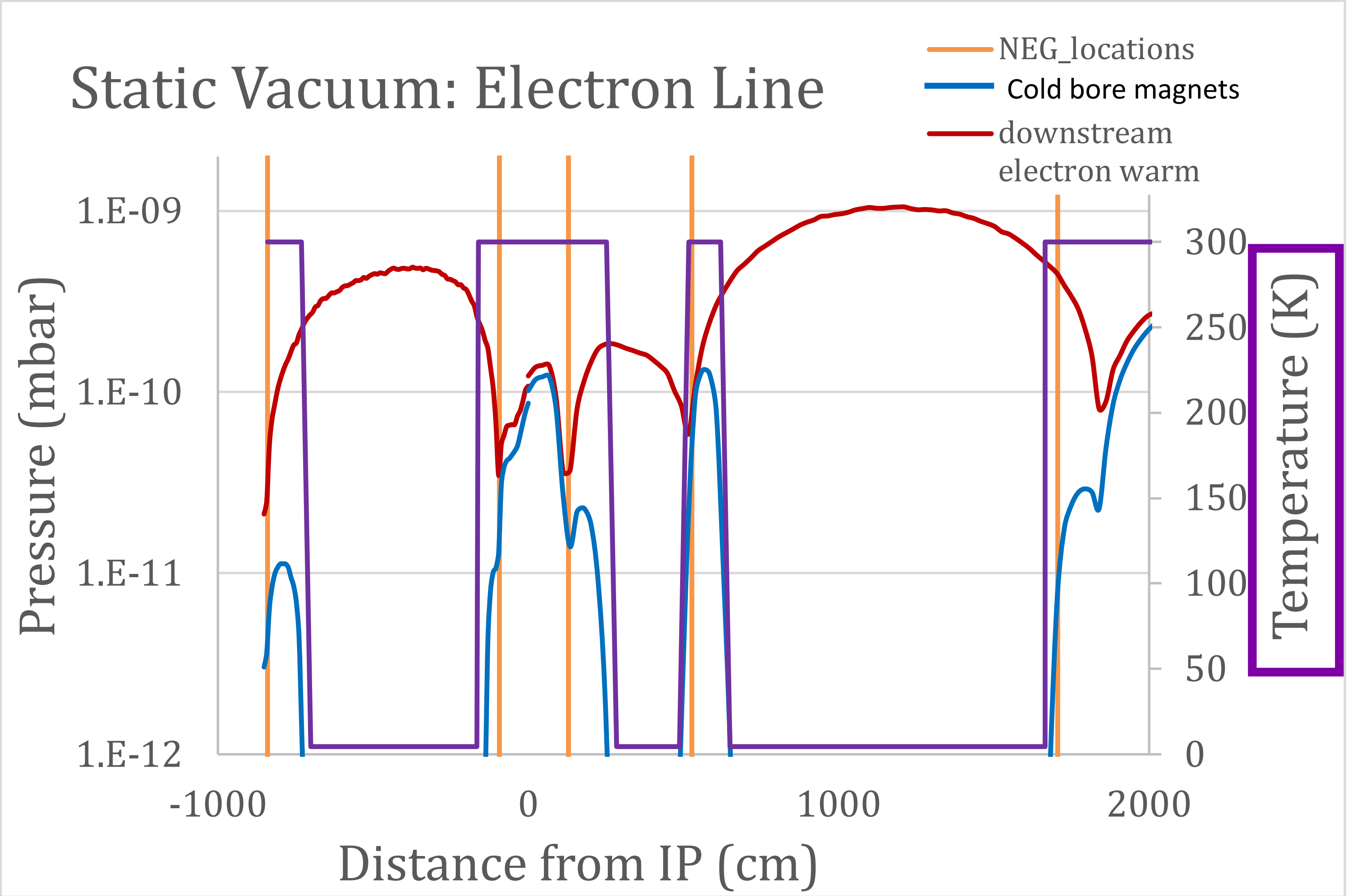
- **±10 mrad angular aperture acceptance** in the whole energy range up to 100 GeV COM with a high dispersion secondary focus 50m point downstream of IP (after 3FFQ & 3Dipoles)
- Conventional **Nb-Ti technology** Final-Focusing Quadrupole technology
- Same **high luminosity and detection performance** as the 65 GeV COM design
- **Shorter- and longer-focus configurations** at lower and higher energies, respectively





MolFlow Vacuum Study

- Realistic Pumping
  - Blue is vacuum (left-axis) with cold-bore magnets(right axis, magenta line)
  - Red is vacuum with warm beam pipe

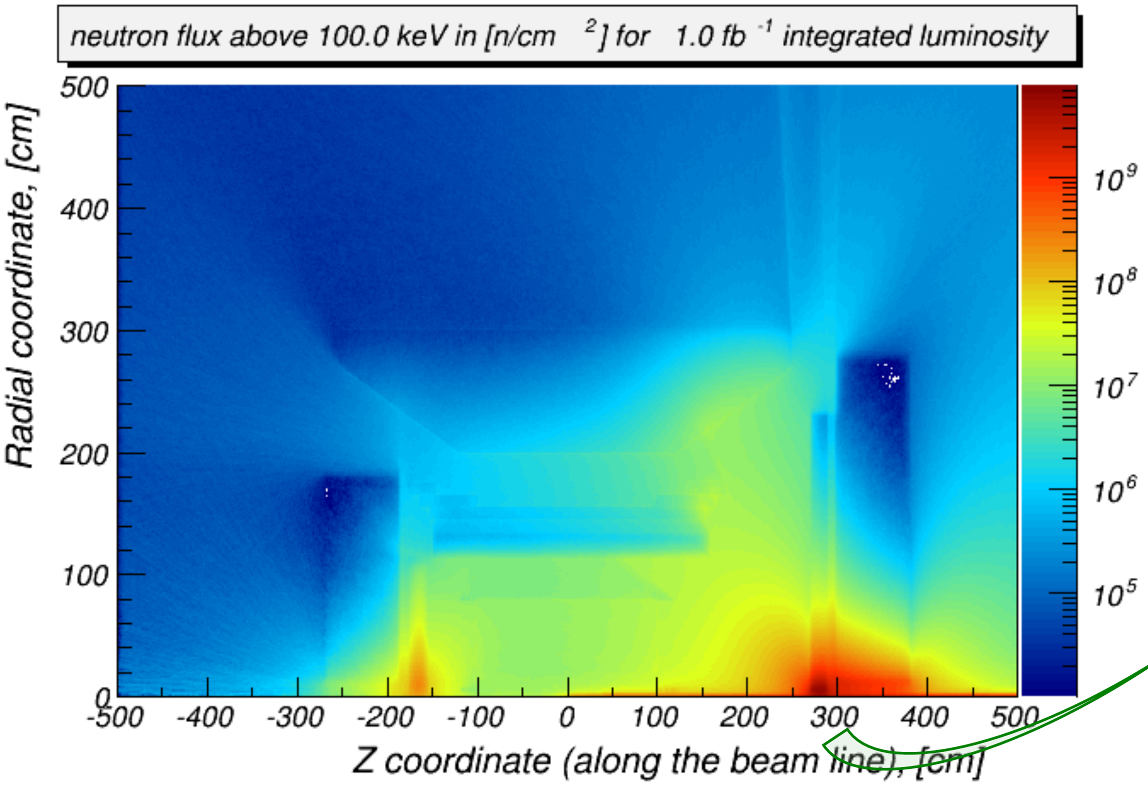


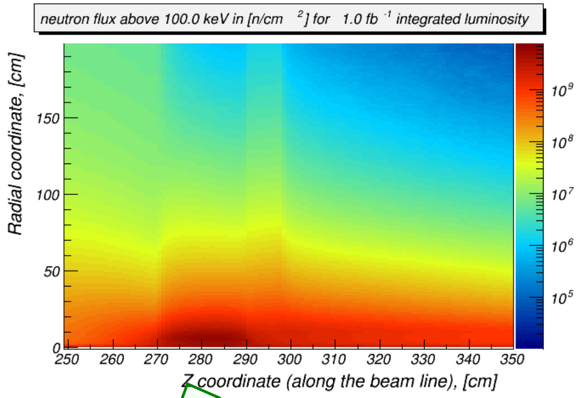
Neutron flux

A. Kiselev

The quantity: Flux = "a sum of neutron path lengths"/"cell volume" for N events

-> basically use Y. Fisyak's approach





-> forward EmCal: up to ~$5*10^9$ n/cm^2 per fb^{-1} (*inside the towers*); perhaps ~x5 less at the SiPM location;

NB: "standard" EIC run at ~10^{33} cm^{-2}s^{-1} luminosity is 10 fb^{-1}

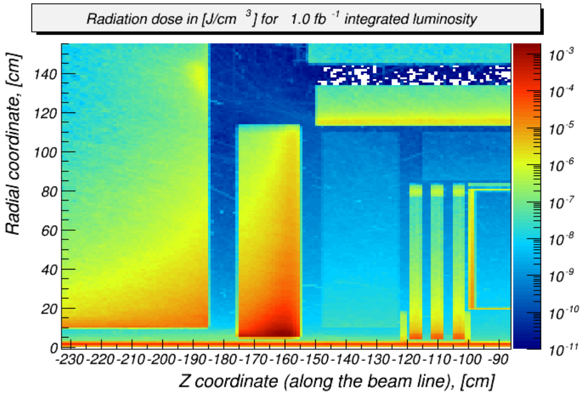
- Assume azimuthally-symmetric setup -> so build {R,Z} map

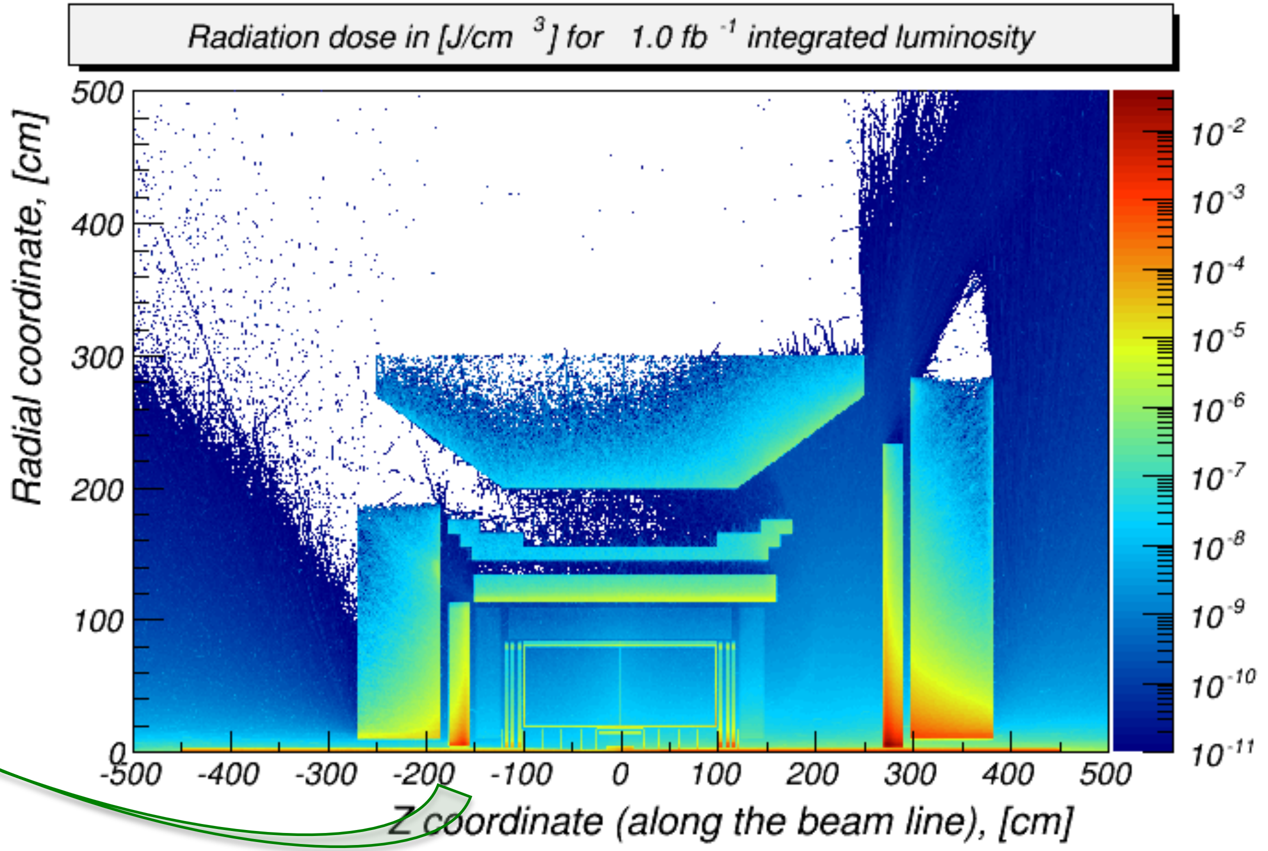
BEAST Radiation dose study

BROOKHAVEN NATIONAL LABORATORY

<u>The (primary) quantity</u>: E_{sum} = "a sum of dE/dx"/"cell volume" for N events

A. Kiselev





-> crystal EmCal: up to ~$2*10^{-3}$ J/cm^3 per fb^{-1} (close to beam line)

1 rad = 0.01 Gy . [Gy] = [J/kg] & PWO density ~8g/cm^3 ->

~250 rad/year (at "nominal" luminosity ~10^{33} cm^{-2} s^{-1})

(Possible) next steps (BNL)

BROOKHAVEN NATIONAL LABORATORY

- Variable energies ...
- Other event generators (eA in particular) ...

- ... and/or other detector geometries (JLEIC, etc) ...
- ... and/or different calorimeter materials ...
- ... and/or some realistic beam line magnet layout ...

- Cross-check with GEANT4

Radiation Dose Rates Evaluation (Pavel Degtiarenko)

- The radiation source terms are input to beam transport simulation software, and Monte Carlo simulation of nuclear cascades
  - GEANT3
  - Geant4
  - FLUKA
  - MARS
- Reliability is achieved by multiple redundant cross-checks using different models and different methods, different people
- The plan is to investigate applicability of different model approaches to the calculations of the radiation environment at the JLEIC Interaction Points, with the emphasis on the model cross-comparison and (if possible) comparison with experimental data

ODU Plan for neutron thermalizaton study

- 2018 SULI project at JLab demonstrated most ion beam-loss happens at the collimators
- Build a simplistic model of the accelerator tunnel
  - Uniform concrete wall thickness
  - Iron (mostly, + air) distributed quasi-uniformly throughout tunnel.
- Generate hadrons
  - Uniform Beam-Gas interactions
  - Point sources at collimators
- Propagate / thermalize the `neutron gas' to estimate backgrounds at IP from distant sources.
- eRD21 + StonyBrook CFNS + ODU grant funding (DOE)
  - New Post Doc expected to start in Feb. ~75% on eRD21 studies

Beam Tails

- All electron storage rings have a beam tail
  - Interactions with gas molecules
  - IBS (Touschek, etc.)
  - Beam tune shift
  - Nearby resonances in the tune plane
  - Other…
- Usually sets the beam lifetime
- The tail can be up to a few percent of the core distribution

Beam Tails

- The collimators in the ring need to be set to a beam sigma that is smaller than the IP apertures
  - Else the IP becomes the tight spot in the ring and collects all of the beam backgrounds
- So if the BSC in the IR is 15 sigma then the collimators must be ~12 sigma
- The collimators will then set the electron beam lifetime
- Based on recent super KEKB and Belle II experience beam tail distributions appear to be a significant source of detector background