Update on IP8 DD4hep Simulation: Vetoing Efficiency and Beam Parameters

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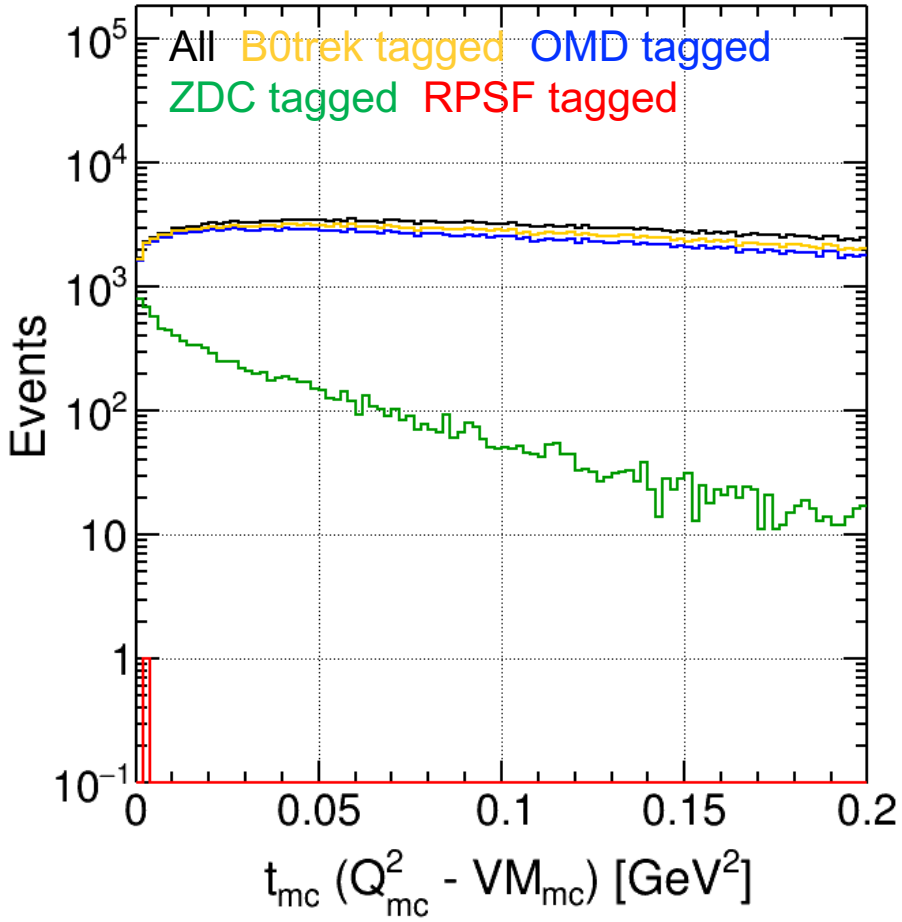
Approach – Incoherent Vetoing Efficiency

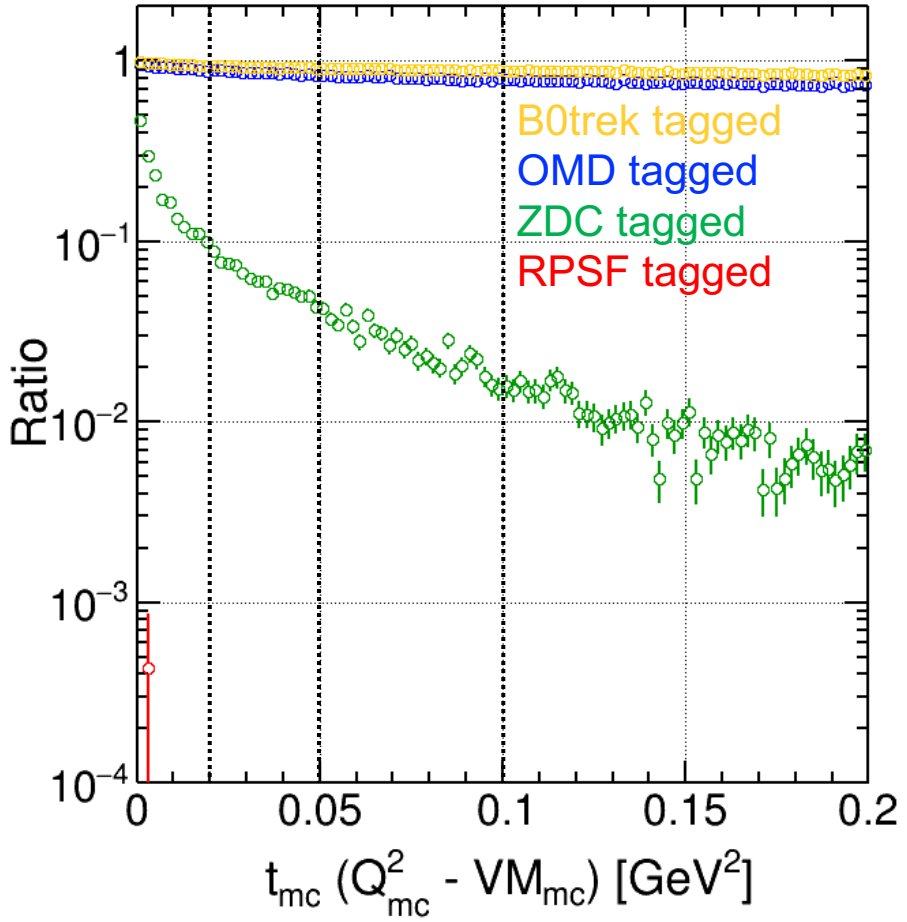
- Used simulated **BeAGLE** 801k events with **$1 < Q^2 < 10$**
  - **ePb 18×110 GeV incoherent $J/\psi(\mu\mu)$ events** $ePb \rightarrow e' + J/\psi(\mu\mu) + X$ (S3/eictest/EPIC/EVGEN/EXCLUSIVE/DIFFRACTIVE_JPSI_ABCONV/BeAGLE/ePb_18x108.41_tau10_B1.1_Jpsi_highstats/ePb_18x108.41_tune3_tau10_B1.1_extracted_Jmu_1.hepmc)
- Passed through **afterburner IP8 eAu** configuration
  - IP8 crossing angle (35 mrad) and IP6 eAu beam effects based on **EIC CDR table 3.5**
- Discarded events having **more than one electron in final state with η < -1**
- Calculated **10σ safe distance cut** based on ***eAu β @ IP6 and @ IP8 RPSF***
- **Tagged events for nuclear breakups *tagging purpose***
  - B0 Tracker: **at least two out of four layers** have registered RAW hits
  - OMD: **two layers** (actual four layers as redundancy) have registered RAW hits
  - ZDC: **any registered RAW hits** in either ECAL and HCAL
  - RPSF: **one layer (closet to 2nd focus)** has registered RAW hits outside **10σ** safe distance
  - B0 Ecal: **energy** of all hits greater than **100 MeV**

t distribution

BeAGLE 18x110 GeV^2
Incoherent events
$ePb \rightarrow e' + J/\psi(\mu\mu) + X$



Coherent diffractive minima

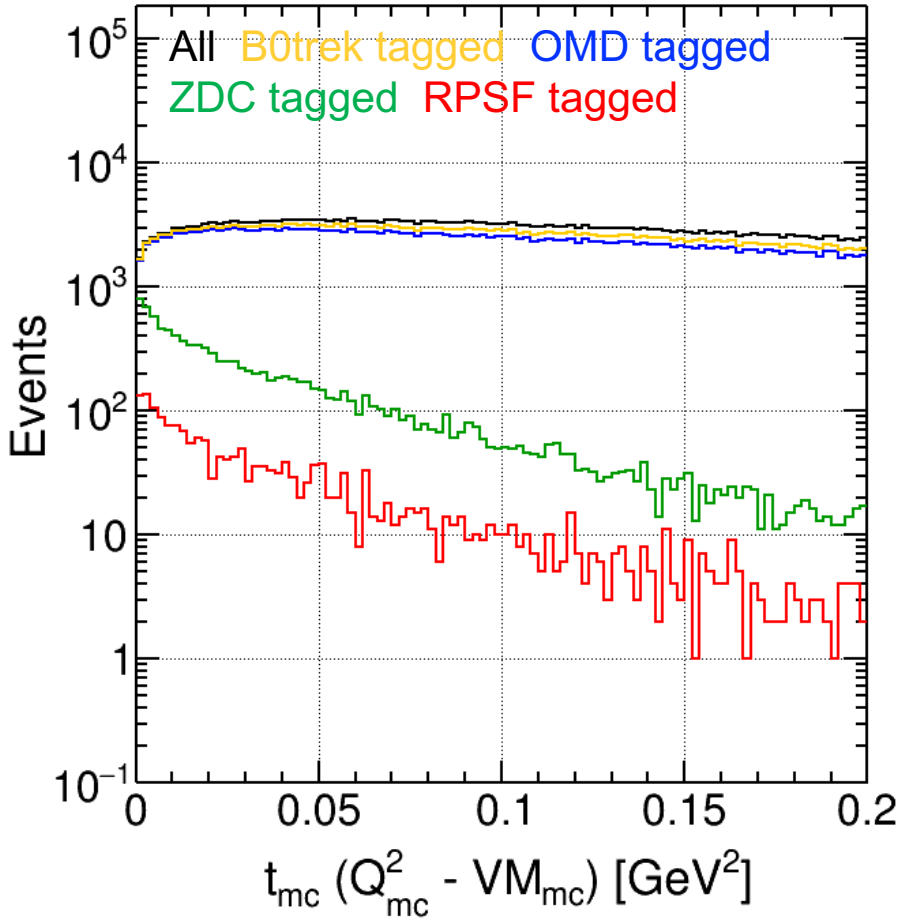


With 10σ safe distance cut based on ***ep β @ IP6***

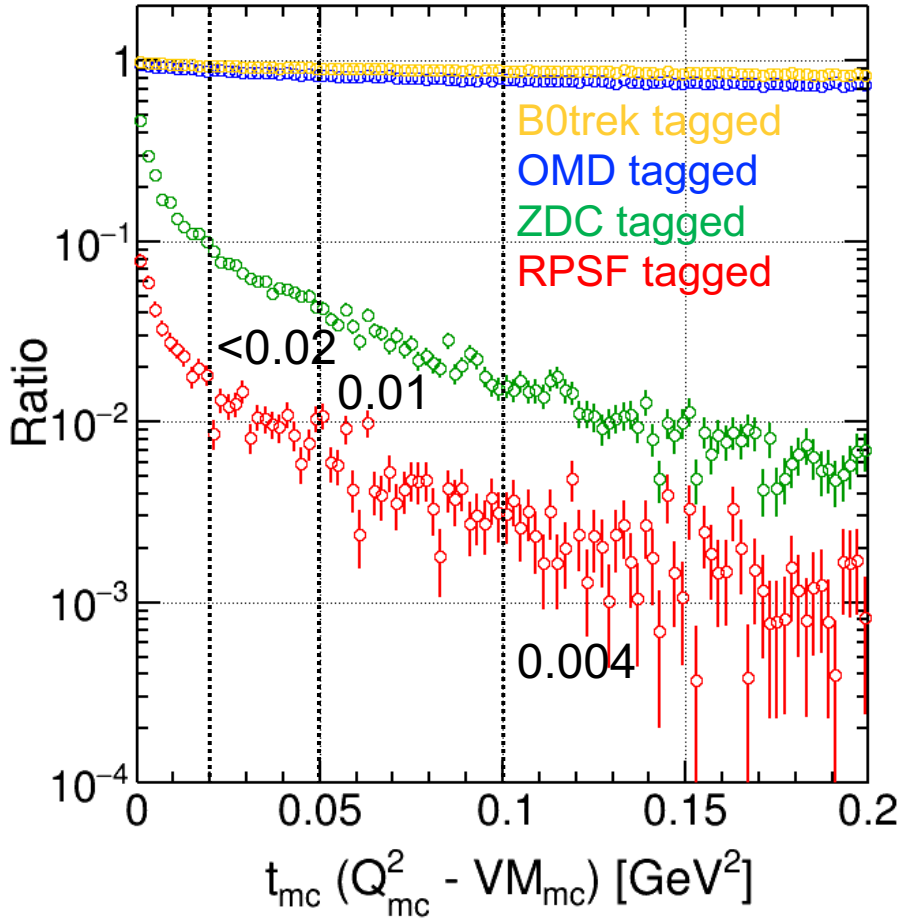
1 of 800,964 events were NOT tagged

t distribution

BeAGLE 18x110 GeV^2
Incoherent events
$ePb \rightarrow e' + J/\psi(\mu\mu) + X$



Coherent diffractive minima



With 10σ safe distance cut based on ***ep β @ IP8 RPSF***

2,250 of 800,964 events were NOT tagged

t distribution

BeAGLE 18x110 GeV^2
Incoherent events
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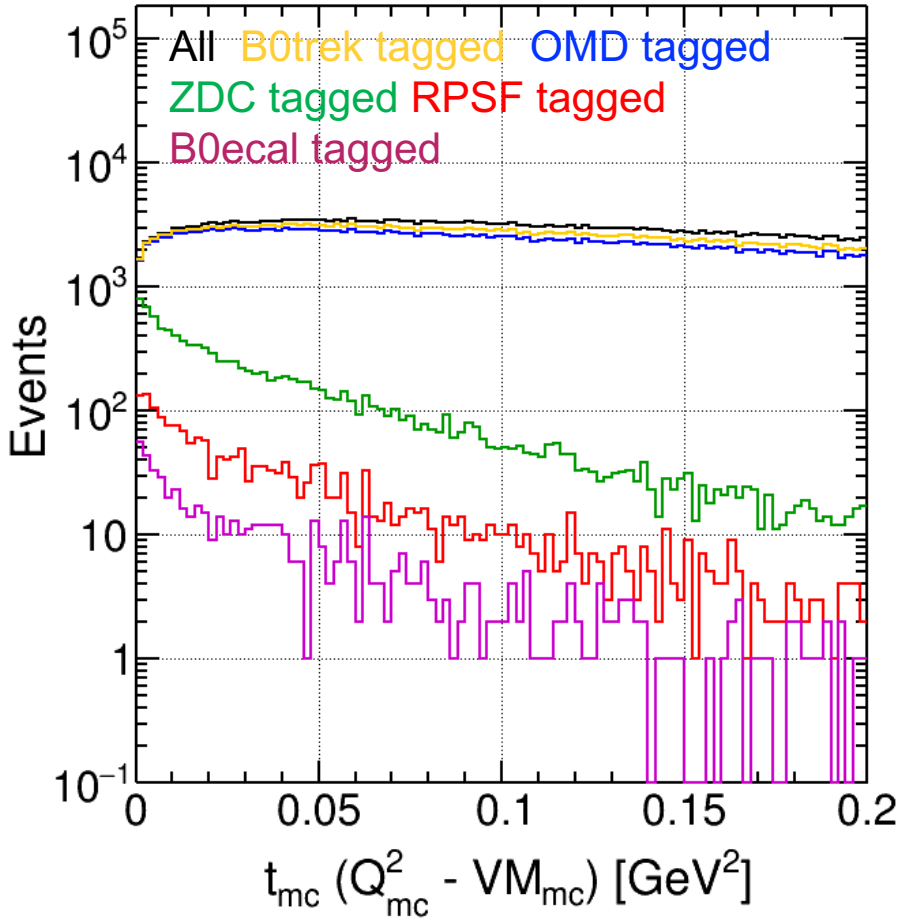
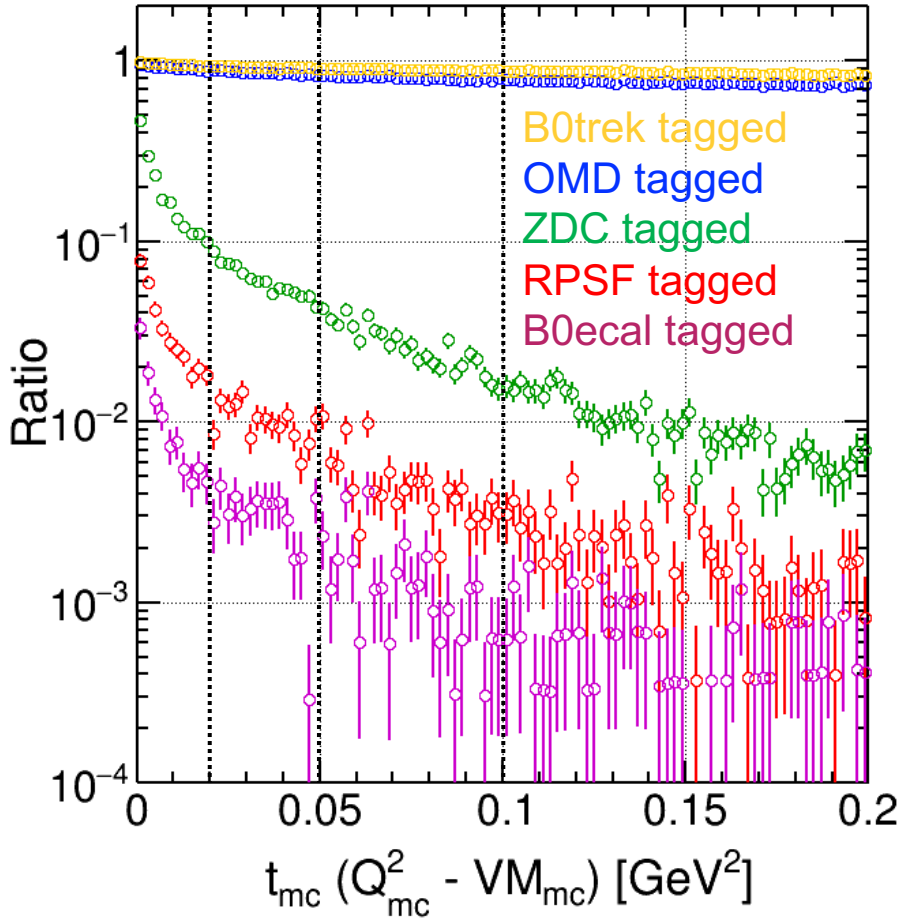


Coherent diffractive minima

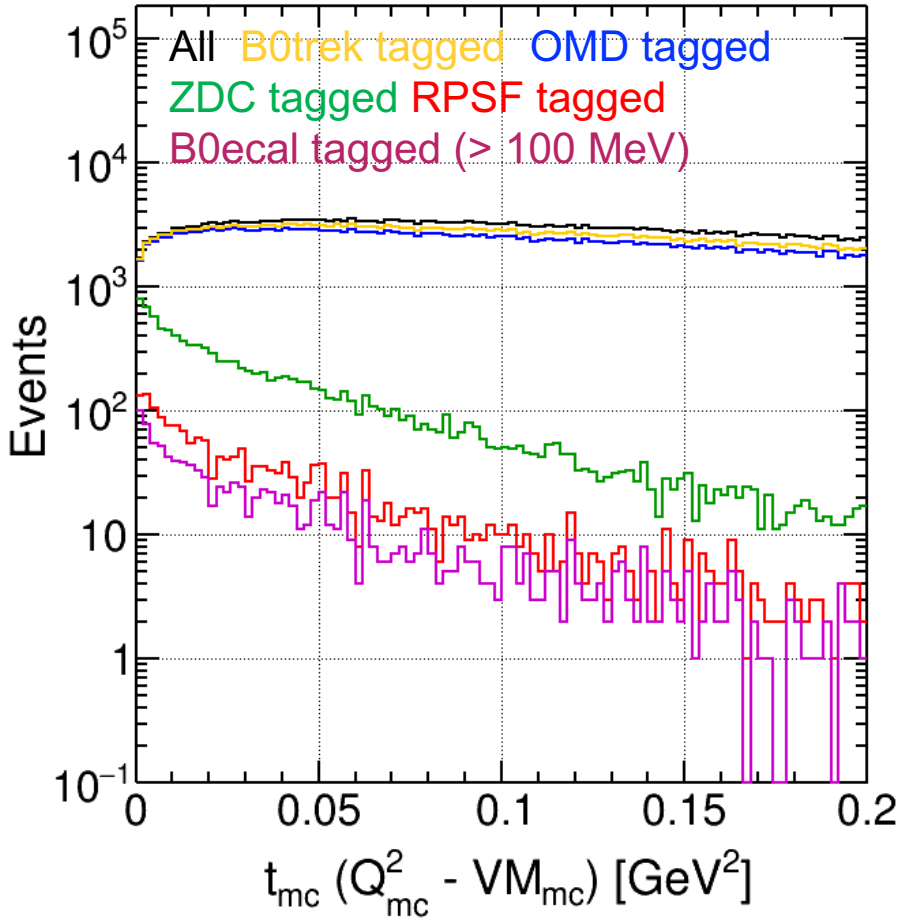


With 10σ safe distance cut based on ***ep β @ IP8 RPSF* + B0 Ecal tagged (any raw hits)**

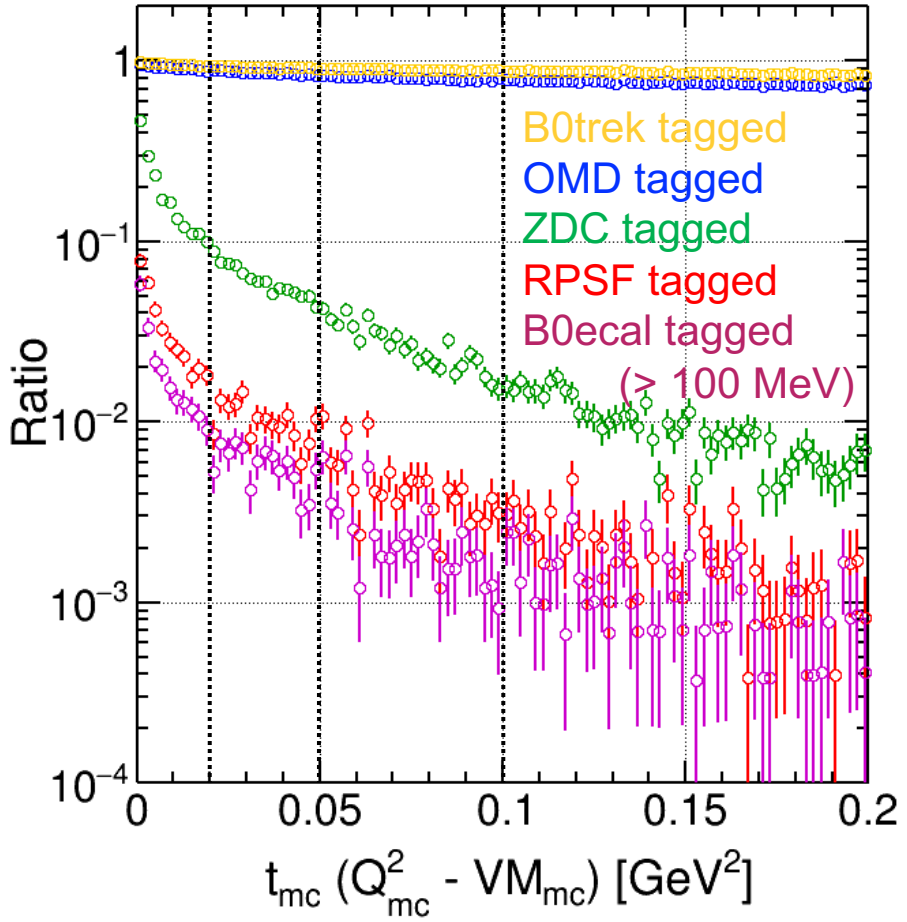
638 of 800,964 events were NOT tagged

t distribution

BeAGLE 18x110 GeV^2
Incoherent events
$ePb \rightarrow e' + J/\psi(\mu\mu) + X$



Coherent diffractive minima



With 10σ safe distance cut based on ***ep β @ IP8 RPSF* + B0 Ecal tagged (> 100 MeV)**

1286 of 800,964 events were NOT tagged

Approach – Missing Components for IP8

- **10σ safe distance cut** based on **beam parameters**
  - Safe distance where Roman Pot detectors can be placed close to beam
  - **Transverse beam size (σ)** is defined as $\sigma_{x,y} = \sqrt{\epsilon_{x,y}\beta(z)_{x,y} + D_{x,y}\frac{\Delta p}{p}}$

    where ϵ : Emittance, $\boldsymbol{\beta}$ **: Beta function**, D : Momentum dispersion, $\frac{\Delta p}{p}$: Momentum spread

18 GeV on 275 GeV	Momentum Dispersion (D)	Emittance X (ϵ_x) [mm]	Emittance Y(ϵ_y) [mm]	Beta function X (β_x*) [mm]	Beta function Y (β_y*) [mm]	Momentum spread $\Delta p/p$
IP6 ep High Divergence	-0.21	18.e-6	1.6e-6	800	71	6.8e-4
18 GeV on 110 GeV	**Momentum Dispersion (D)**	**Emittance X (ϵ_x) [mm]**	**Emittance Y(ϵ_y) [mm]**	**Beta function X (β_x*) [mm]**	**Beta function Y (β_y*) [mm]**	**Momentum spread $\Delta p/p$**
IP6 eAu	-0.21	43.2e-6	5.8e-6	910	40	6.2e-4

Momentum Dispersion (D) are from Randy's. Beta functions(β_x* and β_y*) in table are values at IP6 interaction point (z = 0)

Beam Parameters for IP8 Study

- Use IP6 beam conditions except for **momentum dispersion (D) and Beta function @ secondary focus from Randy's**

18 GeV on 275 GeV	Momentum Dispersion (D)	Emittance X (ϵ_x) [mm]	Emittance Y(ϵ_y) [mm]	Beta function X (β_x) [mm]	Beta function Y (β_y) [mm]	Momentum spread $\Delta p/p$
IP8 ep High Divergence	0.382	18.e-6	1.6e-6	$\beta_x^{*(z=0)}$ = 800	$\beta_y^{*(z=0)}$ = 71	6.8e-4
	0.382	18.e-6	1.6e-6	β_x Secondary focus 2289.454596	β_y Secondary focus 4538.713168	6.8e-4
18 GeV on 110 GeV	**Momentum Dispersion (D)**	**Emittance X (ϵ_x) [mm]**	**Emittance Y(ϵ_y) [mm]**	**Beta function X (β_x*) [mm]**	**Beta function Y (β_y*) [mm]**	**Momentum spread $\Delta p/p$**
IP8 eAu	0.382	43.2e-6	5.8e-6	$\beta_x^{*(z=0)}$ = 910	$\beta_y^{*(z=0)}$ = 40	6.2e-4
	0.382	43.2e-6	5.8e-6	β_x Secondary focus 2289.454596	β_y Secondary focus 4538.713168	6.2e-4

Summary 10σ Safe Distance Cut

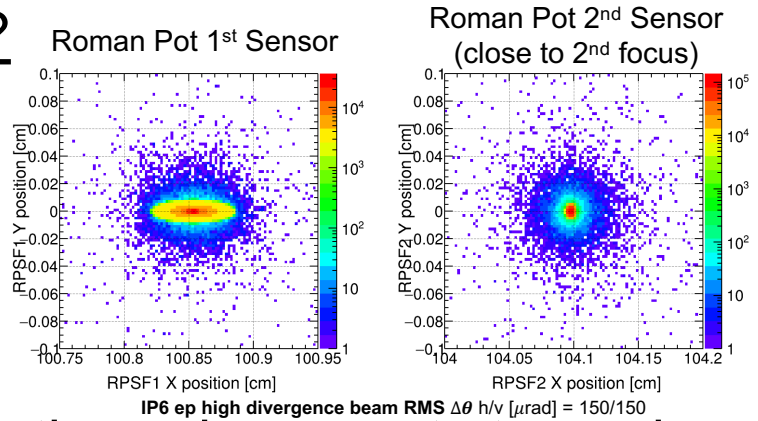
- For IP8, used IP6 beam conditions except for **momentum dispersion (D) and Beta function @ secondary focus from Randy's**

	σ_{1x}	σ_{1y}
ep β @ IP8 (= IP6)	0.121077	0.0193225
ep β @ IP8 RPSF	**0.203642**	**0.0867277**
eAu β @ IP8 (= IP6)	0.198869	0.0216527
eAu β @ IP8 RPSF	**0.314867**	**0.1629770**
Wan's IP8 Study	0.328283	0.085217

Missing Components for IP8

- Evaluate more **realistic $\beta(z)_{x,y}$** especially for **IP8 eAu Beam Optics** (**other nuclei?**)
  - Need $\beta(z)_{x,y}$ at roman pot detector
  - For incoherent vetoing efficiency study, eAu beam optics would be very helpful
  - Assume **ep $\beta(z)_{x,y}$ at IP6 and IP8** can be **similar**?
  - May need use different $\beta(z)_{x,y}$

  for possible 3 roman pot stations, see figures →
  (ex. 1st – 2nd "secondary focus" – 3rd)

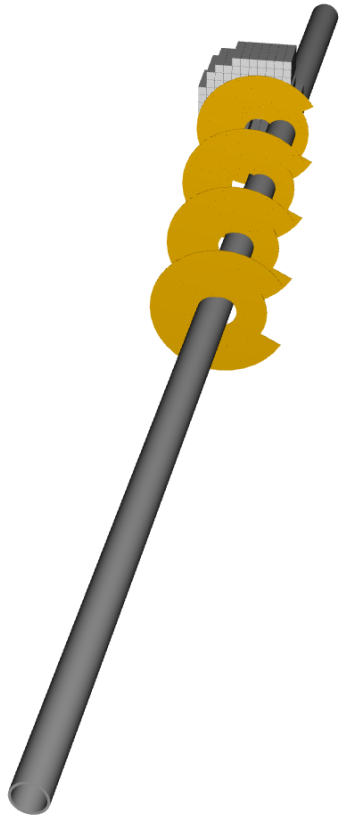


- Evaluate **transfer matrices** to describe particle motion through magnets towards detector
  - In order to reconstruct very forward final-state protons

Next Steps

- Need IP8 beam optics study
  - Evaluate more realistic $\beta(z)_{x,y}$ especially for at secondary focus to quantify vetoing power for 2nd detector

- (Work in progress) Implementing hadron downstream beam pipe at B0 spectrometer (+ ZDC)
  - Quantify impact on low pT cutoffs and acceptance



EIC CDR Table 3.3 (ep High Divergence)

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Table 3.3: EIC beam parameters for different center-of-mass energies $\sqrt{s}$, with strong hadron cooling. High divergence configuration.

Species	proton	electron	proton	electron	proton	electron	proton	electron	proton	electron
Energy [GeV]	275	18	275	10	100	10	100	5	41	5
CM energy [GeV]	140.7		104.9		63.2		44.7		28.6	
Bunch intensity [10^{10}]	19.1	6.2	6.9	17.2	6.9	17.2	4.8	17.2	2.6	13.3
No. of bunches	290		1160		1160		1160		1160	
Beam current [A]	0.69	0.227	1	2.5	1	2.5	0.69	2.5	0.38	1.93
RMS norm. emit., h/v [µm]	5.2/0.47	845/71	3.3/0.3	391/26	3.2/0.29	391/26	2.7/0.25	196/18	1.9/0.45	196/34
RMS emittance, h/v [nm]	18/1.6	24/2.0	11.3/1.0	20/1.3	30/2.7	20/1.3	26/2.3	20/1.8	44/10	20/3.5
β^*, h/v [cm]]	80/7.1	59/5.7	80/7.2	45/5.6	63/5.7	96/12	61/5.5	78/7.1	90/7.1	196/21.0
IP RMS beam size, h/v [µm]	119/11		95/8.5		138/12		125/11		198/27	
K_x	11.1		11.1		11.1		11.1		7.3	
RMS $\Delta\theta$, h/v [µrad]	150/150	202/187	119/119	211/152	220/220	145/105	206/206	160/160	220/380	101/129
BB parameter, h/v [10^{-3}]	3/3	93/100	12/12	72/100	12/12	72/100	14/14	100/100	15/9	53/42
RMS long. emittance [10^{-3}, eV·s]	36		36		21		21		11	
RMS bunch length [cm]	6	0.9	6	0.7	7	0.7	7	0.7	7.5	0.7
RMS $\Delta p/p$ [10^{-4}]	6.8	10.9	6.8	5.8	9.7	5.8	9.7	6.8	10.3	6.8
Max. space charge	0.007	neglig.	0.004	neglig.	0.026	neglig.	0.021	neglig.	0.05	neglig.
Piwinski angle [rad]	6.3	2.1	7.9	2.4	6.3	1.8	7.0	2.0	4.2	1.1
Long. IBS time [h]	2.0		2.9		2.5		3.1		3.8	
Transv. IBS time [h]	2.0		2		2.0/4.0		2.0/4.0		3.4/2.1	
Hourglass factor H	0.91		0.94		0.90		0.88		0.93	
Luminosity [10^{33}cm^{-2}s^{-1}]	1.54		10.00		4.48		3.68		0.44	

EIC CDR Table 3.5 (eAu)

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Table 3.5: EIC beam parameters for e-Au operation for different center-of-mass energies $\sqrt{s}$, with strong hadron cooling.

Species	Au ion	electron	Au ion	electron	Au ion	electron	Au ion	electron
Energy [GeV]	110	18	110	10	110	5	41	5
CM energy [GeV]	89.0		66.3		46.9		28.6	
Bunch intensity [10^{10}]	0.08	6.2	0.05	17.2	0.05	17.2	0.036	17.2
No. of bunches	290		1160		1160		1160	
Beam current [A]	0.23	0.227	0.57	2.50	0.57	2.50	0.41	2.50
RMS norm. emit., h/v [µm]	5.1/0.7	705/20	5.0/0.4	391/20	5.0/0.4	196/20	3.0/0.3	196/20
RMS emittance, h/v [nm]	43.2/5.8	20.0/0.6	42.3/3.0	20.0/1.0	42.3/3.0	20.0/2.0	68.1/5.7	20.0/2.0
β^*, h/v [cm]]	91/4	196/41	91/4	193/12	91/4	193/6	90/4	307/11
IP RMS beam size, h/v [µm]	198/15		196/11		197/11		248/15	
K_x	0.077		0.057		0.056		0.061	
RMS $\Delta\theta$, h/v [µrad]	218/379	101/37	216/274	102/92	215/275	102/185	275/377	81/136
BB parameter, h/v [10^{-3}]	1/1	37/100	3/3	43/47	3/2	86/47	5/4	61/37
RMS long. emittance [10^{-3}, eV·s]	16		16		16		16	
RMS bunch length [cm]	7	0.9	7	0.7	7	0.7	11.6	0.7
RMS $\Delta p/p$ [10^{-4}]	6.2	10.9	6.2	5.8	6.2	6.8	10	6.8
Max. space charge	0.007	neglig.	0.008	neglig.	0.008	neglig.	0.038	neglig.
Piwinski angle [rad]	4.4	1.1	4.5	1.2	4.5	1.5	5.8	1.2
Long. IBS time [h]	0.33		0.36		0.36		0.85	
Transv. IBS time [h]	0.81		0.89		0.89		0.16	
Hourglass factor H	0.85		0.85		0.85		0.71	
Luminosity [10^{33}cm^{-2}s^{-1}]	0.52		4.76		4.77		1.67	