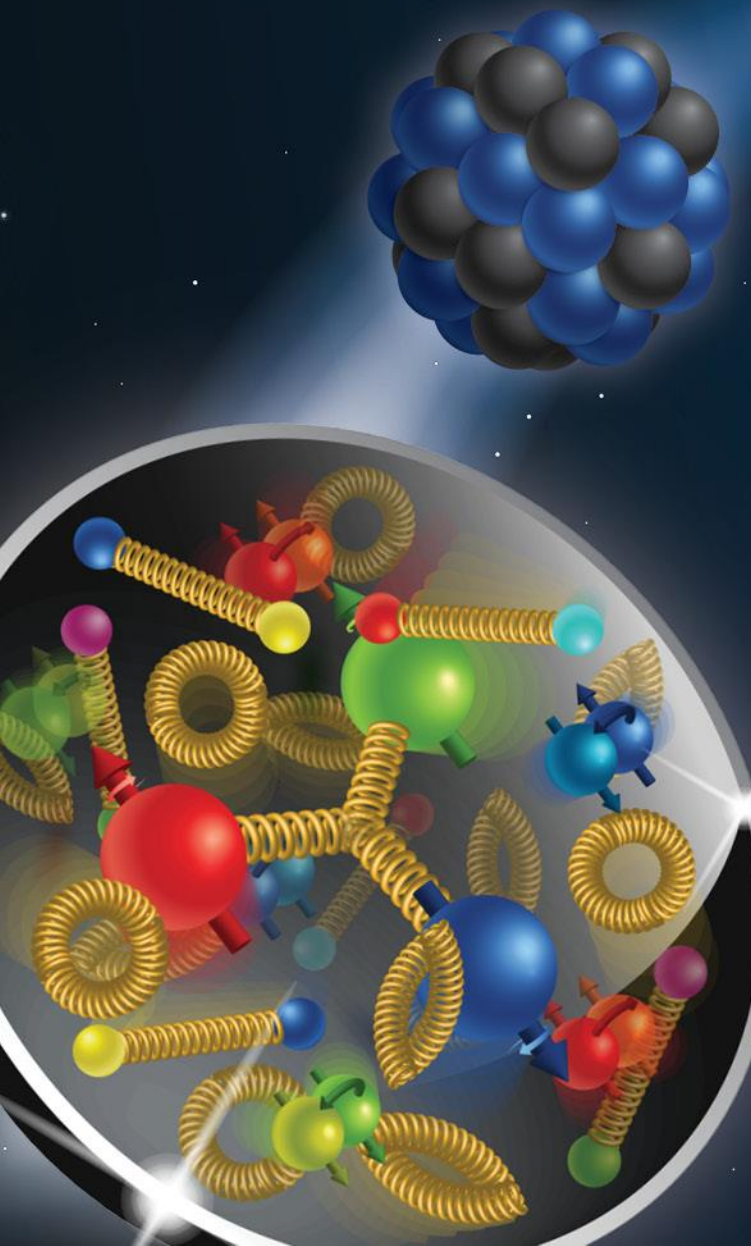


Interaction Region Synchrotron Radiation and Vacuum

Marcy Stutzman, JLab Staff Scientist

Charles Hetzel, BNL Vacuum Group Leader

TRIUMF 2021

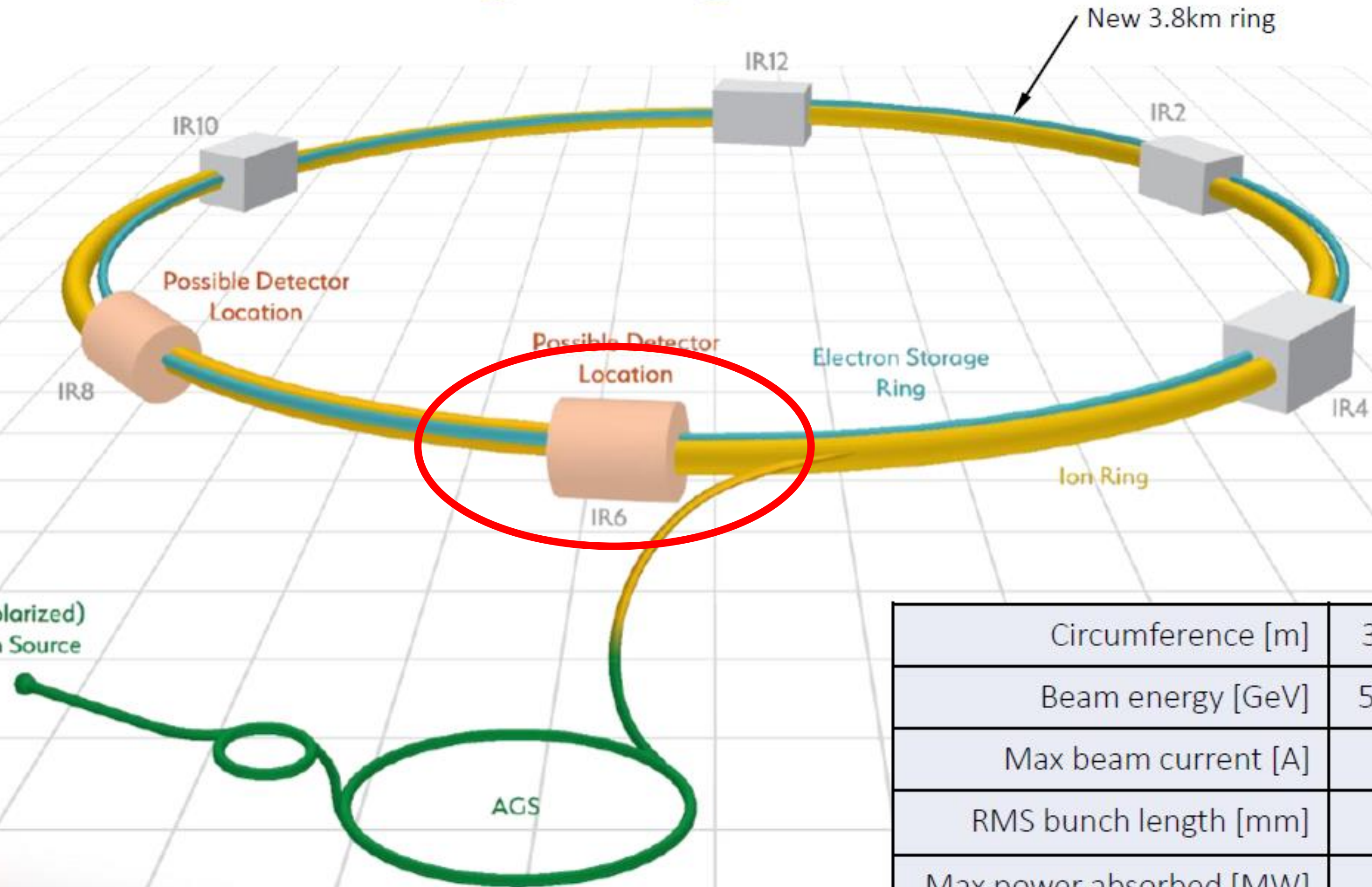
EIC Accelerator Partnership Workshop

October 27, 2021

Electron-Ion Collider

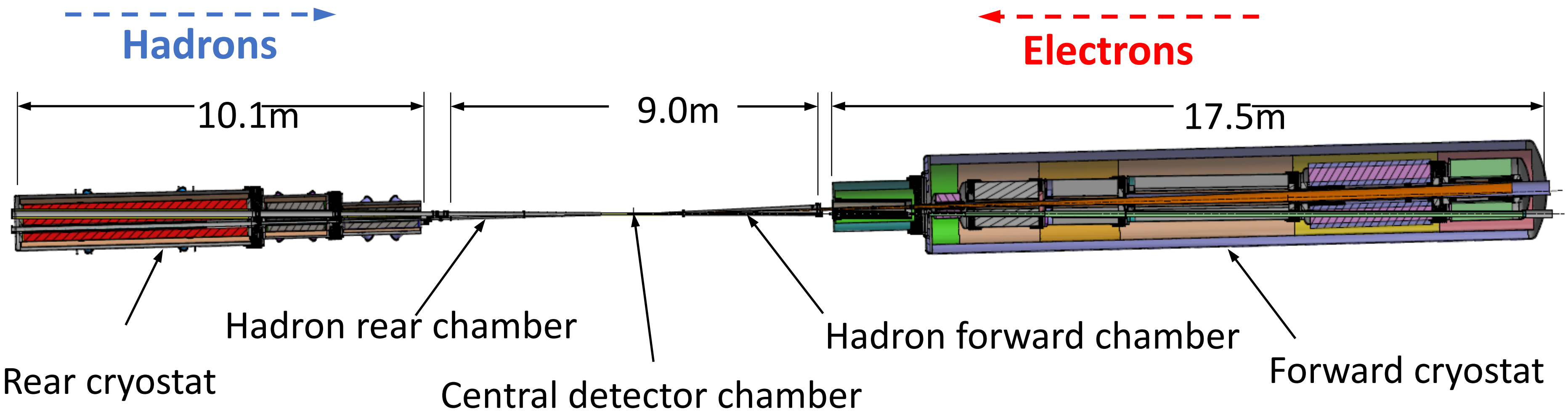
BROOKHAVEN NATIONAL LABORATORY · Jefferson Lab · U.S. DEPARTMENT OF ENERGY | Office of Science

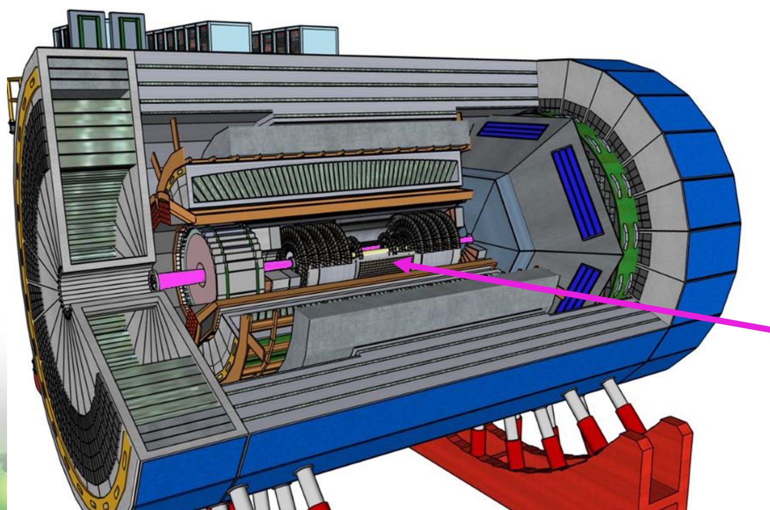
Electron Storage Ring



Circumference [m]	3833.94
Beam energy [GeV]	5, 10, 18
Max beam current [A]	2.5
RMS bunch length [mm]	~7
Max power absorbed [MW]	~10
Number of cells	96

Interaction Region





Detector system concept

Vacuum Chamber in Pink

Interaction Region Requirements

Accelerator

- Clearance for beam and tails
- Minimize wake fields and longitudinal impedance
- Thermal management
- Magnets & Cryostats
- Good **vacuum** to minimize beam broadening

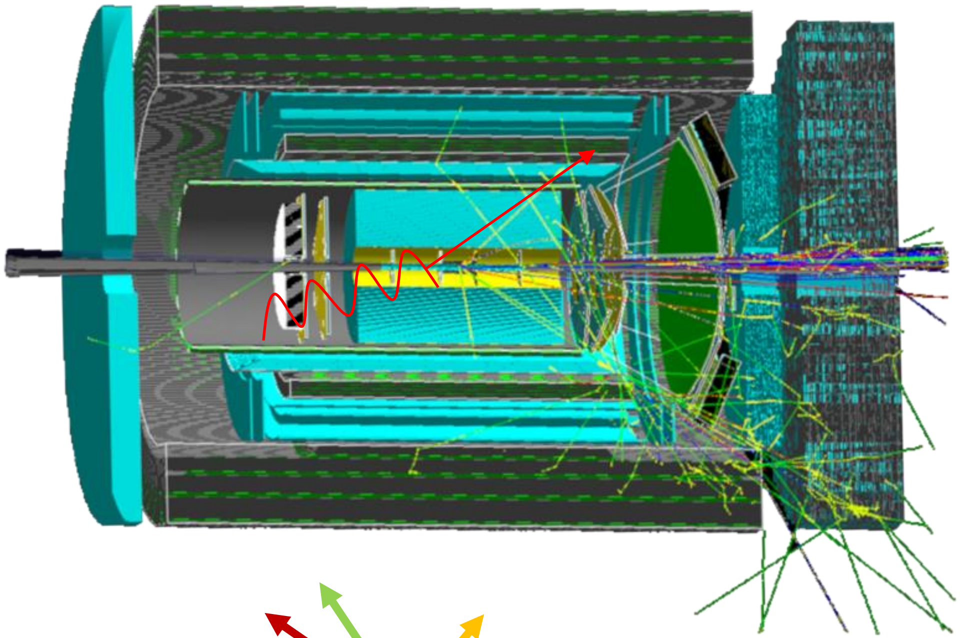
Goal: Average dynamic pressure < 1×10^{-9} mbar

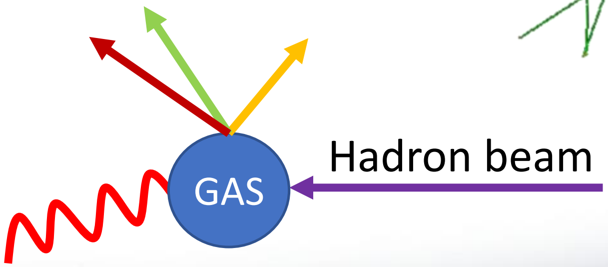
Detector

- Low z materials (Be, Al)
- Detectors close to IP
- Detector temperature limits
- Low energetic photon flux
- Accommodate ancillary detectors
- Mobile for maintenance
- Synchrotron radiation management
- Good **vacuum** to minimize detector background

Two Detector Background Sources from Synchrotron Radiation

- Synchrotron Radiation -> detector hits
  - Low energy (keV) photons
  - Photon or secondary particles detected
  - ~2-5 μm Gold coating mitigates
- Synchrotron Radiation induces gas desorption -> beam/gas interaction background
  - Hadron beam on residual gas "target"
  - High energy particles from nuclear scattering
  - Hard to shield, must reduce





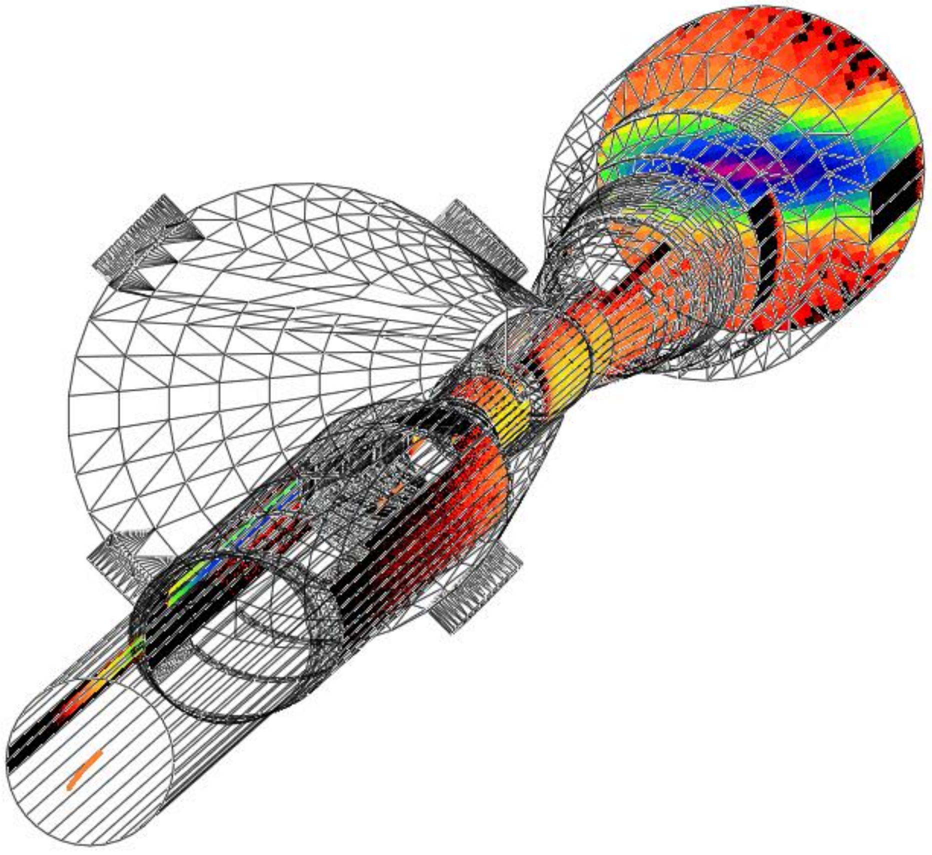
SynRad+ modeling software

Input

- 3D model of beampipe
- Beam emittance, current
- Magnet locations and fields

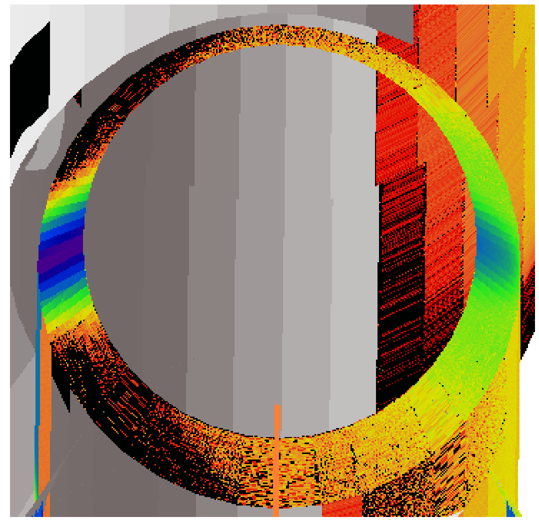
Output

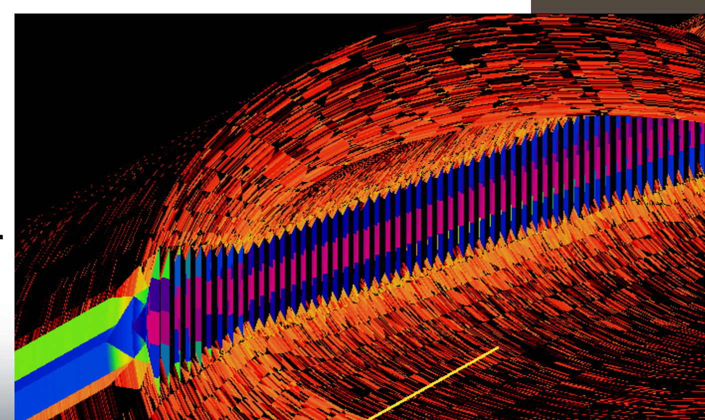
- Synchrotron Radiation
  - Position
  - Flux
  - Energy
  - Direction
- Input for Molflow+ dynamic vacuum modeling



Synchrotron Radiation Mitigation

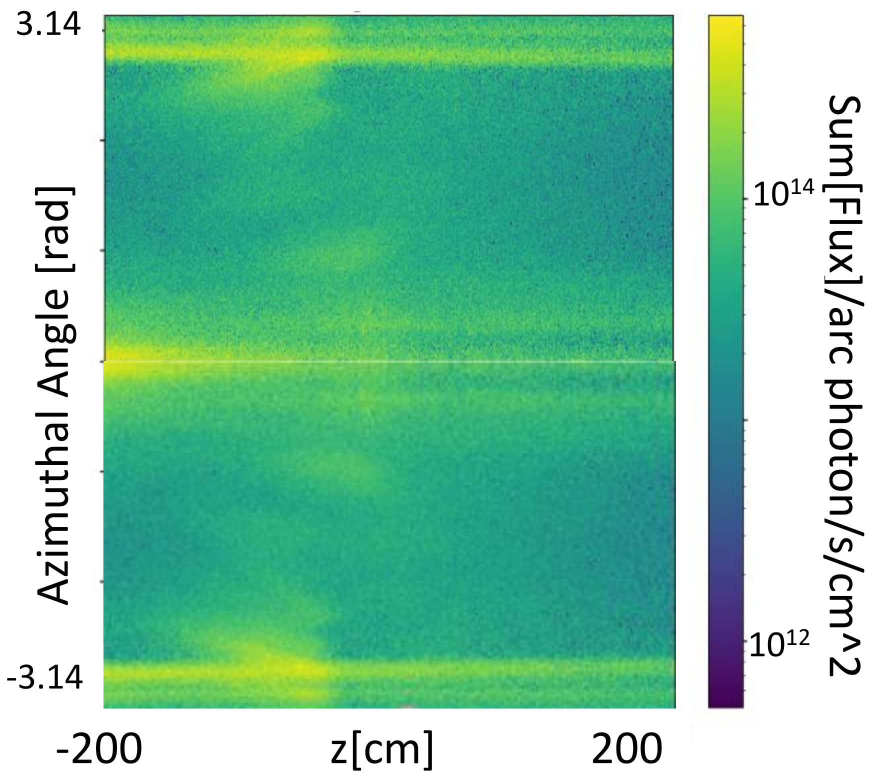
- Final photon absorber configuration
  - Horizontal plane only
  - Annular configuration
    - Length, diameter, position
- Beamline dimensions
  - Wider beam pipe for
    - 13.5 **σ** clearance in x
    - 23 **σ** clearance in y
- Beamline profile
  - Sawtooth/ridge texture for photon absorption





Interface between Synrad and Geant4

- SynRad+ simulations can give photon
  - Energy
  - Position & direction
  - Flux related current
- Iterate with design mods
  - In process: 0.5 m detector shift results
- Provide SynRad+ photon distributions to collaborations
  - Input for GEANT4 and Fun4All simulations of detector hits



Photon flux incident on vacuum chamber
10 GeV, photons > **10 eV**

Interface between Synrad and Geant4

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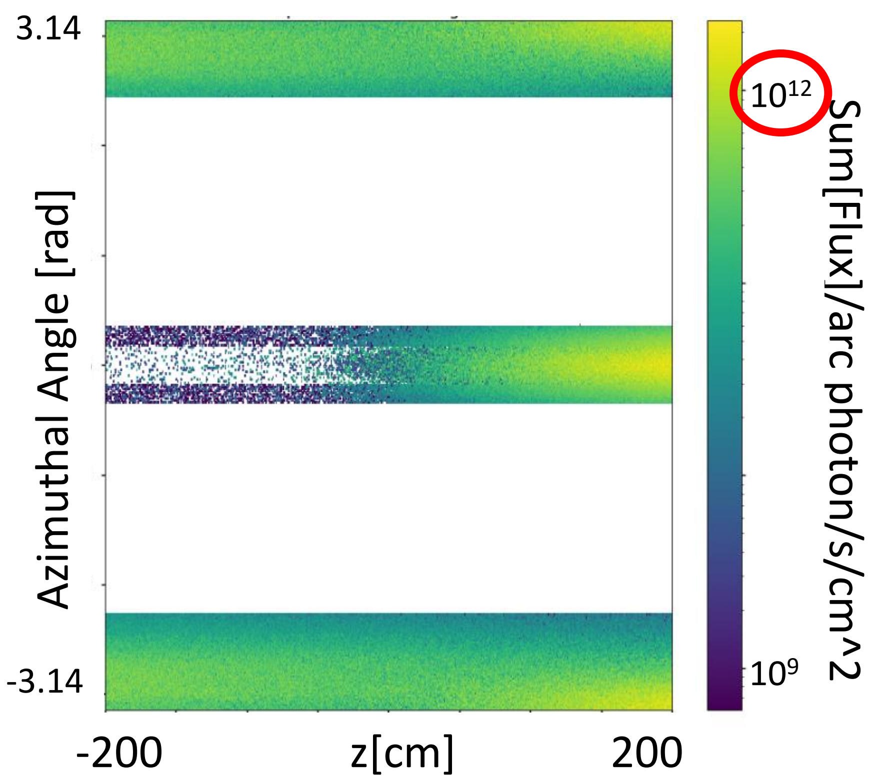
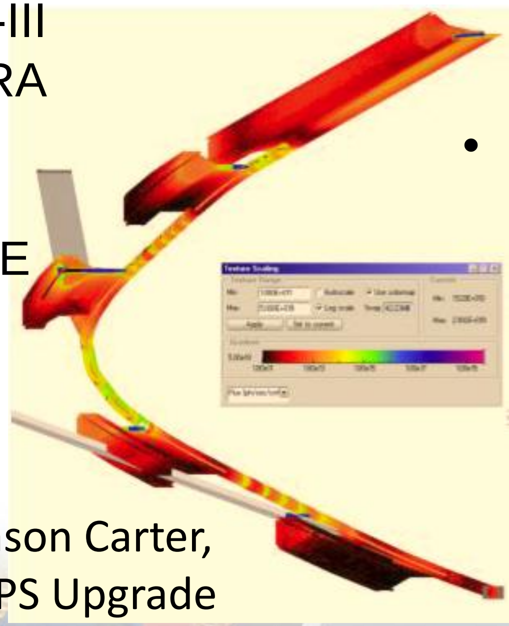


Photon flux incident on vacuum chamber
10 GeV, Photons > **5 keV**
which can penetrate gold
Flux drops by ~1000x

Benchmarking SynRad+ code

- SynRad+ widely used
  - CERN: LEP & LHC
  - Argonne APS Upgrade
  - SuperKEKB positron
  - ESRF
  - PETRA-III
  - ELETTRA
  - CESR
  - NSLS-II
  - SESAME
  - ALBA



Jason Carter,
APS Upgrade

Collaboration with M. Sullivan, SLAC

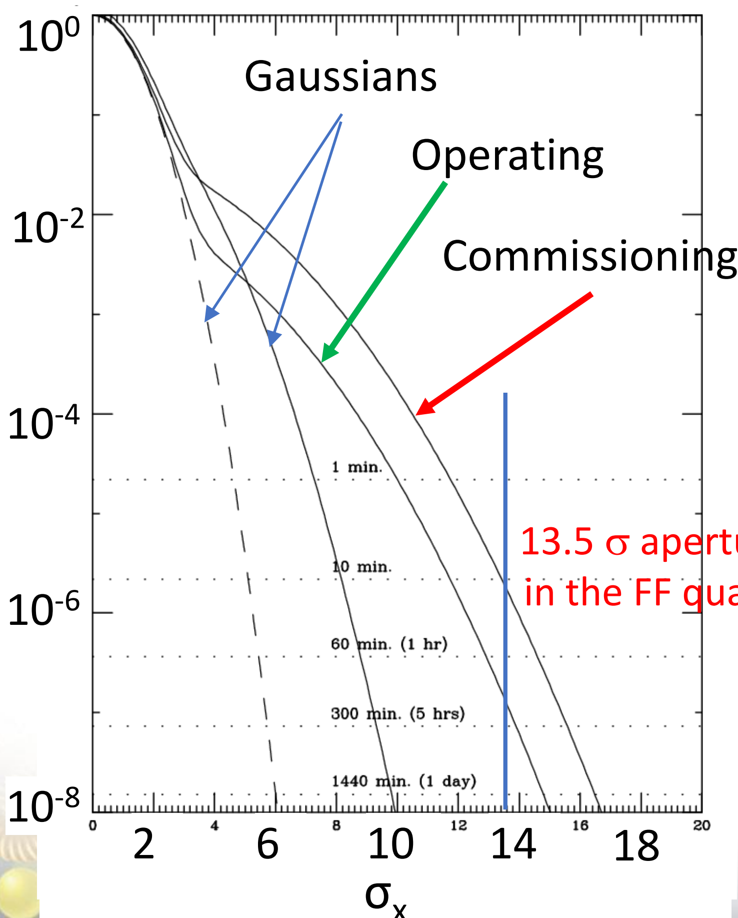
- 2D synchrotron radiation simulation
  - Developed for SLAC B Factory
  - Used for BELLE and SuperKEKB IR
  - Beam Tail profile critical for EIC: Optimizing tail models using SuperKEKB commissioning data
- Comparison with HERA
  - HERA model in SynRad+ complete
  - Future project to compare vacuum predictions

Ref: Kersevan IUVSTA 51st workshop, 2007

Tail simulation details

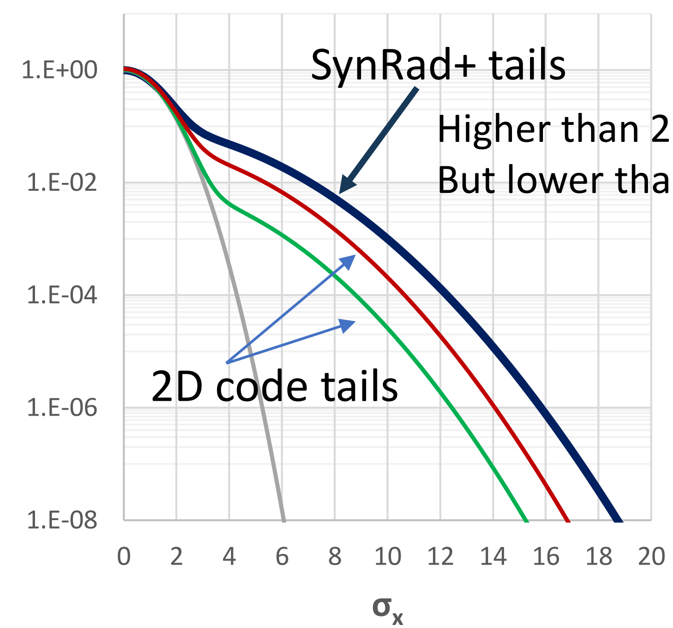
2D SYNC-BKG (M.Sullivan)

Tails optimized with SuperKEKB data



3D SynRad+ uses Gaussian tails

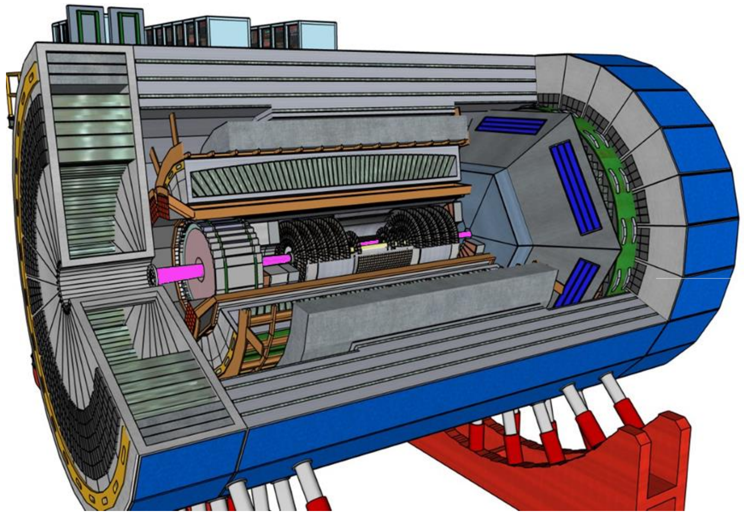
To approximate EIC tails in SynRad+, add two Gaussian distributions



Tail calculations by C. Montag (July 2021) lower than either profile in simulations

Ongoing studies of the tail profile effect for detector backgrounds and vacuum levels

IR Beamline Vacuum Challenges

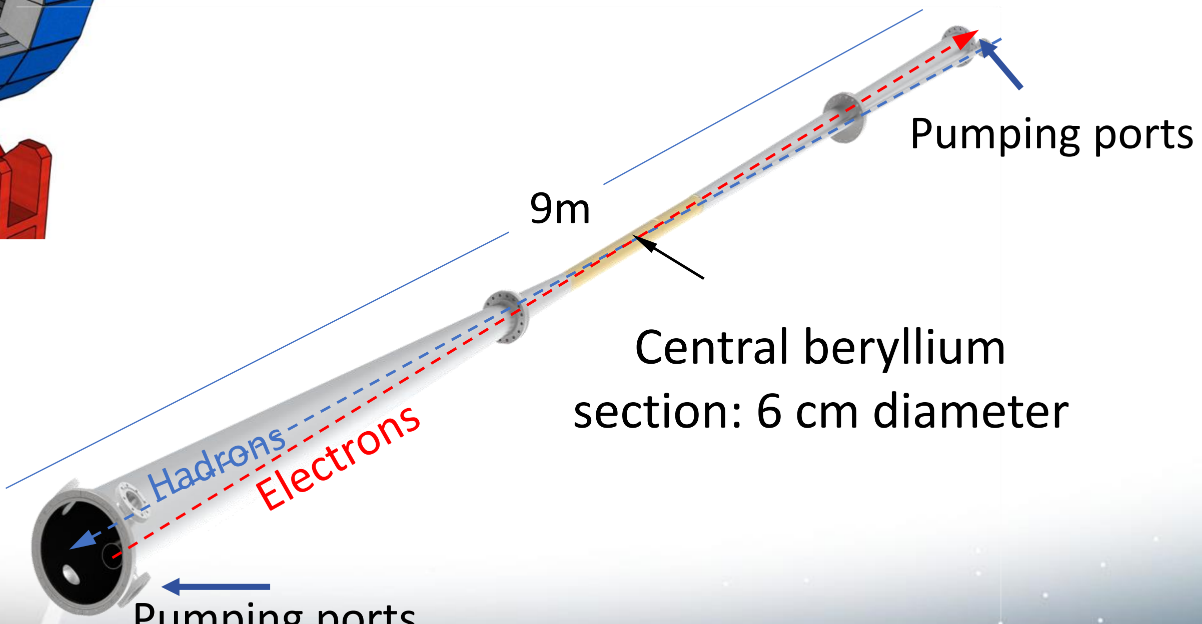


9 m section with no pump ports

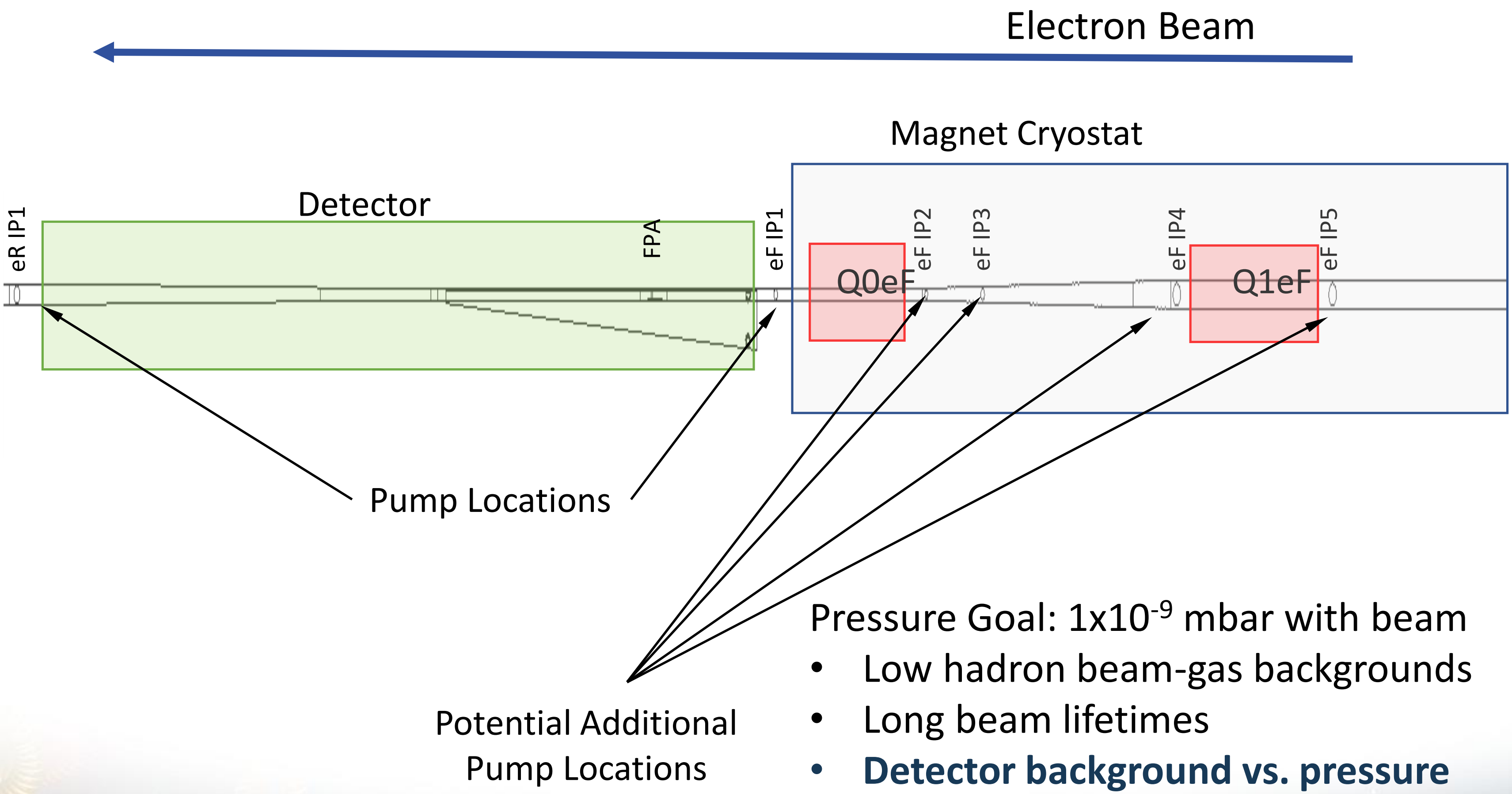
Synchrotron radiation liberates gas

Close interface with detectors

- Bakeouts limited due to detectors sensitivity
- Isolation valves for beamline during detector movement interfere with detectors



Vacuum System



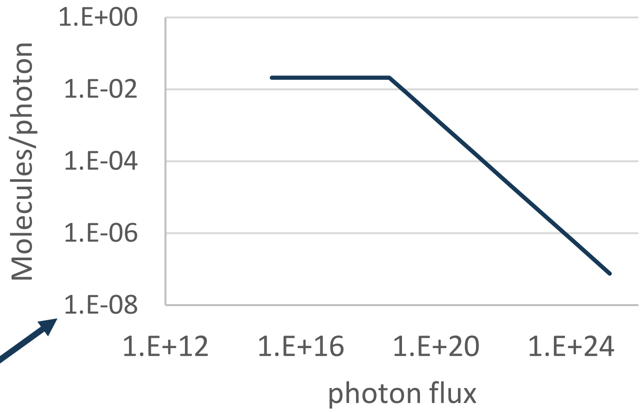
Pressure Goal: $1x10^{-9}$ mbar with beam

- Low hadron beam-gas backgrounds
- Long beam lifetimes
- **Detector background vs. pressure under study**

SynRad+ & Molflow+ for Dynamic Vacuum

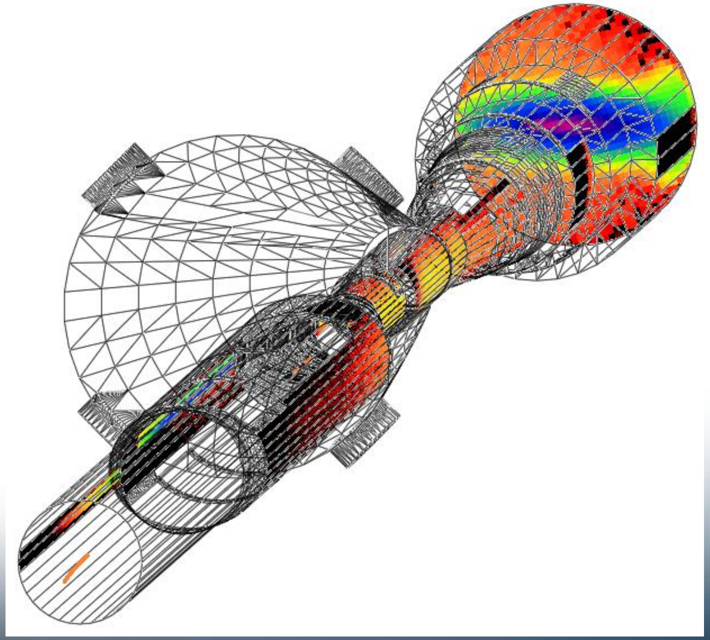
Input

- 3D model of beampipe
- Pump locations
- Materials & Outgassing Rates
- SynRad+ flux per facet
  - Photon Stimulated Desorption Rate
  - Depends on material and gas species

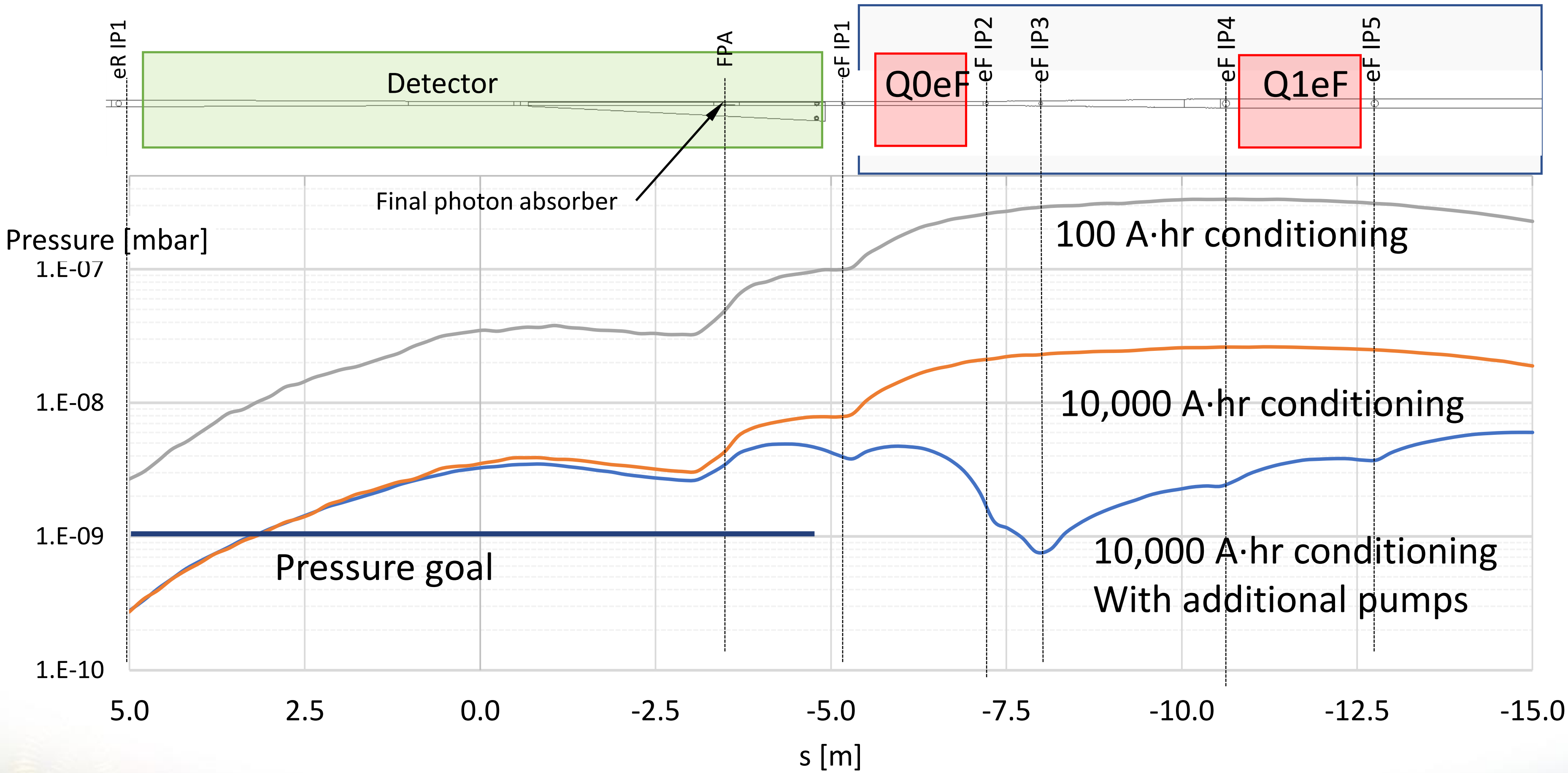


Output

- Base Pressure distribution
- Outgassing rate of each facet with synchrotron radiation
  - Pressure vs. Amp-hours during commissioning



Dynamic Vacuum

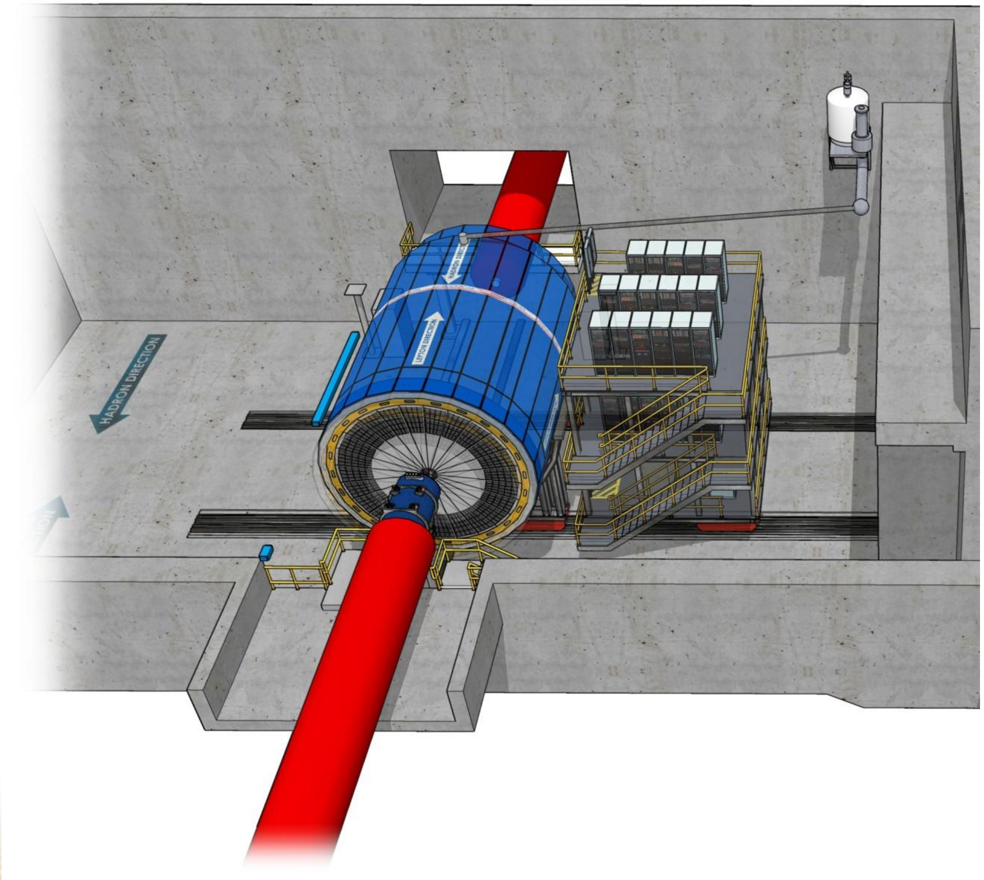


All discrete pumps, No NEG coating, no bakeout

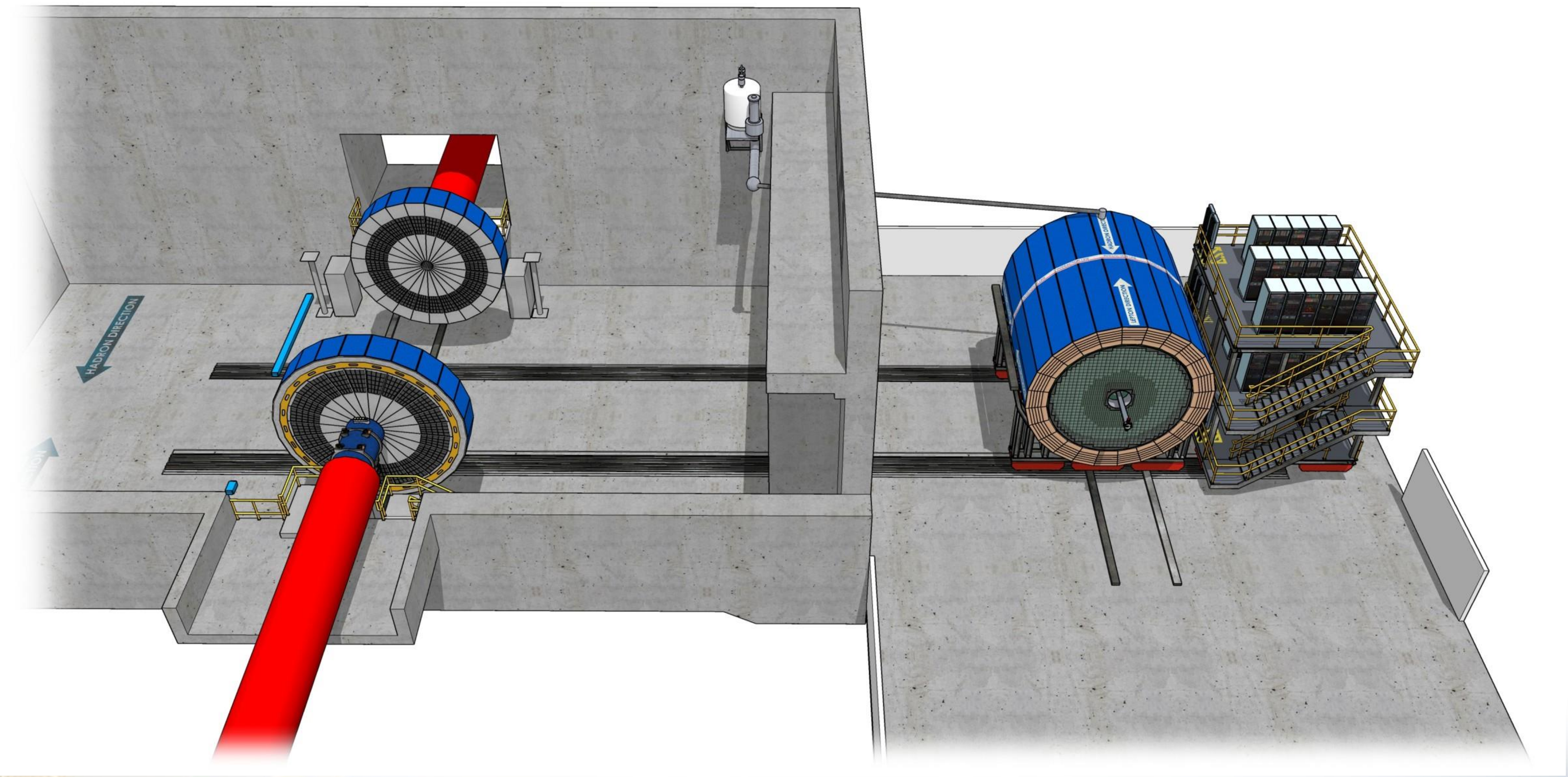
- Activation or bake temperature would harm Si detectors

Cryogenic beamline pumping not taken into account thus far

IP-6: Detector Removal for Maintenance



IP-6: Detector Removal for Maintenance



Model from Walt Akers

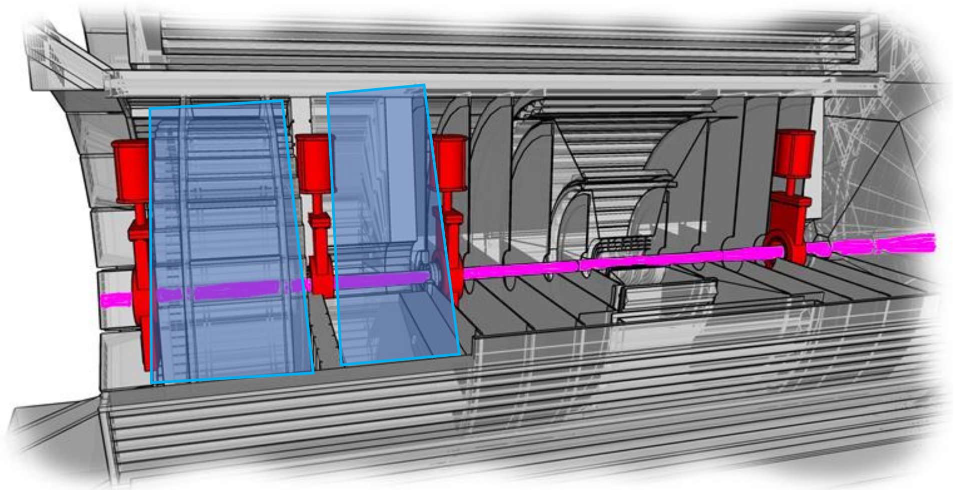
IR Vacuum Reovery after maintenance

- Detector package removal from beamline for maintenance

- Vacuum Concerns
  1. Yearly IR beamline vent
  2. Gate valves difficult/impossible
     1. Detectors blocked and additional background
     2. Calorimeter must slide off beamline

- Need to develop

Venting, pumpdown, conditioning



Ongoing studies

- Recovery after maintenance
- Additional Pump Locations
- Materials Selection, Preparation
- Synchrotron Radiation Mitigation?

Conclusions

- Complex interface between beamline, detectors and magnets
- Synchrotron radiation: SynRad+
  - Benchmarking against 2D codes and operational experience
  - Good integration with detector background modeling
  - Tail distribution still under study
- Dynamic vacuum studies: SynRad+ and Molflow+
  - Dynamic vacuum calculations vs. conditioning time
  - Materials selection and processing for improved conditioning time
  - Downstream effects and cryogenic adsorption still to be considered
- IR Synchrotron Radiation Background working group: bi-weekly
  - Proto-Collaboration detector working groups
  - Accelerator collaborators welcomed

Thanks for your attention. Questions?

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