

EIC 2nd Detector Working Group Meeting
19 December 2023

Z-Tagging Mini-DIRC

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EICGENR&D2023_09



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 $\pm 1\%$ 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 2nd focus.

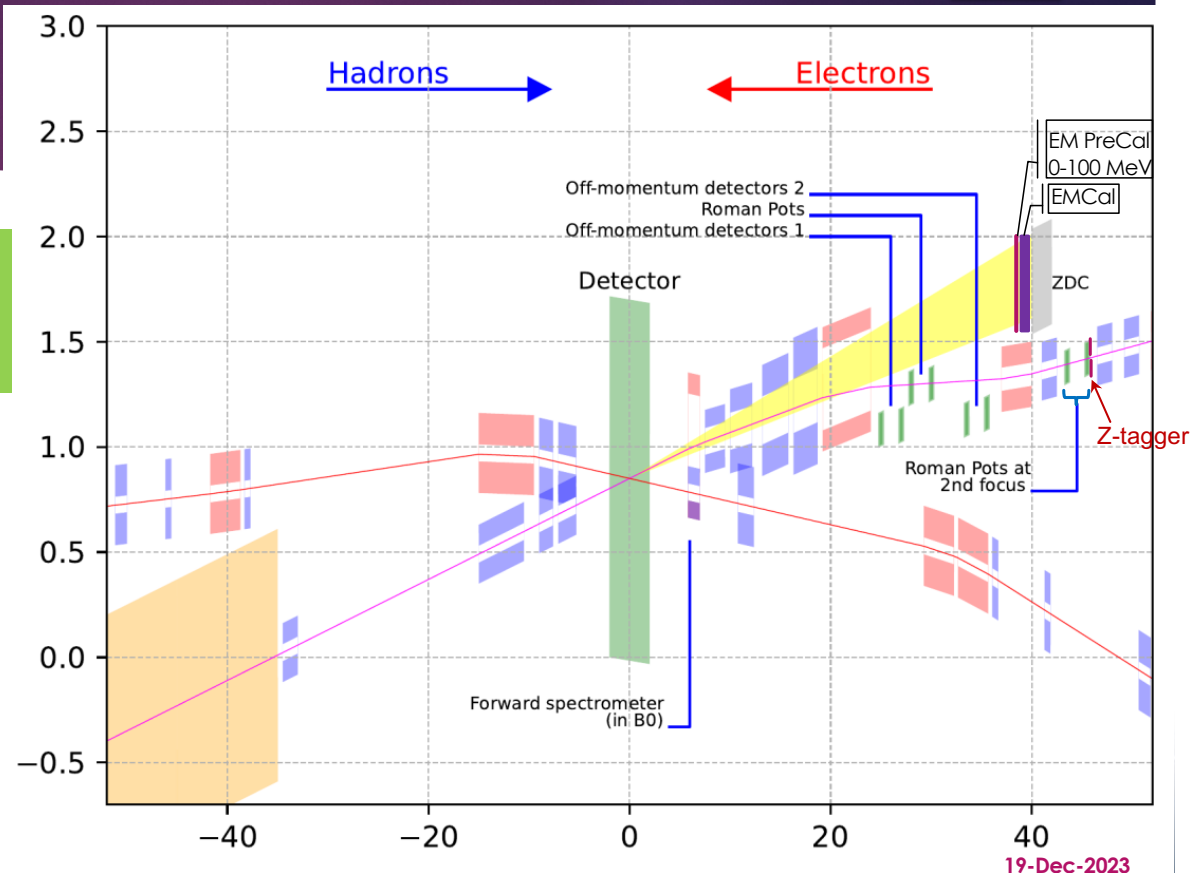
IR-8 Layout

Second Focus

D_x = Dispersion = 0.48 m/100%
 $1 - x_L = \pm \text{Beam-Stay-Clear} \leq 1\%$

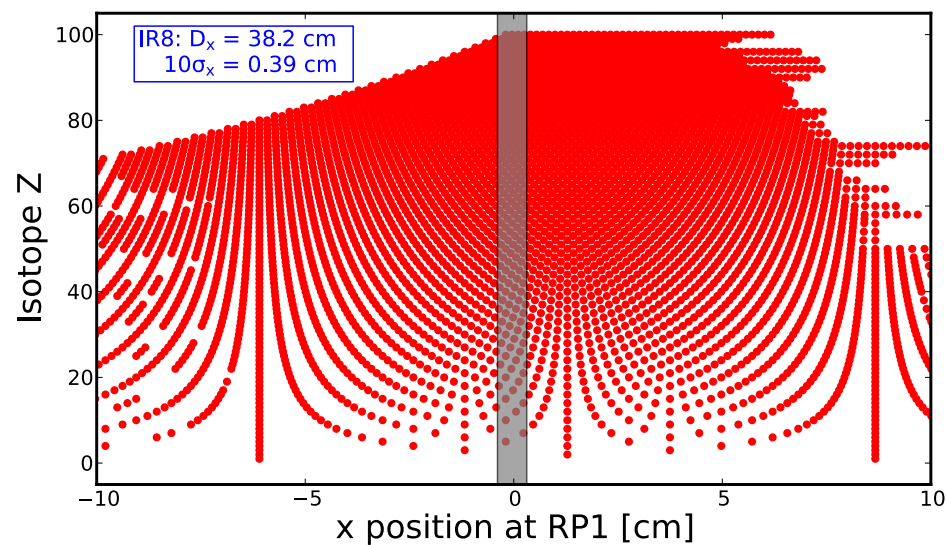
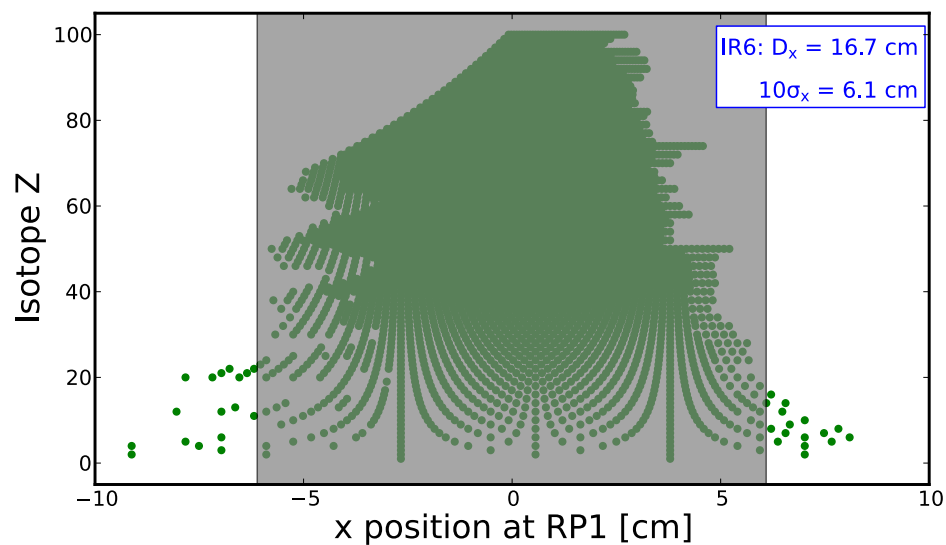
Parameters at the 2nd focus for different energies

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



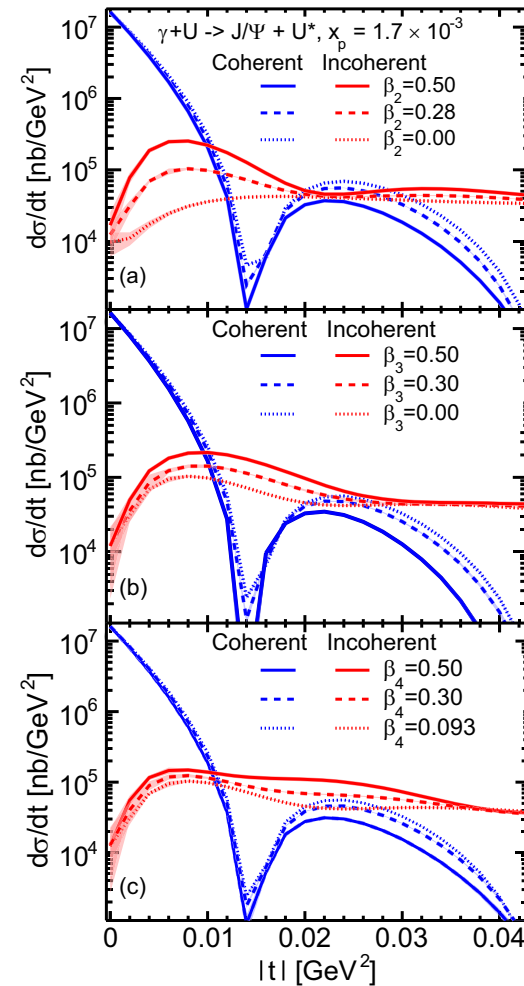
Isotope Tagging

- ▶ 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)

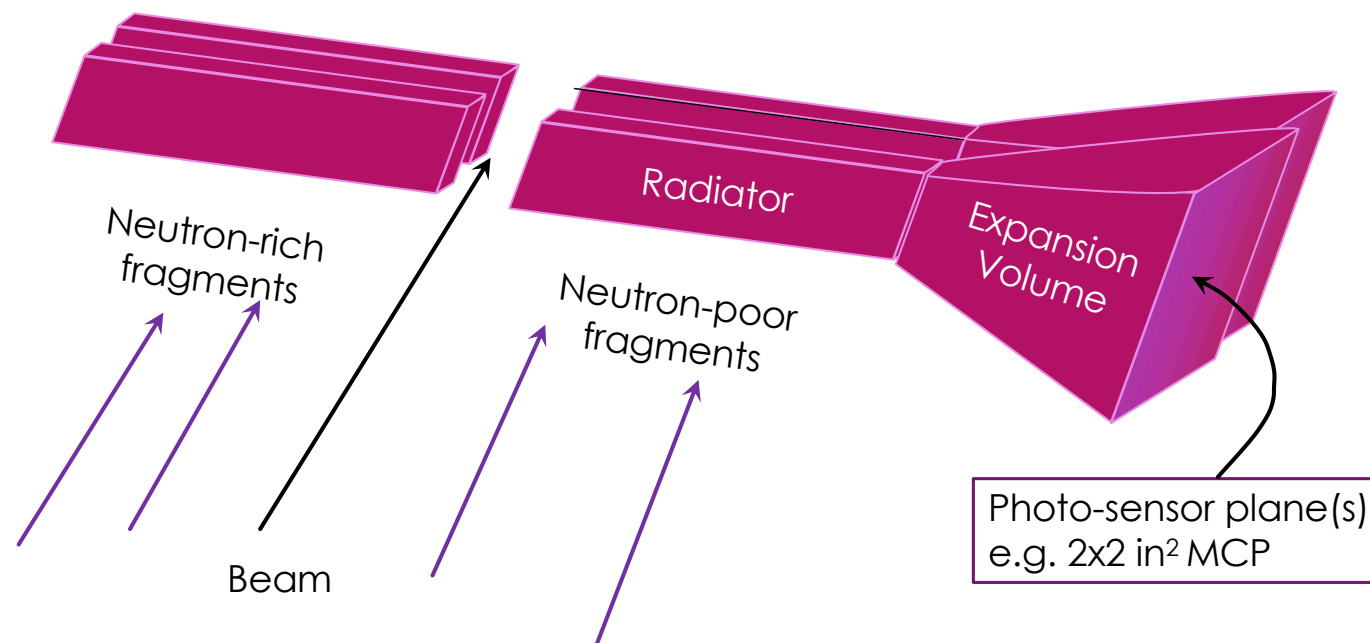


Cherenkov Light

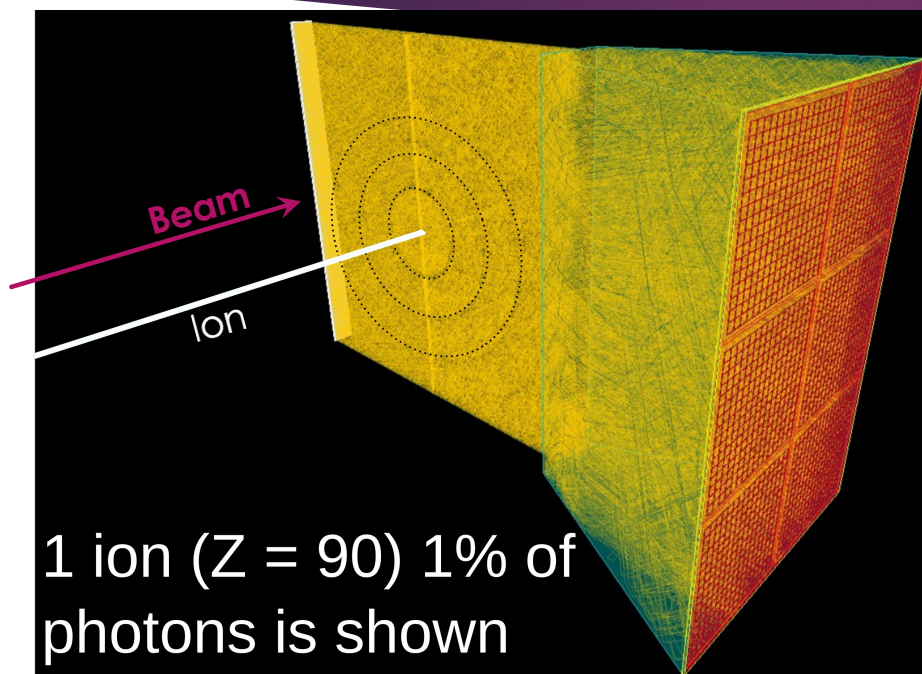
- ▶ $\frac{d^2n_\gamma}{dx d\lambda} = Z^2 \left[1 - \frac{1}{\beta^2 n^2(\lambda)} \right]$
- ▶ Thin Quartz radiator (0.5 cm), 50% light-collection, MCP-PMT Quantum Efficiency
 - ▶ $1.6 \cdot 10^5$ photo-electrons from Z=90 ion
 - ▶ 21 photo-electrons from Z=1 ion
- ▶ Imaging not necessary/feasible
- ▶ Poisson statistics are (in principle) sufficient to resolve Z from $Z \pm 1$ for all Z from 1 to 90

Schematic layout (behind trackers) in 2nd Roman Pot at second focus of IR8

- ▶ Approx dimensions
 - ▶ 0.5 cm deep
 - ▶ 1.0 cm tall
 - ▶ 15 cm wide
- ▶ Two Layers
 - ▶ High gain for low-Z: $p, d, {}^3\text{H}, {}^3\text{He}, {}^4\text{He} \dots$
 - ▶ Low-gain high-Z fragments



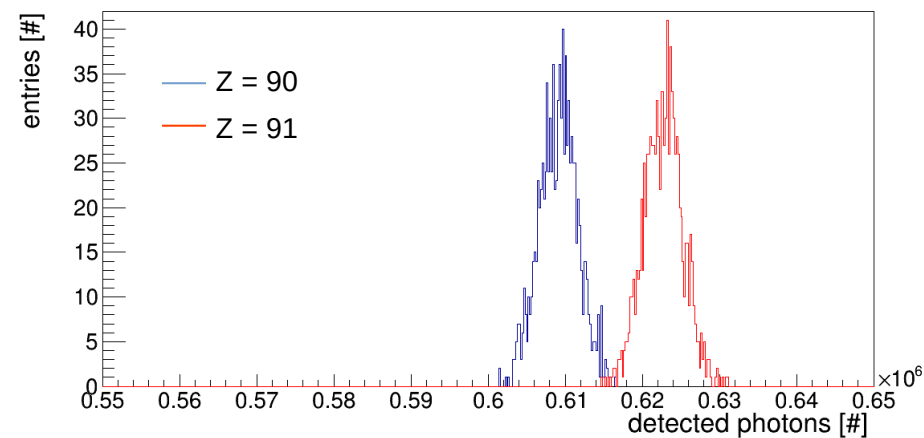
Initial Simulation Results



EIC 2nd Detector WG

C. Hyde

Photon yield



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

19-Dec-2023

Performance Challenges

- ▶ Variation of light collection for ion impact points over ≥ 10 cm length of radiator.
- ▶ Photo-sensor non-uniformities:
 - ▶ Spatial variation of Q.E.
 - ▶ Gain saturation at large amplitudes
- ▶ Effect of delta-rays
- ▶ Optimal strategy for High-Gain / Low-Gain combination
 - ▶ Separate sensors (as drawn)?
 - ▶ Light sharing (splitting expansion volume)?
 - ▶ Deuteron fragment in ^{208}Pb has 79% of beam rigidity \rightarrow Appears in RP 10 cm from beam

Z-Tagging MiniDIRC Collaboration

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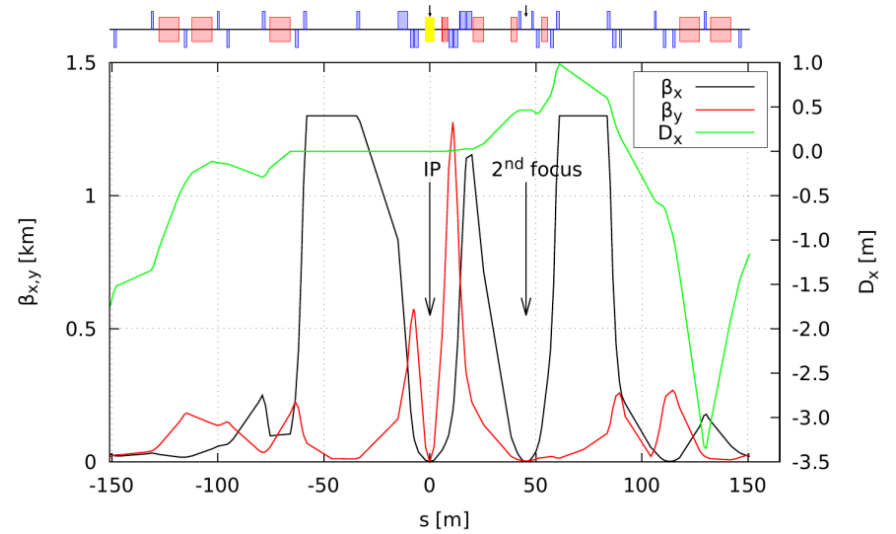
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Summary of Background Estimates

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

IR8

- Beta-functions and Dispersion of IR8



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