# EICGENR&D2023_09
# Z-Tagging Mini-DIRC

CHARLES HYDE

OLD DOMINION UNIVERSITY

# Z-Tagging MiniDIRC

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# Z-Tagging Mini-DIRC R&D

- Proposed IR-8 beamline for a second EIC detector includes a high-dispersion focus in the downstream ion beamline 45 m from the IP.
  - This enables detection/tracking of ions with magnetic rigidity deviating as little as ±1% from beam rigidity. This is an order of magnitude greater acceptance than the IR-6 beamline.
- This is an R&D project to **prove the principle** that a high precision Cherenkov detector could identify the charge of **any** ion from proton to uranium detected by the tracking detectors at the $2^{nd}$ focus.

# Questions from Committee: I.

I. Physics case: The proposed detector measures the Z of a fragment.
   1. How do we get the mass?
      A. Second Focus tracker measures rigidity *P/Z*
      B. All forward fragments have ≈ Beam velocity
      C. Rigidity ⊗ Z ➔ Isotope unique ID
   2. How do we get spectroscopy? Does that require a high-resolution calorimeter?
      Photo decays are boosted into a high-resolution pre-shower EMCal foreseen as part of ZDC.
   3. Is the physics case strong enough if it was just to establish coherent scattering for some reactions?
      A. The Z-tagger is essential to realize the full physics potential of the $2^{nd}$ focus and its trackers.
      B. Physics impact of Z-tagger for both Coherent and Incoherent scattering is discussed below

# Questions from Committee: II.

II. The proposal is simulation.
 1. How are they validated?
 GSI photon collection MC code has been validated by Beam-Tests of PANDA DIRC prototypes.
 2. What is new or special in this proposal concerning DIRC technology?
 Z-tagging requires uniform light collection at the 1% level over the 10-15 cm range of fragment impact points
 3. What has been approximated in the current simulation?
 A. Surface roughness is parameterized
 B. Key elements for this R&D project:
 i. Uniformity of light collection over the range of impact points
 ii. Non-uniformity of photo-sensor QE and gain
 4. What is the preferred photon sensor solution, taking radiation hardness and external magnetic field into account?
 A. MCP-PMT or conventional PMT. Detector is ≥1m from accelerator magnet, fringe fields should be ~gauss.

# Questions from Committee: III.

III. Which alternative technologies (Si-telescope?) have been considered?
A dE/dX-based detector would have the same $Z^2$ sensitivity, but Landau-Vavilov fluctuations preclude achieving the desired resolution. There will be a Si-tracker (probably AC-LGAD) in the Roman Pot detectors at the second focus.

IV. Will the detector benefit from higher granularity?
The fragments will be focused to a very narrow vertical band. The tracker will identify the location of the hit or hits. Granularity may be more a complication than advantage.

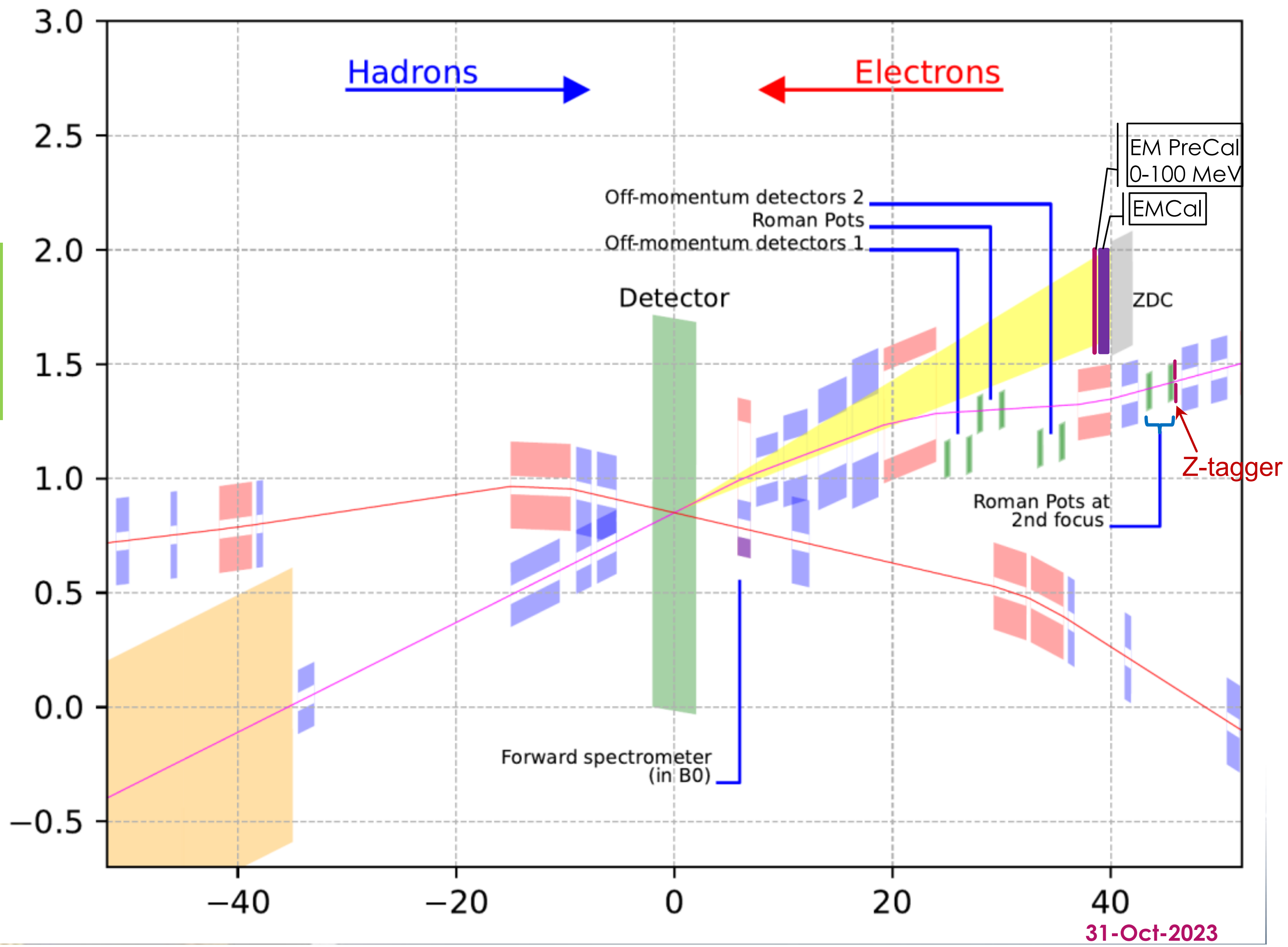
V. What will a reduced Year 1 program achieve compared to the proposal text?
Budget discussion at end.

# IR-8 Layout

**Second Focus**
**$D_x$ = Dispersion = 0.48 m/100%**
**$1-x_L$ = ±Beam-Stay-Clear ≤1%**

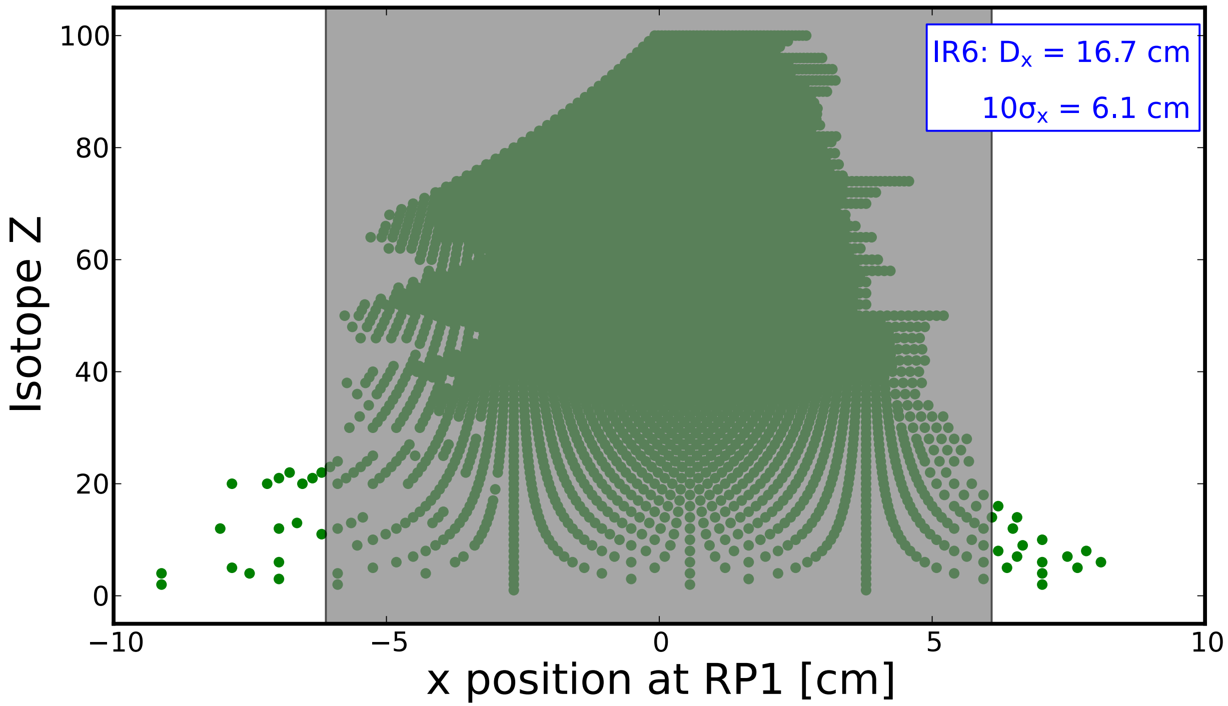
Parameters at the 2nd focus for different energies

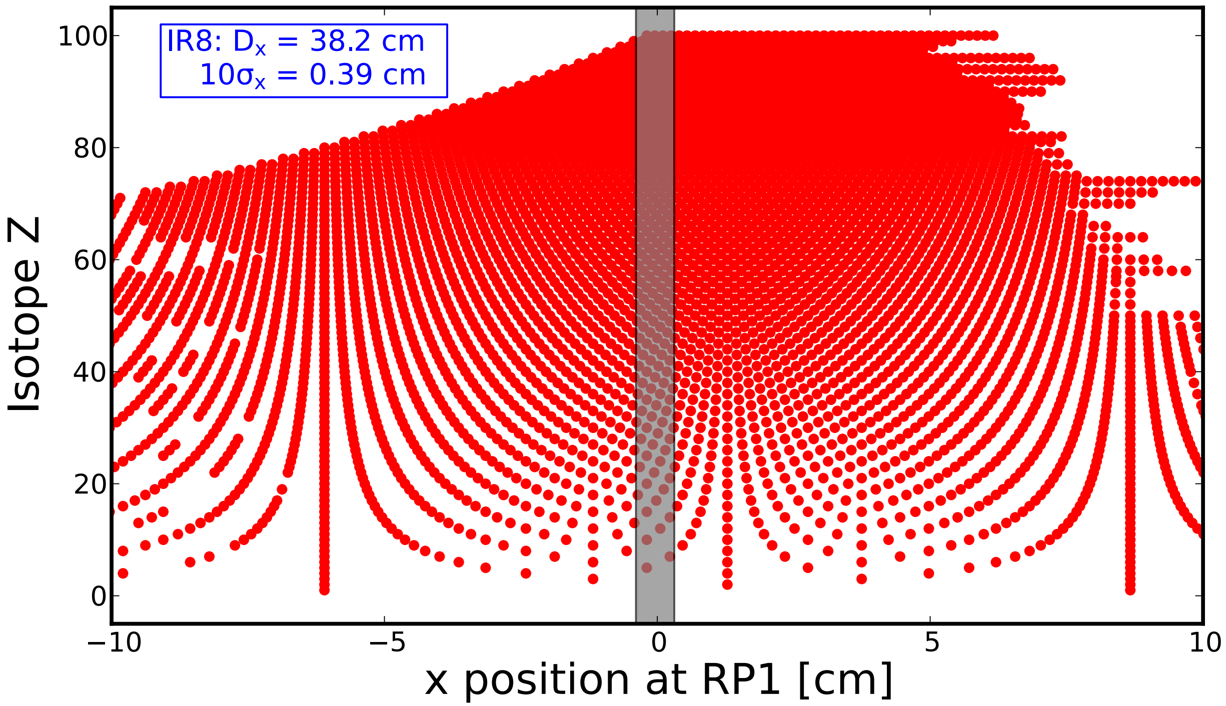
| Parameter | 41 GeV | Value at 100 GeV | 275 GeV | Units |
|---|---|---|---|---|
| $\beta_x$ | 0.85 | 0.8 | 0.5 | m |
| $D_x$ | 0.48 | 0.48 | 0.47 | m |
| $\epsilon_x$ | 44 | 30 | 11.3 | nm |
| $\sigma_\delta$ $(10^{-4})$ | 10.3 | 9.7 | 6.8 | - |
| $1-x_L$ $(10^{-3})$ | 4.16 | 10.2 | 7 | - |



# Isotope Tagging

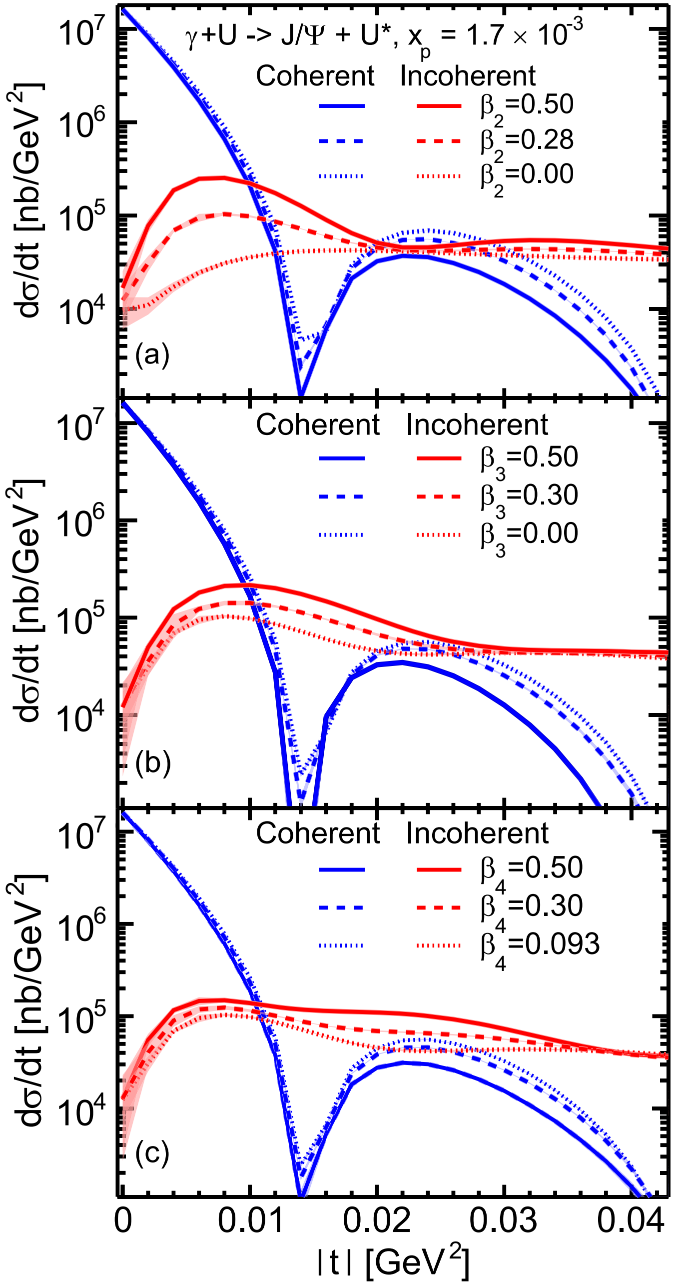
- Evaporation residues
  - All fragments at beam velocity.  Grey zones are Beam-Stay-Clear exclusion zones



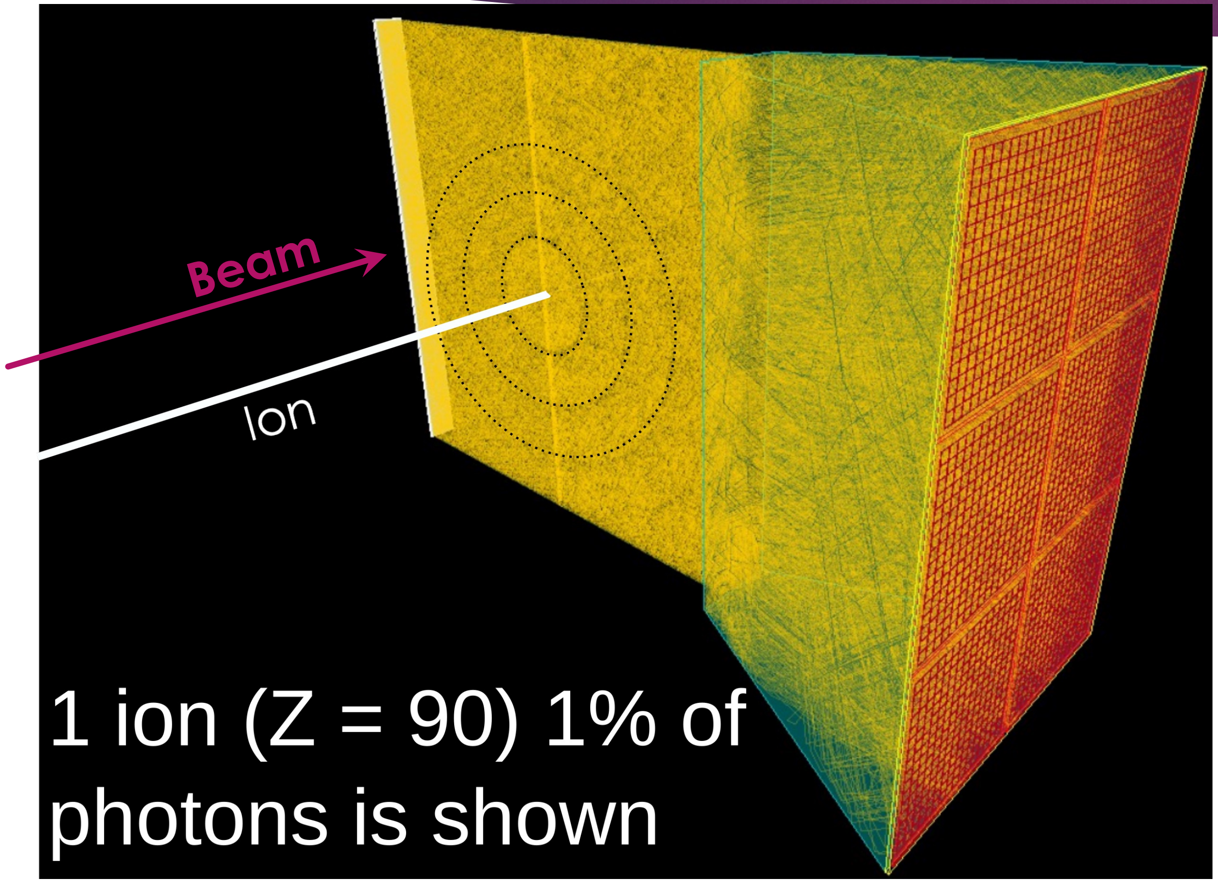



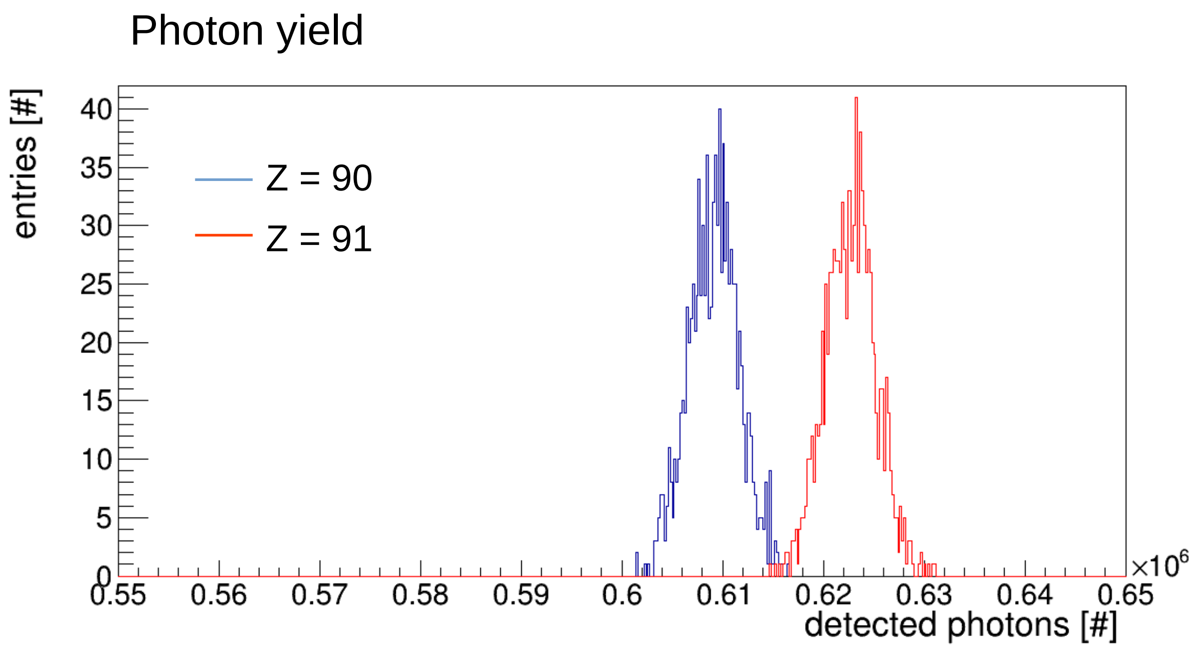
# Coherent & Incoherent Scattering

- Veto Breakup to tag Coherent Scattering
- Tag the specific incoherent channel, 1n, 1p, 2n, 1p1n, …
  - Deformation has been measured in many ground-state and excited-state rotational bands
  - Nuclear deformation in incoherent scattering can depend upon the final channel:
    A–1
    A–2, …
  - Figure from H.Mantysaari, *et al*, PRL **131**, 062301 (2023)



# Initial Simulation Results




- Simulation of 10% of Cherenkov yield, rescaled to full yield
- Geometry copied from EIC DIRC studies, not yet optimized for mini-DIRC

# Year-1 Simulation Deliverables, Full Funding

- Variations in light collection for different impact coordinate [x, horiz.] of the incident ion
- Pulse height dependence on variations of light illumination of the photo-sensor surface.
  - Based on typical efficiency and gain variations across the surface of existing SiPM and MCP-PMT photosensors. Include saturation effects of SiPM.
- Include upstream Si tracker to generate fluctuations in light yield from energetic δ-rays
- Photo sensor dynamic range and gain saturation simulation studies.
  - From protons to U, we anticipate a dynamic range of $1 : 10^4$ in Cherenkov light yield.
  - Design concept for fiber optic array splitting light collection to two sensors, one high-gain, one low-gain.
- Backgrounds from eA physics collisions at the IP and re-scattered particles.
  - Compare primary eA processes from FLUKA with the fragmentation models. Compare charge tracks generated by re-scattering/showering in beamline elements.

# Year-1 Simulation Deliverables, 80% Funding

- Variations in light collection for different impact coordinate [x, horiz.] of the incident ion
- Pulse height dependence on variations of light illumination of the photo-sensor surface.
  - Based on typical efficiency and gain variations across the surface of existing SiPM and MCP-PMT photosensors. Include saturation effects of SiPM.
- ~~Include upstream Si tracker to generate fluctuations in light yield from energetic δ-rays~~
- Photo sensor dynamic range and gain saturation simulation studies.
  - From protons to U, we anticipate a dynamic range of 1 : $10^4$ in Cherenkov light yield.
  - Design concept for fiber optic array splitting light collection to two sensors, one high-gain, one low-gain.
- ~~Backgrounds from eA physics collisions at the IP and re-scattered particles.~~
  - ~~Compare primary eA processes from FLUKA with the fragmentation models. Compare charge tracks generated by re-scattering/showering in beamline elements.~~

# Year-1 Simulation Deliverables, 60% Funding



- Variations in light collection for different impact coordinate [x, horiz.] of the incident ion
- Pulse height dependence on variations of light illumination of the photo-sensor surface.
  - Based on typical efficiency and gain variations across the surface of existing SiPM and MCP-PMT photosensors. Include saturation effects of SiPM.
- ~~Include upstream Si tracker to generate fluctuations in light yield from energetic δ-rays~~
- ~~Photo sensor dynamic range and gain saturation simulation studies.~~
  - ~~From protons to U, we anticipate a dynamic range of 1 : $10^4$ in Cherenkov light yield.~~
  - ~~Design concept for fiber optic array splitting light collection to two sensors, one high-gain, one low-gain.~~
- ~~Backgrounds from eA physics collisions at the IP and re-scattered particles.~~
  - ~~Compare primary eA processes from FLUKA with the fragmentation models. Compare charge tracks generated by re-scattering/showering in beamline elements.~~

# Budget(s)

Table 2: Budget Detail: ODU (Full Funding)

| Item | Description | Salary | Fringe | Subtotal |
|---|---|---|---|---|
| 1 | PostDoc (50% FTE) | \$31,000 | \$16,000 | \$47,000 |
| 2 | Graduate Student (100% FTE) | \$30,000 | \$ 2,235 | \$32,235 |
| 3 | Foreign Travel | | | \$ 4,000 |
| 4 | Domestic Travel | | | \$ 2,117 |
| 5 | Subtotal (Items 1–4) | | | \$85,352 |
| 6 | IDC: 26% of Item 4 (Off-Campus rate) | | | \$22,192 |
| 7 | Tuition (IDC exempt) | | | \$ 9,456 |
| 8 | **Total** (Items 5,6,7) | | | **\$117,000** |

Table 3: Budget Summaries (ODU)

| Budget: 100% | | | |
|---|---|---|---|
| **Item** | **Description** | **Subtotal Direct** | **Total with IDC** |
| 1 | ODU Post Doc (50% FTE) | \$47,000 | \$59,220 |
| 2 | ODU Grad Student (100% FTE) | \$41,691 | \$50,072 |
| 3 | Travel | \$6,117 | \$7,708 |
| | **Total 100% Budget** | | **\$117,000** |
| **Budget:** 80% | | | |
| 1 | ODU Post Doc (50% FTE) | \$47,000 | \$59,220 |
| 2 | ODU Grad Student (50% FTE) | \$20,846 | \$25,036 |
| 3 | Travel | \$6,146 | \$7,744 |
| | **Total 80% Budget** | | **\$92,000** |
| **Budget:** 60% | | | |
| 1 | ODU Post Doc (50% FTE) | \$47,000 | \$59,220 |
| 2 | Travel | \$7,762 | \$9,780 |
| | **Total 60% Budget** | | **\$69,000** |

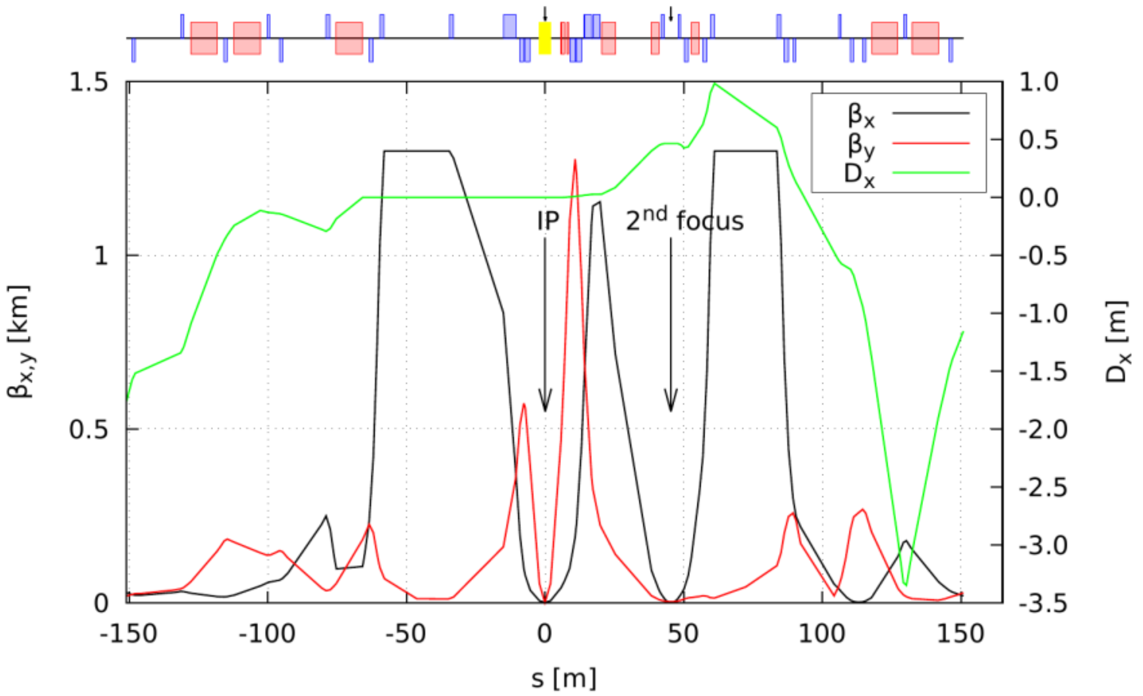
# Additional Slides

# Summary of Background Estimates

- Residual gas (Ion beam ⊗ residual H gas)
  - $< 10^4$ dissociation events / sec with potential to reach 2nd focus
- Random eA rate from physics collisions
  - $\approx 1.5 \bullet 10^5$ / sec
  - Pileup probability per bunch crossing ≈0.12%

# IR8

- Beta-functions and Dispersion of IR8

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