CLIC 380 GeV Post-Collision Line

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John Adams Institute for Accelerator Science
University of Oxford
&
CERN

Monday, January 21, 2019
CLIC Workshop 2019 - CERN

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What will I be presenting today?

1. Goals of post-collision line study
2. Previous work (mostly for CDR)
3. Current studies (mostly for PIP)
4. Partial list of what is left to do

Goals of post-collision study

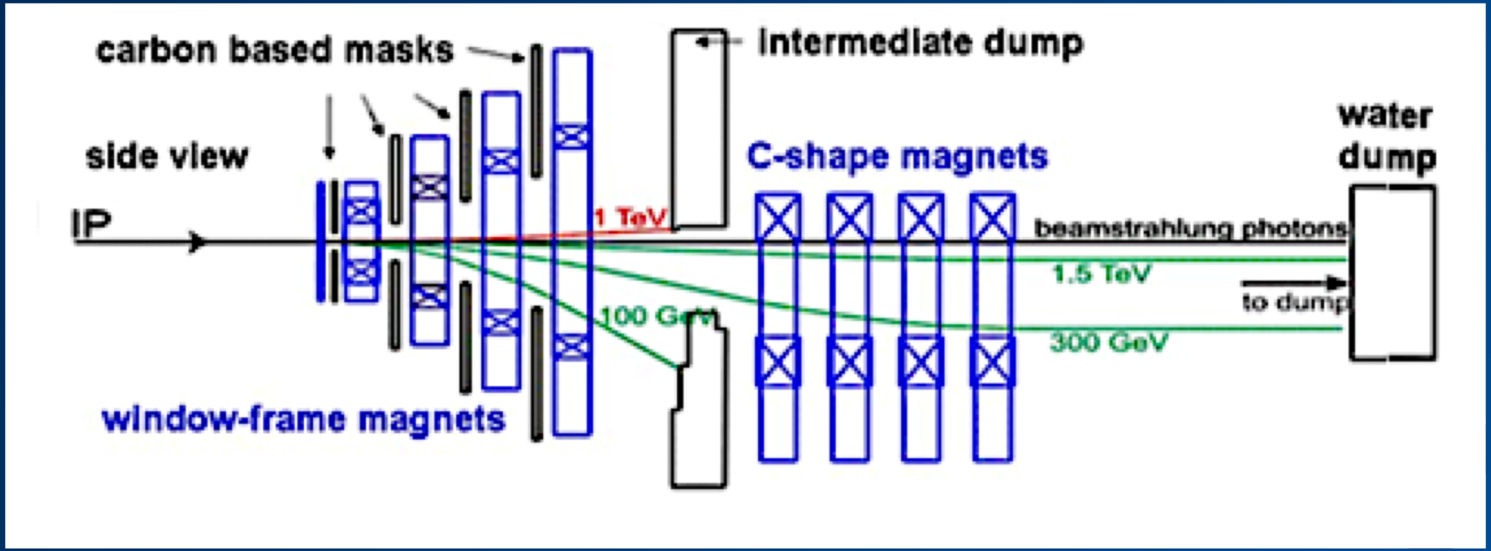
Guide the beam to the dump

- Safely guide both collided and uncollided beam to the dump.
  - Must take into account large energy spread
  - Must be aware of wrong-charge particles
  - Must minimize deposition on beamline components, especially magnets
- For PIP, needed to check if CDR version would work for 380 GeV
  - Very basic study, but needed to check that there are no unexpected surprises
- The design of the dump itself is not included in this work

Previous studies

Previous work in CDR for 3 TeV

- Several 3 TeV designs inconsistent with each other
- Previous work written up, but incomplete
  - No codes, scripts, lattices, etc… are available from previous work



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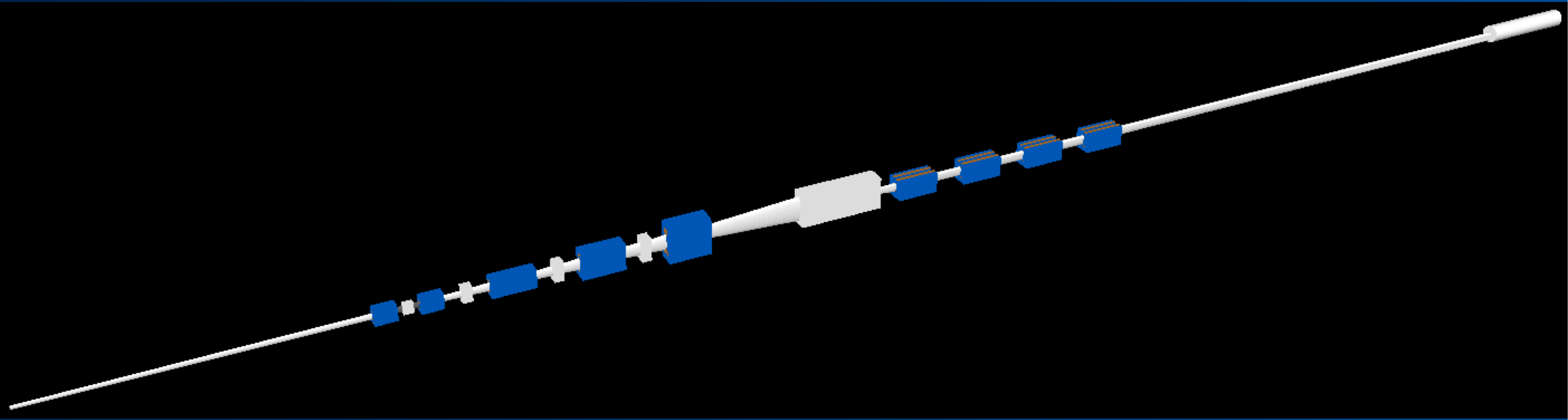
Going back to the beginning…

Time to re-invent the wheel

- Using only inconsistent descriptions from several sources, re-made the whole PCL from scratch using BDSIM and its utilities
- With the support of Laurie Nevay and Andrey Abramov (RHUL & CERN), went through piece-by-piece and created all of the necessary components
- Required some added capabilities of BDSIM - beam pipe shapes inside magnets and v/hkicker fringe fields
- Unexpectedly, required creating custom geometries for almost every component

A bigger task than expected



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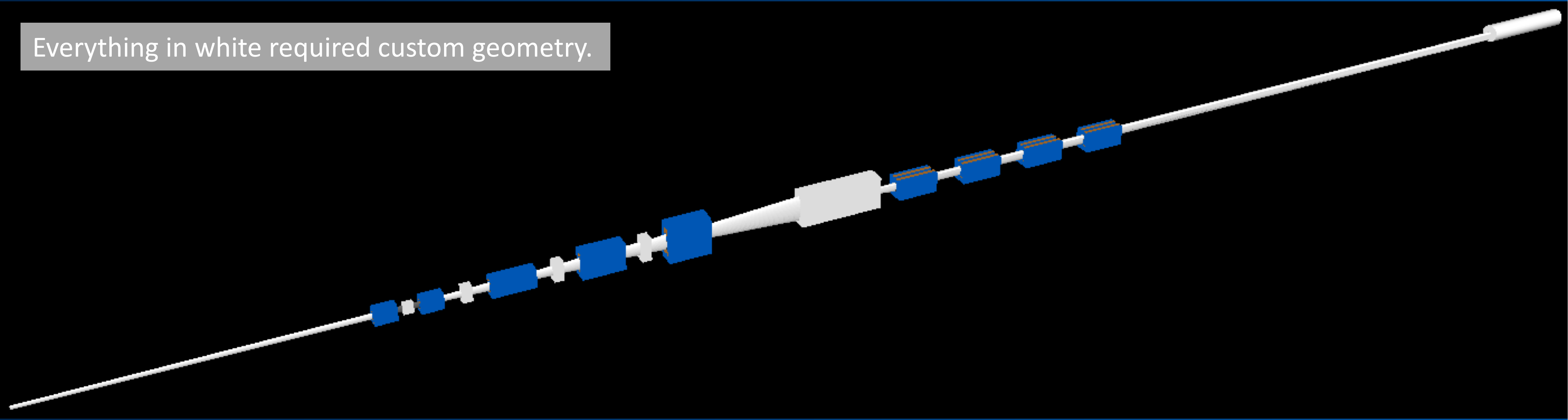
A bigger task than expected

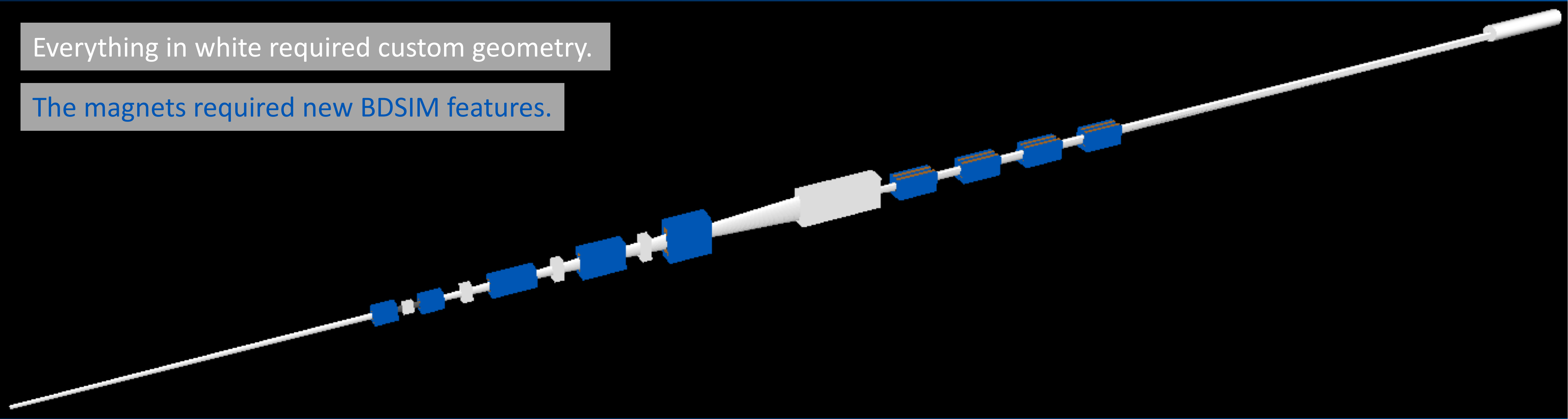
Everything in white required custom geometry.



A bigger task than expected

Everything in white required custom geometry.

The magnets required new BDSIM features.



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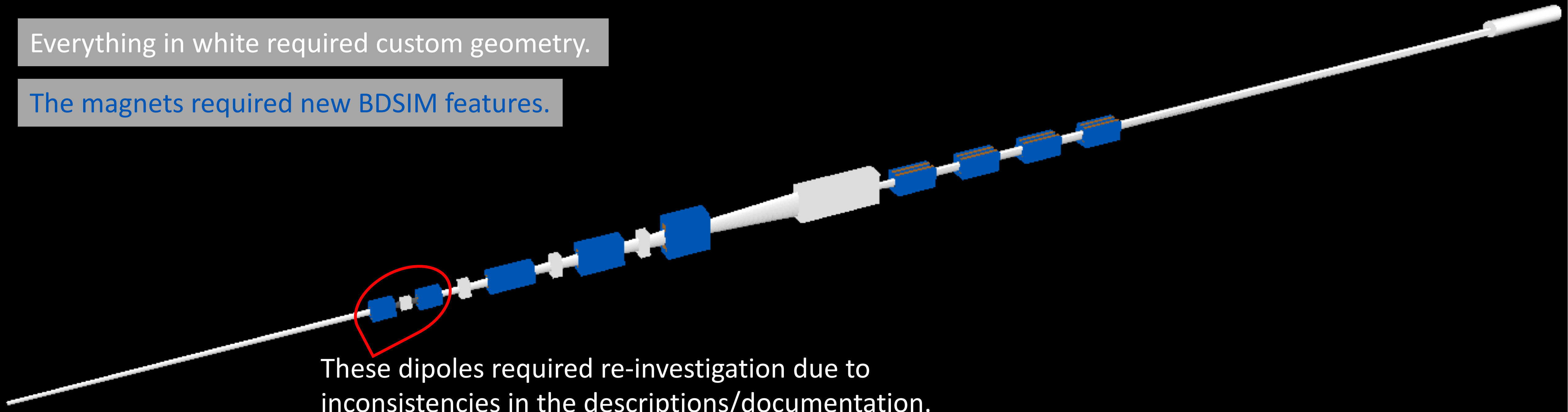
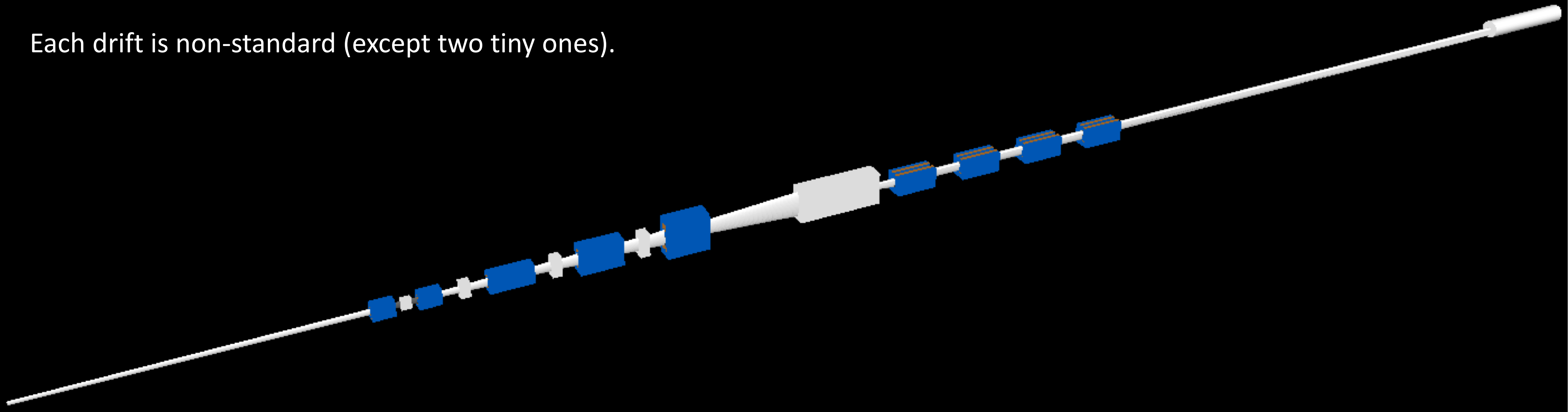


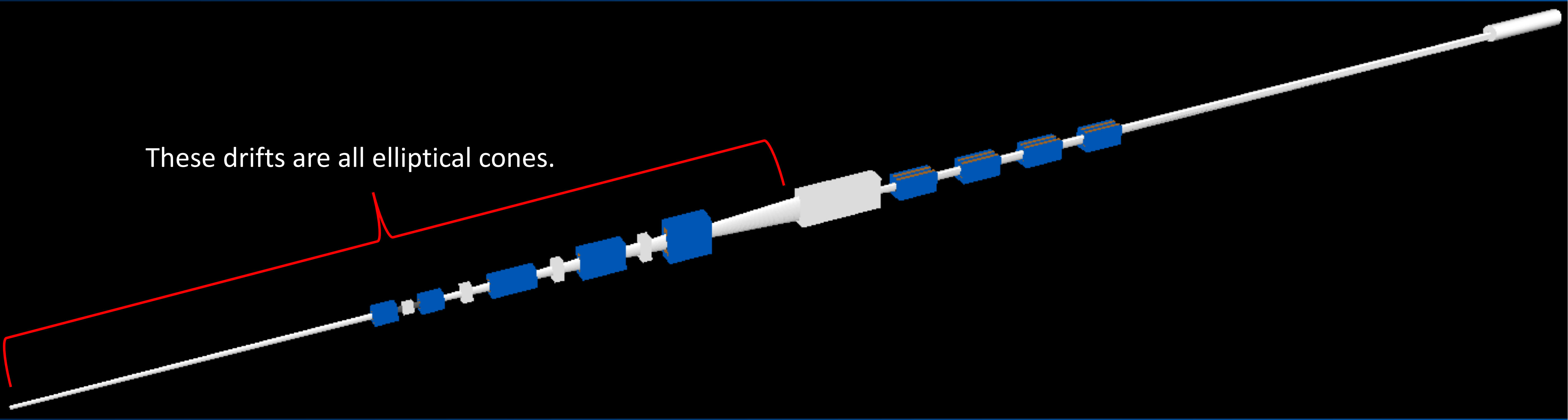
These dipoles required re-investigation due to inconsistencies in the descriptions/documentation.

A bigger task than expected

Each drift is non-standard (except two tiny ones).



A bigger task than expected



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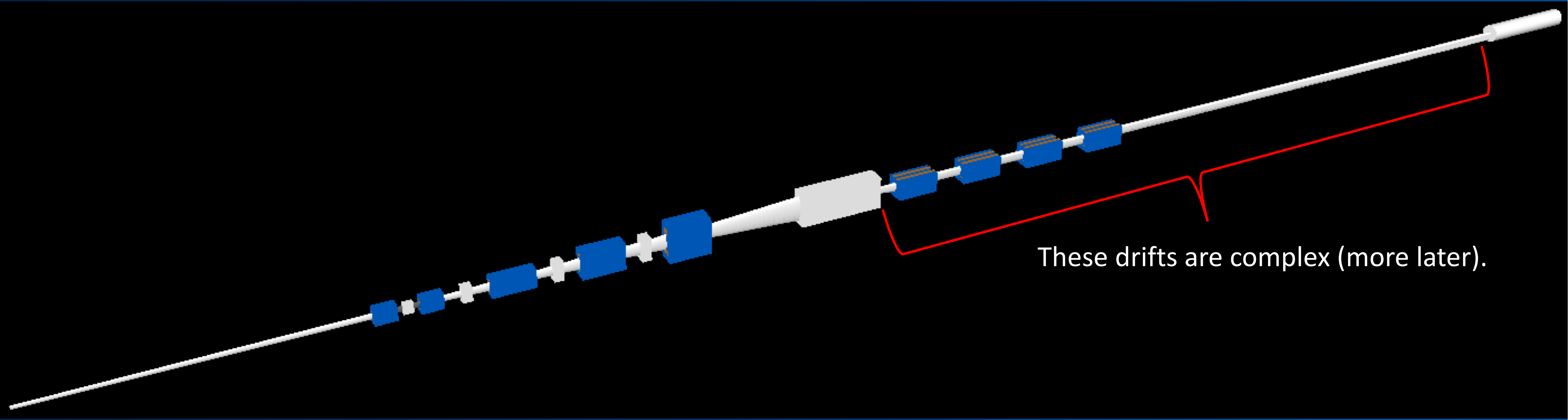
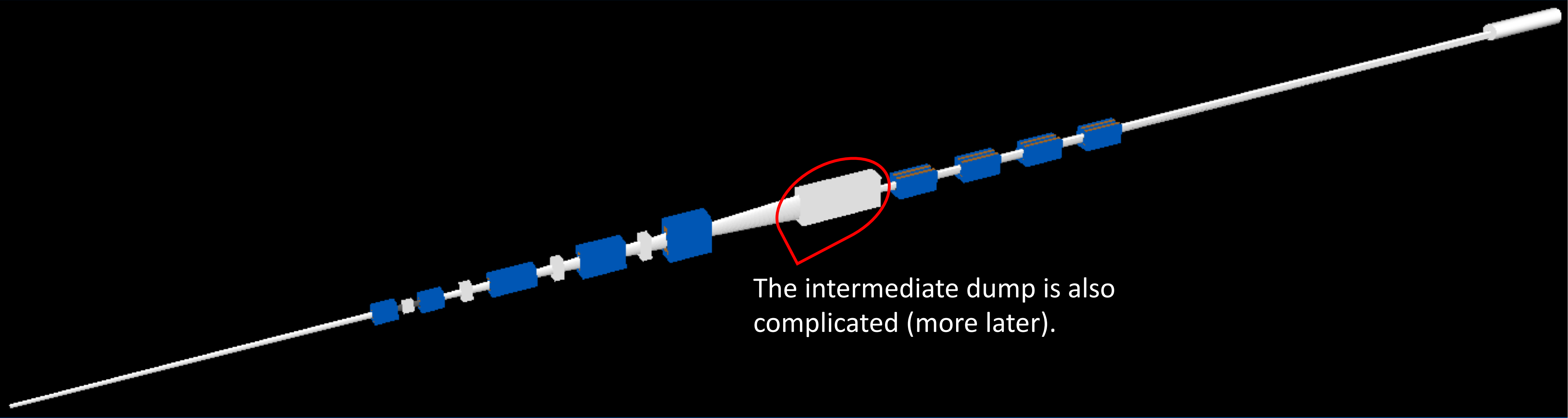
A bigger task than expected

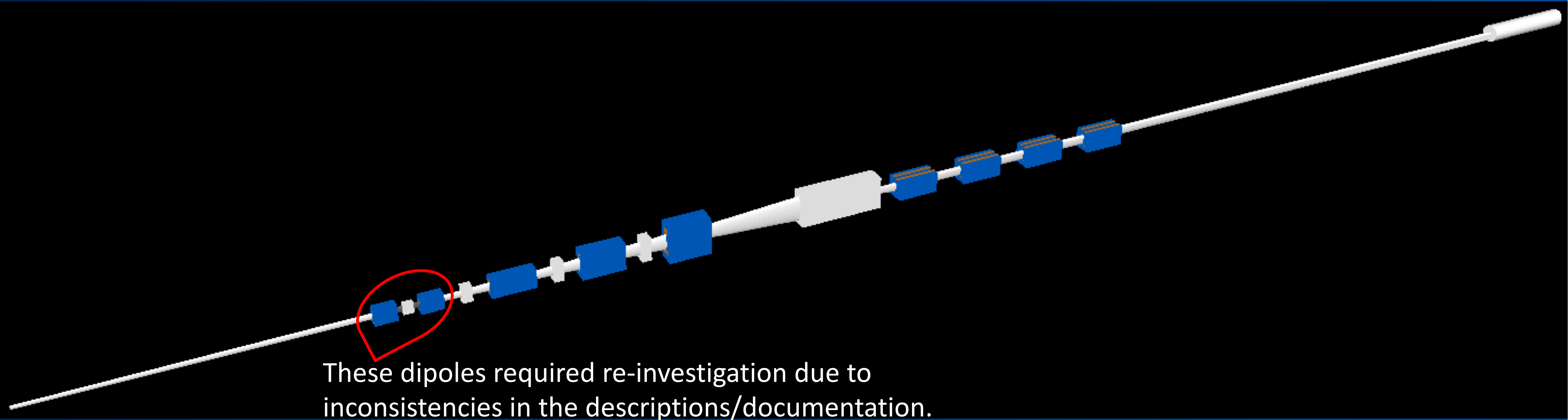


A bigger task than expected

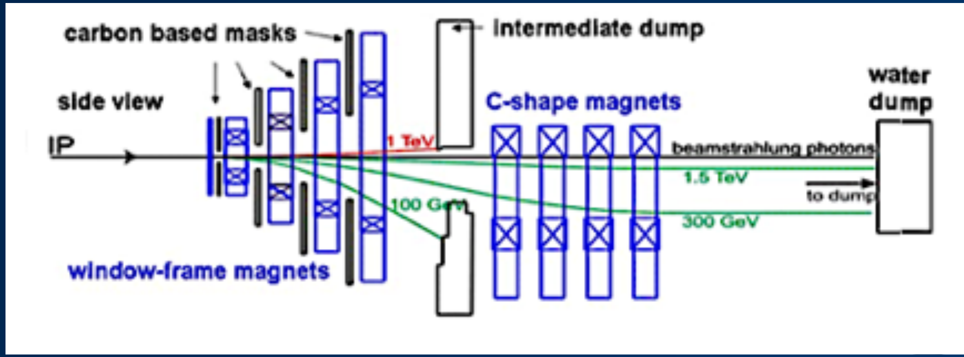


The intermediate dump is also complicated (more later).

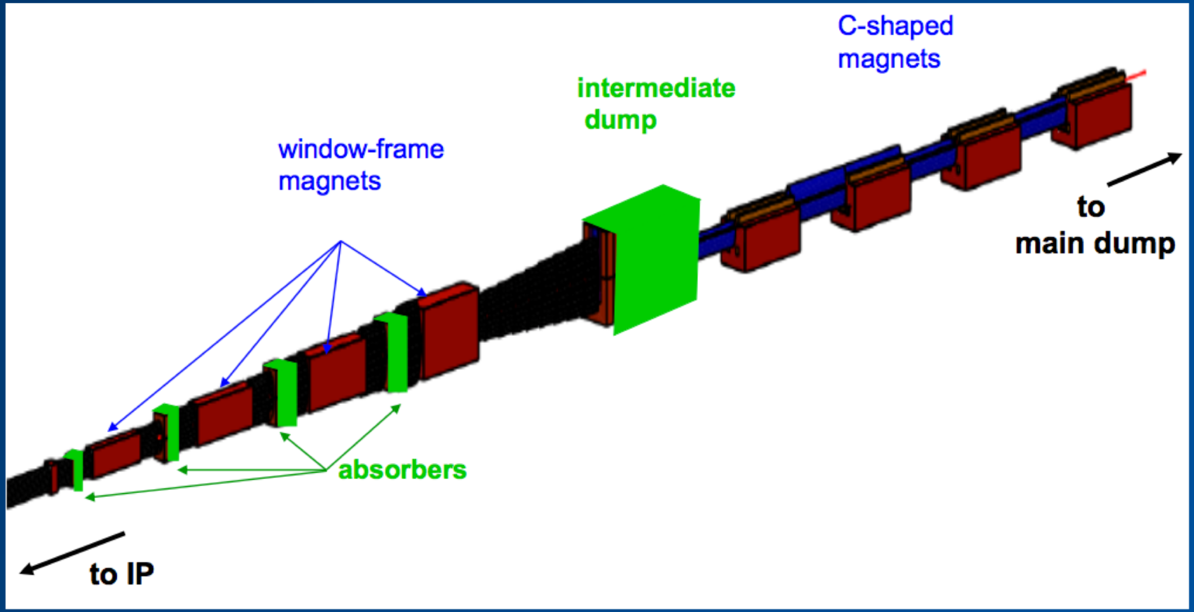
Quickly about these magnets



First dipole pair (Mag1a1b)



Previous design



- CDR and previous work splits first dipole into a pair
  - 0.5 m and 3.5 m lengths
  - Carbon-based absorber in between each
  - Total kick angle for pair same as all other dipoles (0.64 mrad)

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First dipole pair (Mag1a1b)

Sub-System: PBS: 4.4.1, 4.4.2, Post-Collision Line e+, e-											
Name	Magnet type	Quantity	Magnetic Length [m]	Full magnet aperture H/V [m]	Shape	Strength	Good Field Region H/V[m]	Tuning Range %	Rel. Field Accuracy	Higher Harmonics bn/b1	Comments
Mag1a1b	Dipole	2×2	2	0.222/0.577*	rectangular	0.8 [T]	0.2/0.44	10	1.00E-02	<10%	Window frame magnet
Mag2	Dipole	1×2	4	0.296/0.839*	rectangular	0.8 [T]	0.27/0.702	10	1.00E-02	<10%	Window frame magnet
Mag3	Dipole	1×2	4	0.37/1.157*	rectangular	0.8 [T]	0.34/1.02	10	1.00E-02	<10%	Window frame magnet
Mag4	Dipole	1×2	4	0.444/1.531*	rectangular	0.8 [T]	0.41/1.394	10	1.00E-02	<10%	Window frame magnet
MagC-type	Dipole	4×2	4	0.45/0.75**	rectangular	0.8 [T]	0.428/0.74	10	1.00E-02	<10%	C-type magnet

First dipole pair (Mag1a1b)

Parameters	UNITS	
Magnet type, name		Dipole Mag1a1b
Full aperture (Horizontal)	[mm]	222
Good field region (Hor/Vert)	[mm]	200/440
Effective length	[mm]	2000
Strength	[T]	0.8
Pole field	[T]	0.8

- Clearly, the magnet group had a different idea
- In fact, even in the CDR, these magnets are listed as 2 m each, but the simulations assumed they were 0.5 m and 3.5 m

- I ran with both configurations, and found no difference
    - Opted to use 2 m each, since that's what magnet group designed

Dipole Mag1a1b PBS [4.4.1-4.4.2]

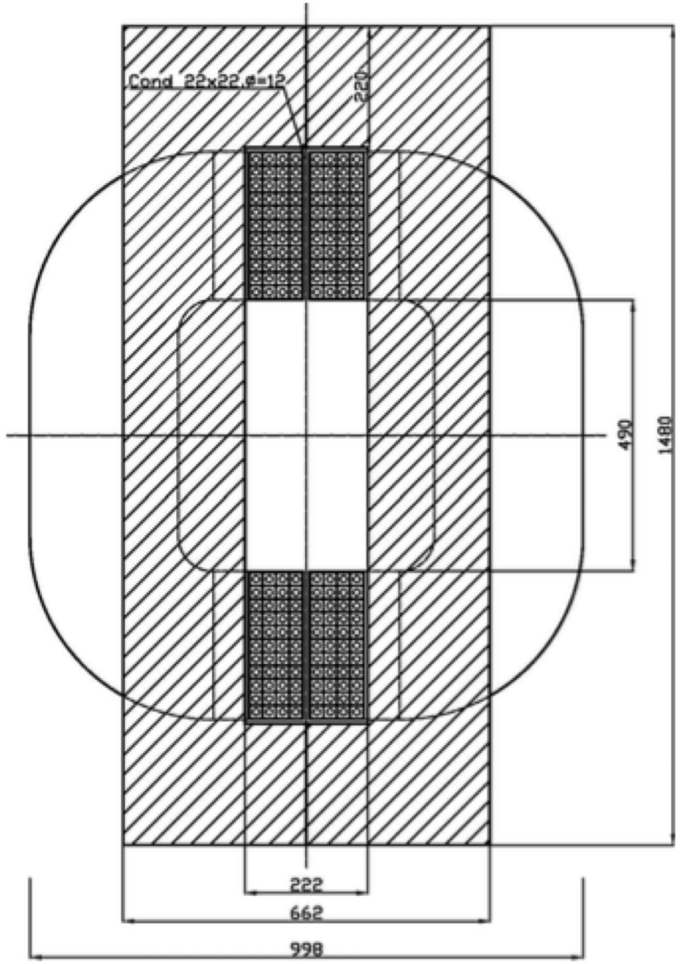
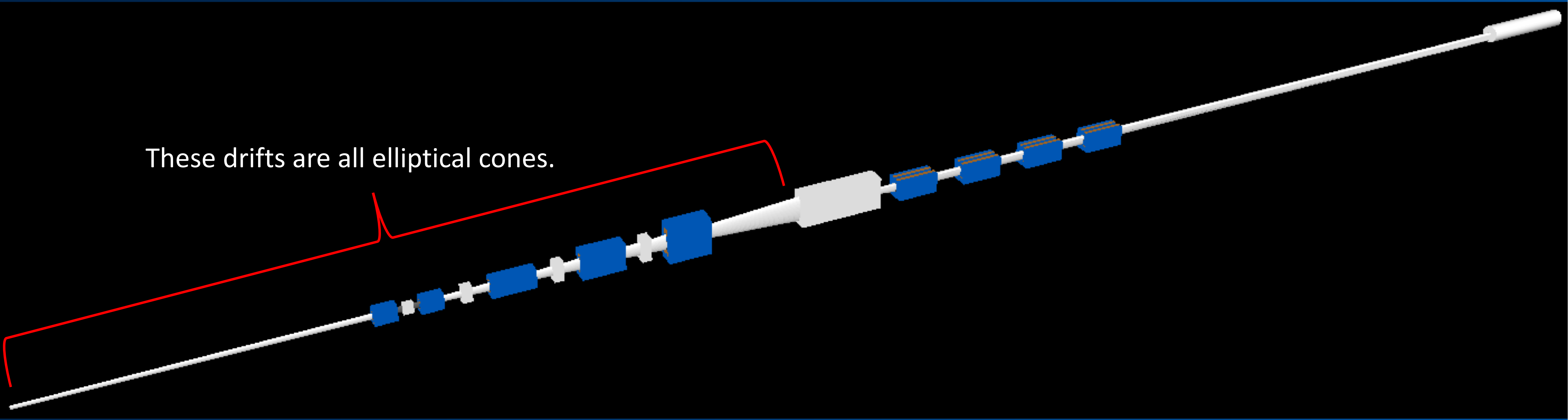


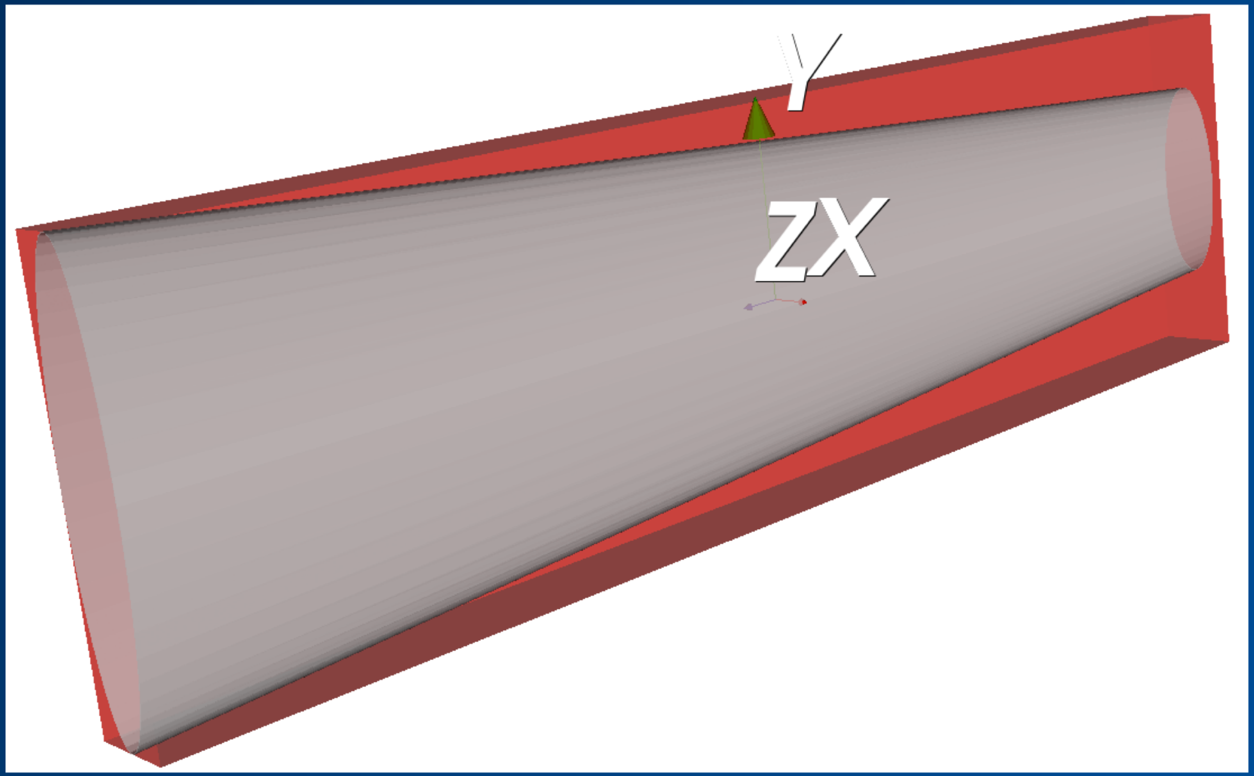
Fig 1. Dipole Mag1a1b, Cross-section

Now let’s discuss these drifts



All beampipes prior to Intermediate Dump

- Elliptical cones in shape
- Created using custom Boolean Geometry program for BDSIM (pyg4ometry)



Masks/Collimators between magnets

- Wildly inconsistent reporting of aperture dimensions
  - Sometimes larger than beampipe itself
  - Sometimes swapped X and Y planes

- For PIP, I made these match the beampipe sizes
  - Later, I will look into decreasing these apertures (more later)

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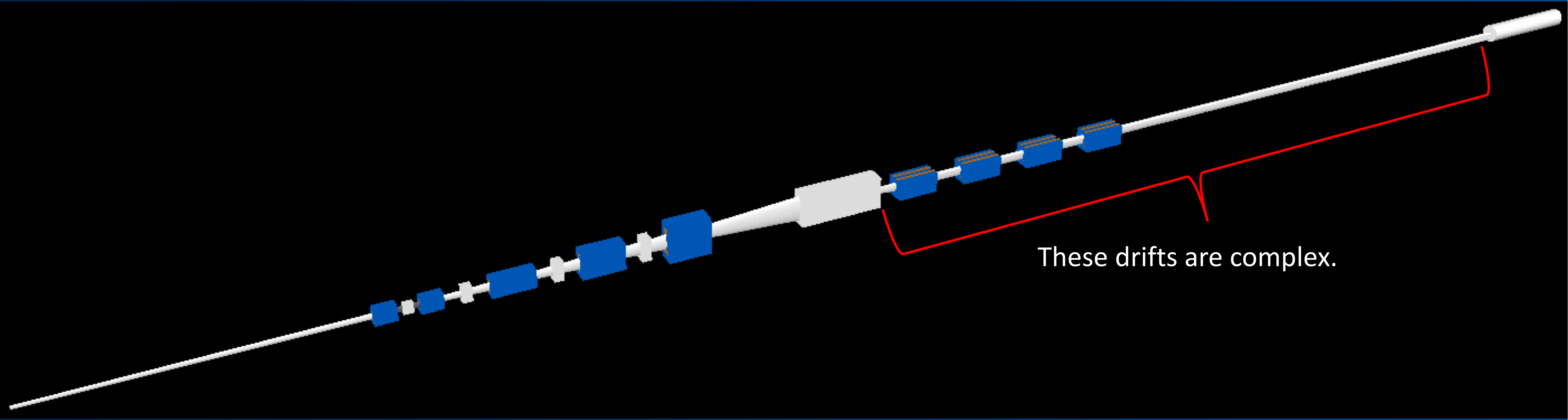
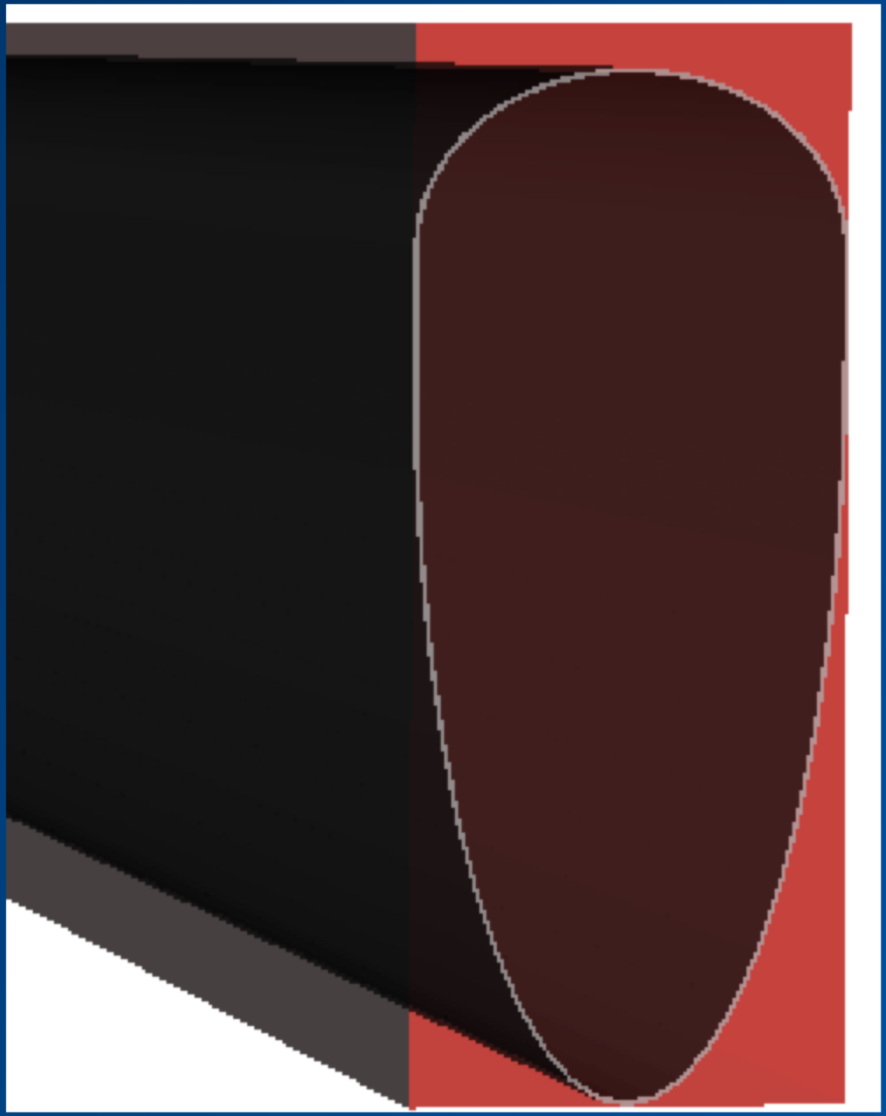
Now, to focus on these beasts



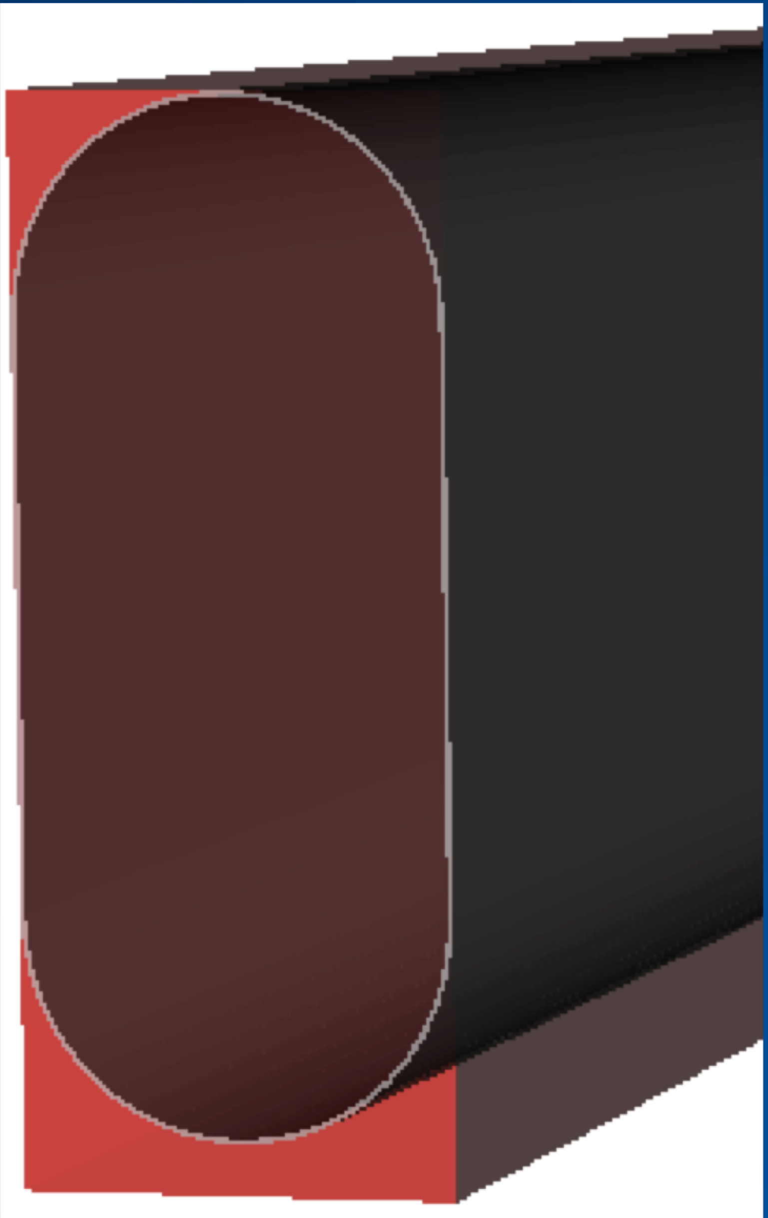
It's easier if I show you

- This is the beginning end of the final drift
- All beampipes after the ID and before this point are of this shape, but vary in size from end to end

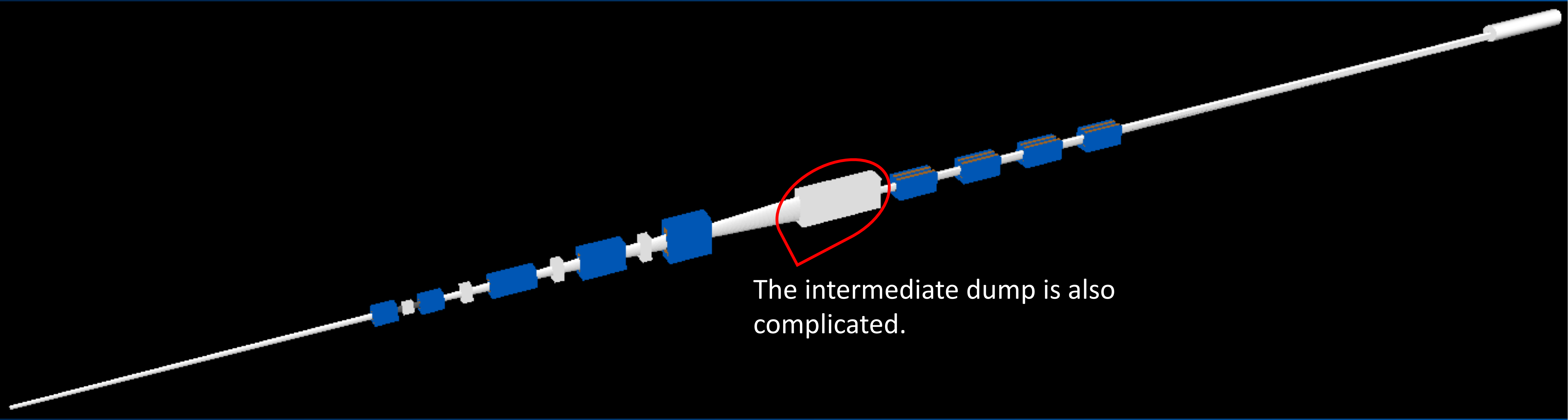


It’s easier if I show you

- This is the downstream end of the final drift
- This is also the shape of the final window into the main dump

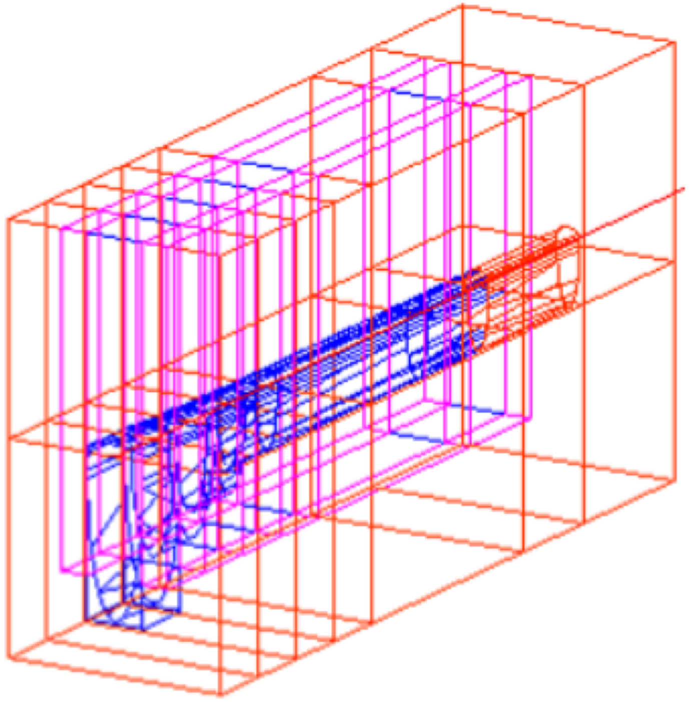


What's the reason for this complexity?
The Intermediate Dump



The Design from Before

Intermediate dump (CNGS style):
iron jacket, carbon based absorber,
water cooled aluminum plates,
3.15m x 1.7m x 6m
→ aperture: X=18cm, Y=86cm



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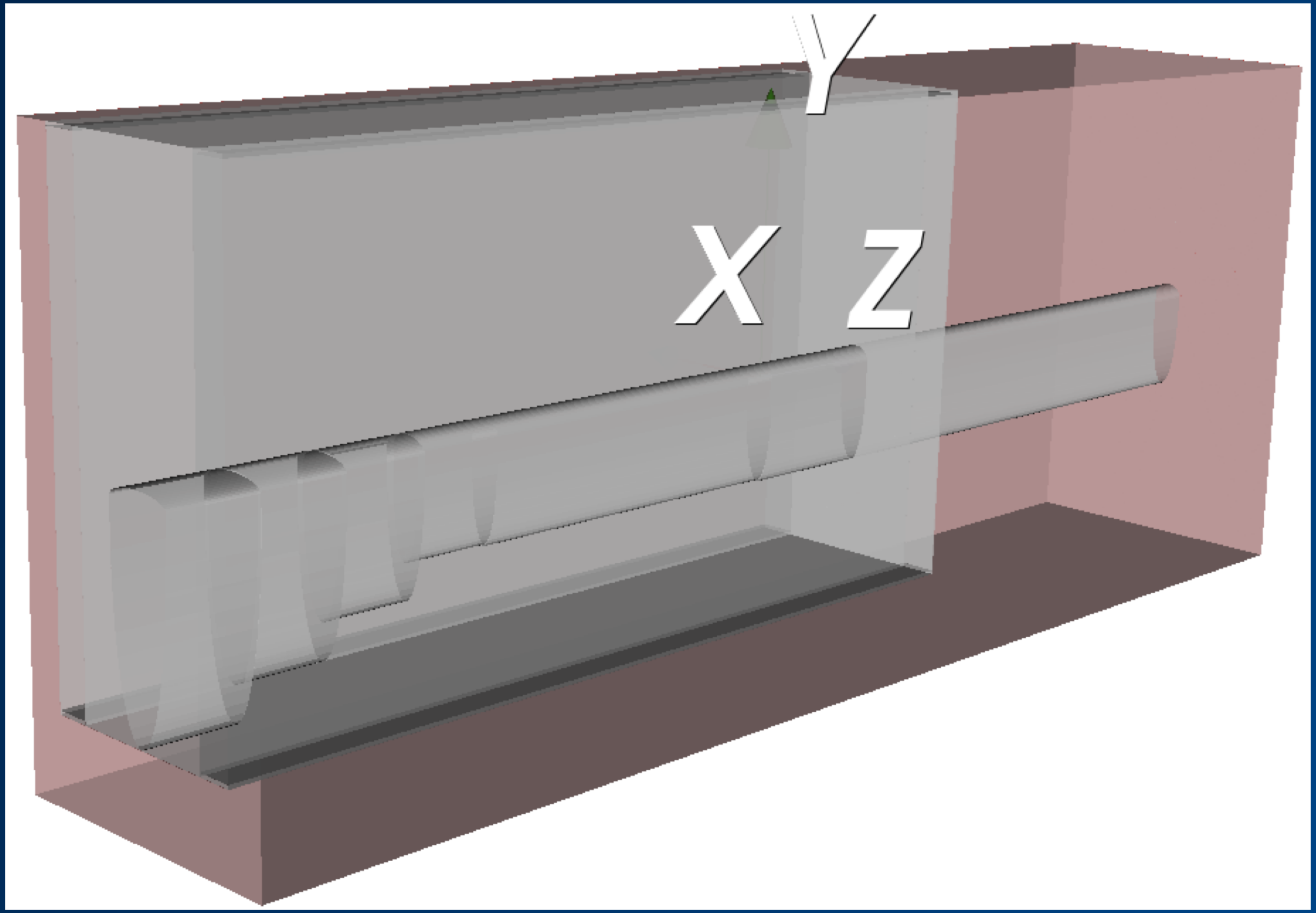
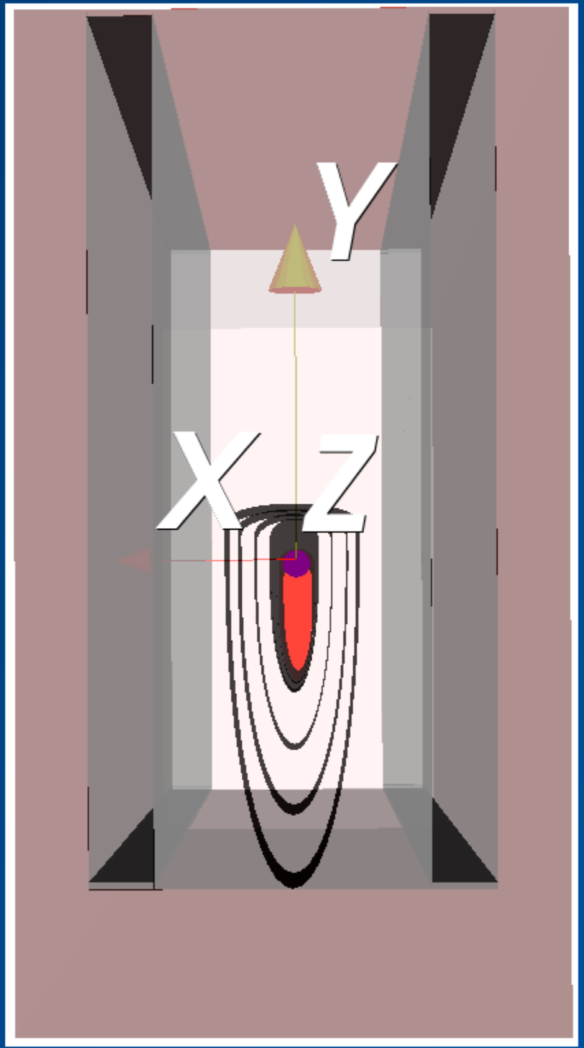
Our design (courtesy Andrey Abramov)





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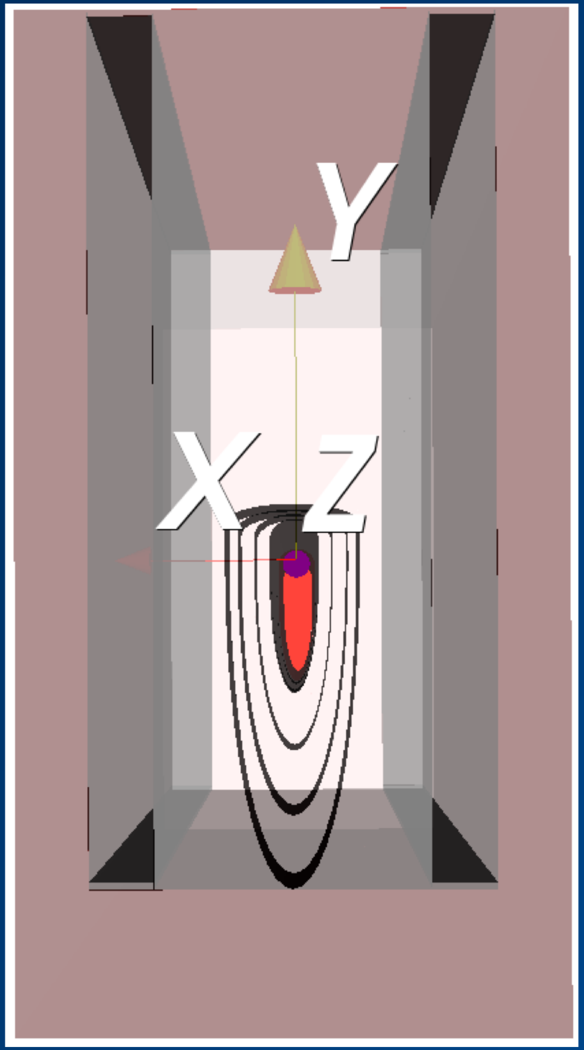
Looking head-on



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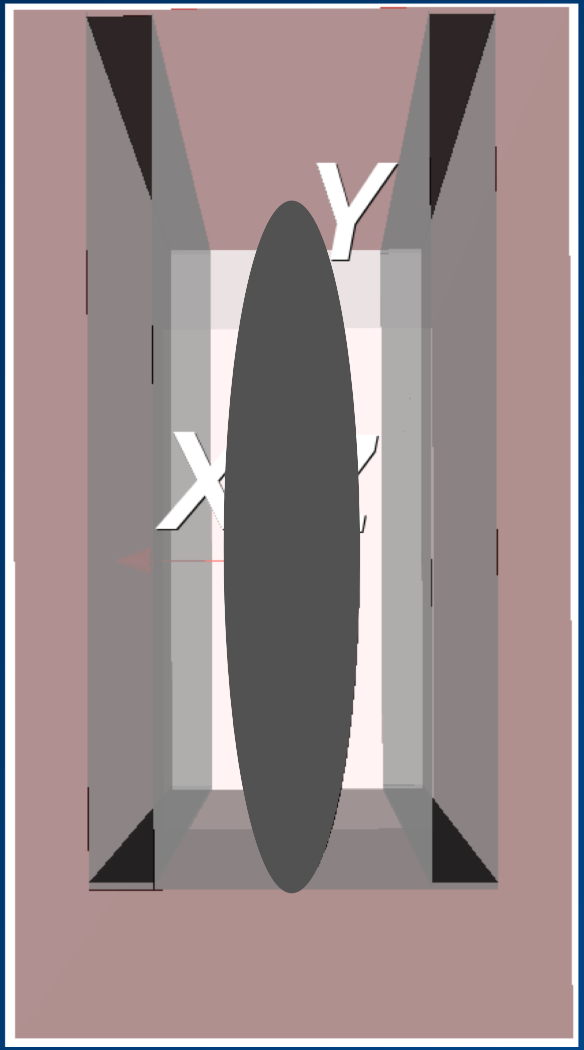
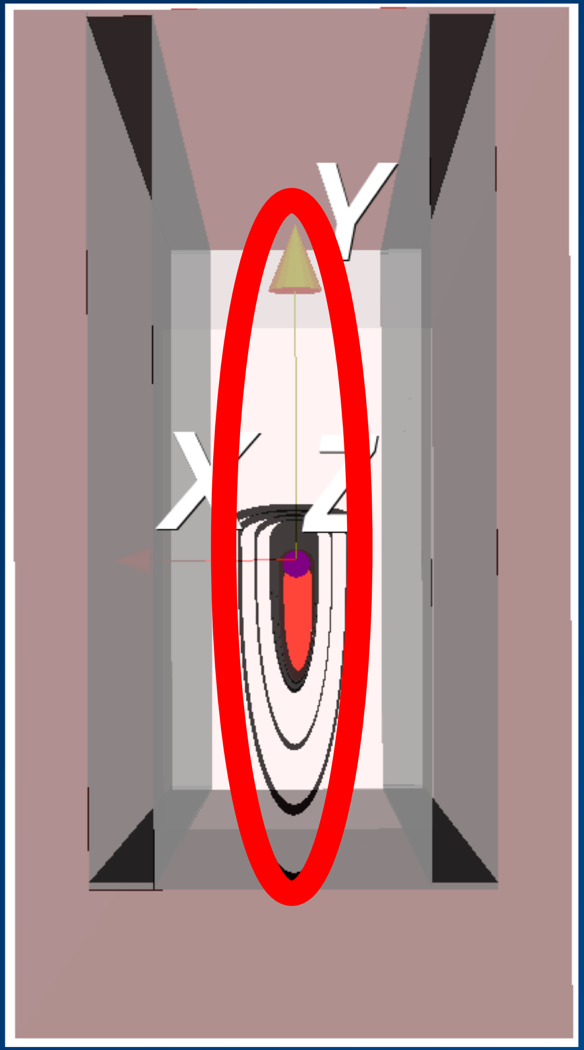
Incoming beampipe shape



ID stops wrong-charge particles



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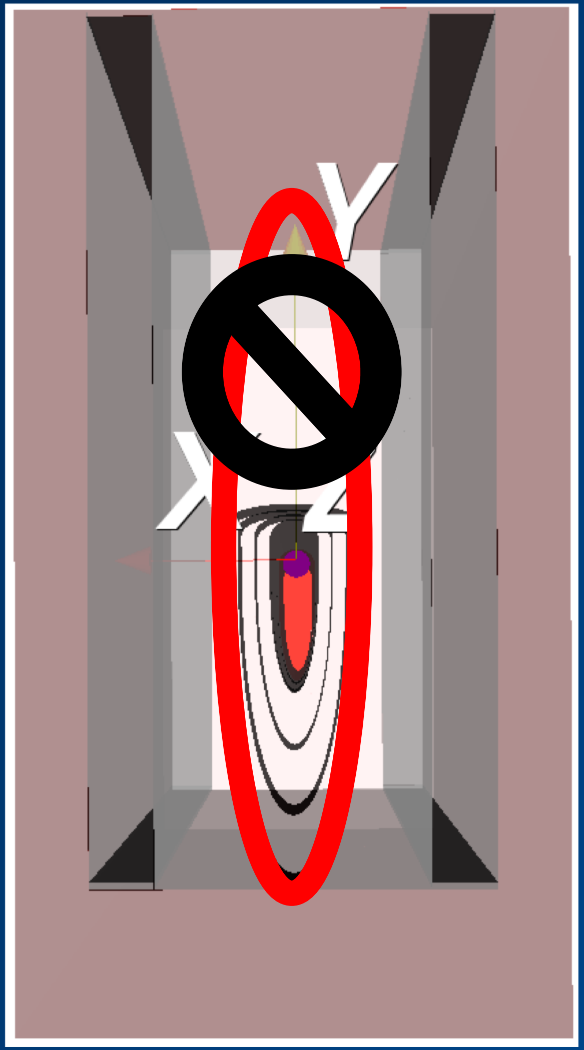


Main Dump (for now at least)

- Andrey made this, including the window, based upon this CLIC Note:

CLIC-Note- 876

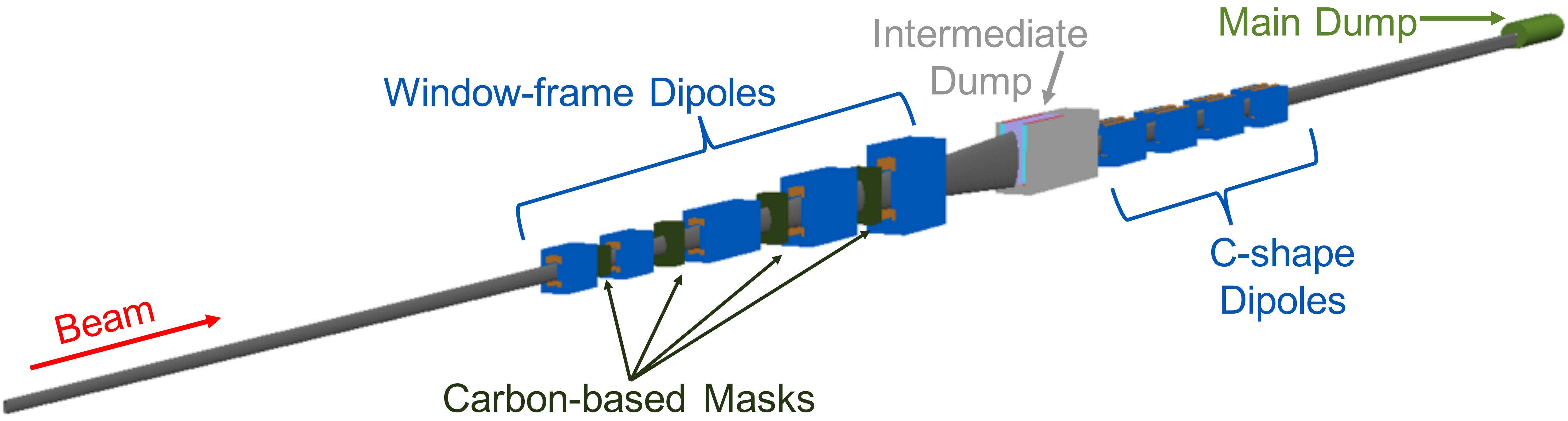
FLUKA AND THERMO-MECHANICAL STUDIES FOR THE CLIC MAIN DUMP

A. Mereghetti[1], C. Maglioni[2], V. Vlachoudis[1]
[1] CERN – European Organization for Nuclear Research, EN-STI-EET
[2] CERN – European Organization for Nuclear Research, EN-STI-TCD

Abstract

In order to best cope with the challenge of absorbing the multi-MW beam, a water beam dump at the end of the CLIC post-collision line has been proposed. The design of the dump for the Conceptual Design Report (CDR) was checked against with a set of FLUKA Monte Carlo simulations, for the estimation of the peak and total power absorbed by the water and the vessel. Fluence spectra of escaping particles and activation rates of radio-nuclides were computed as well. Finally, the thermal transient behavior of the water bath and a thermo-mechanical analysis of the preliminary design of the window were done.

Now to see what it looks like!



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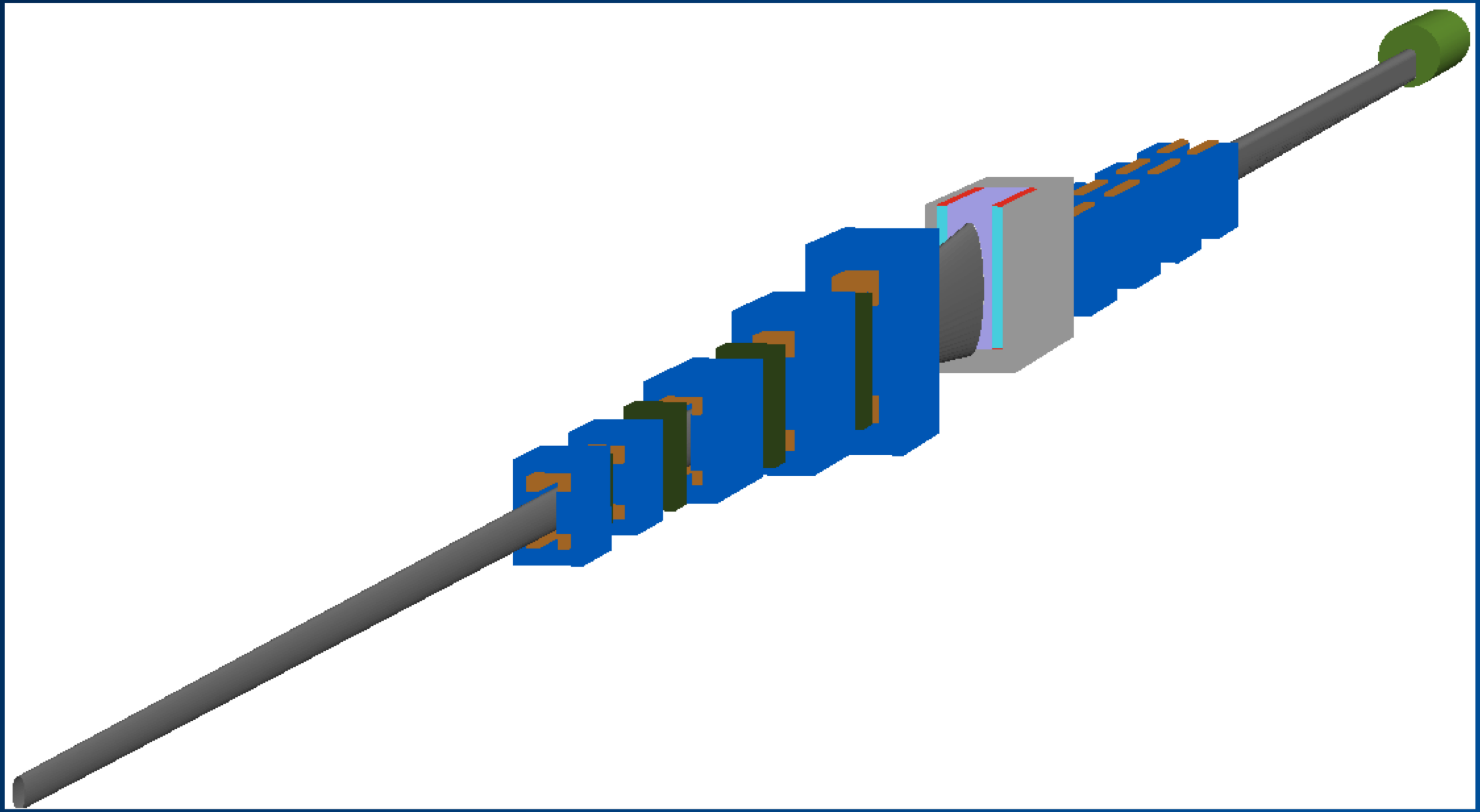

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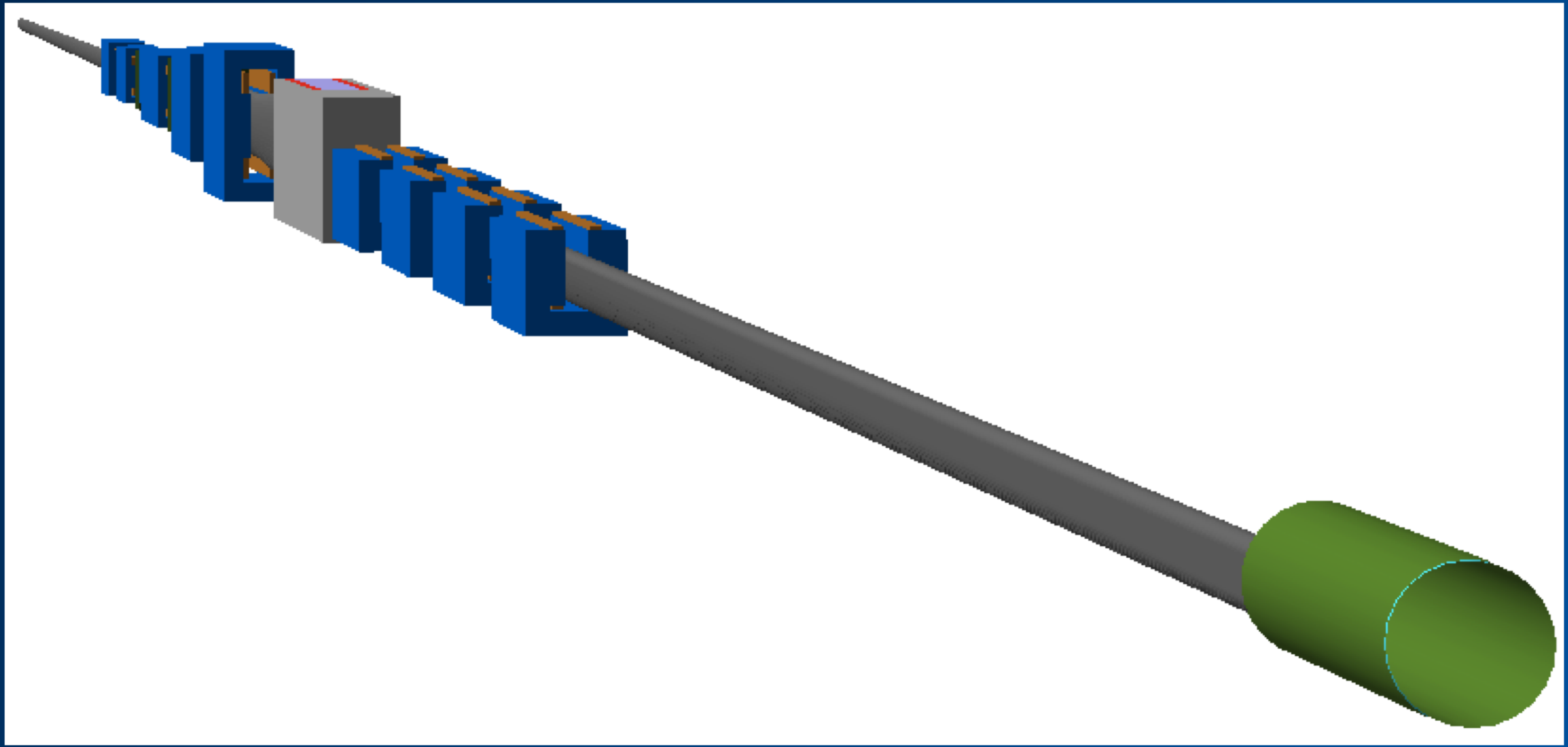

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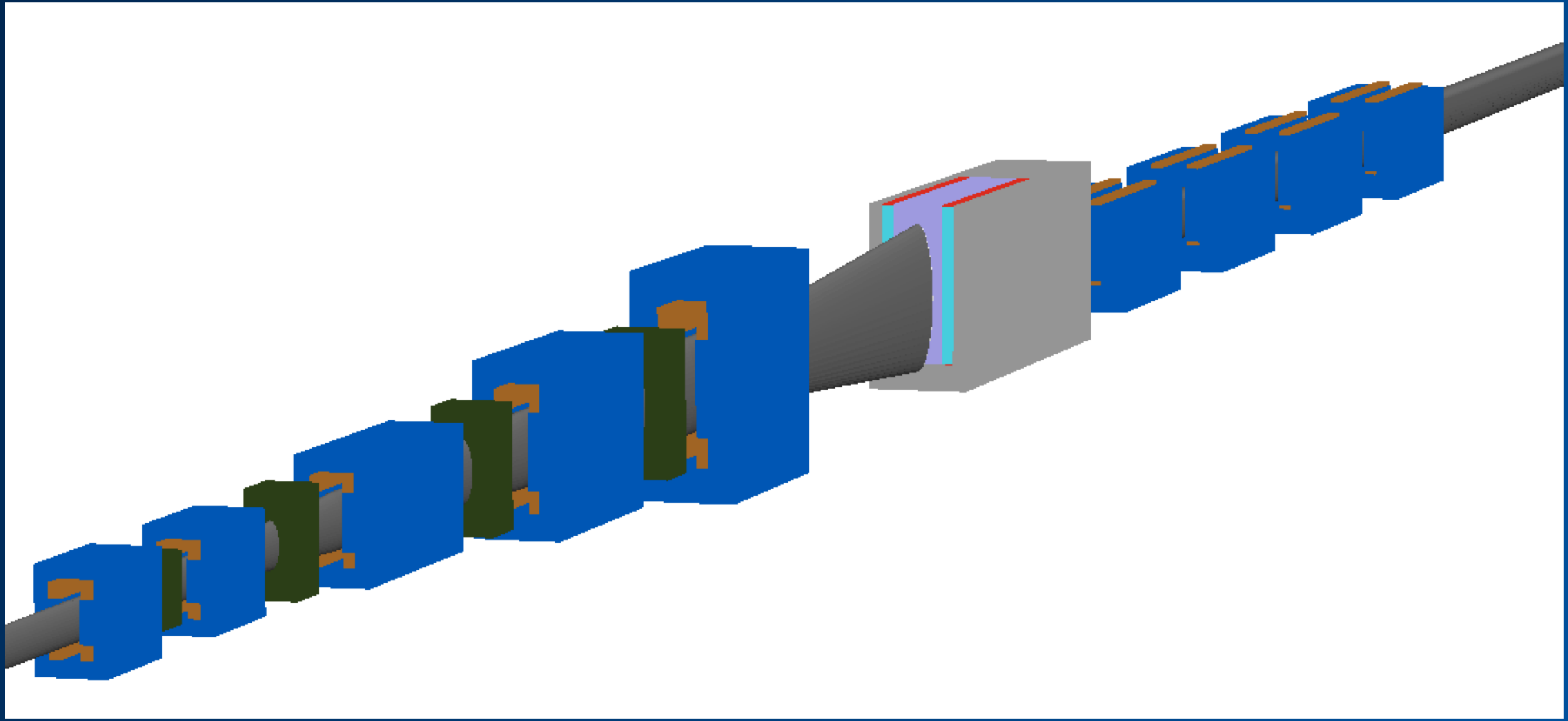

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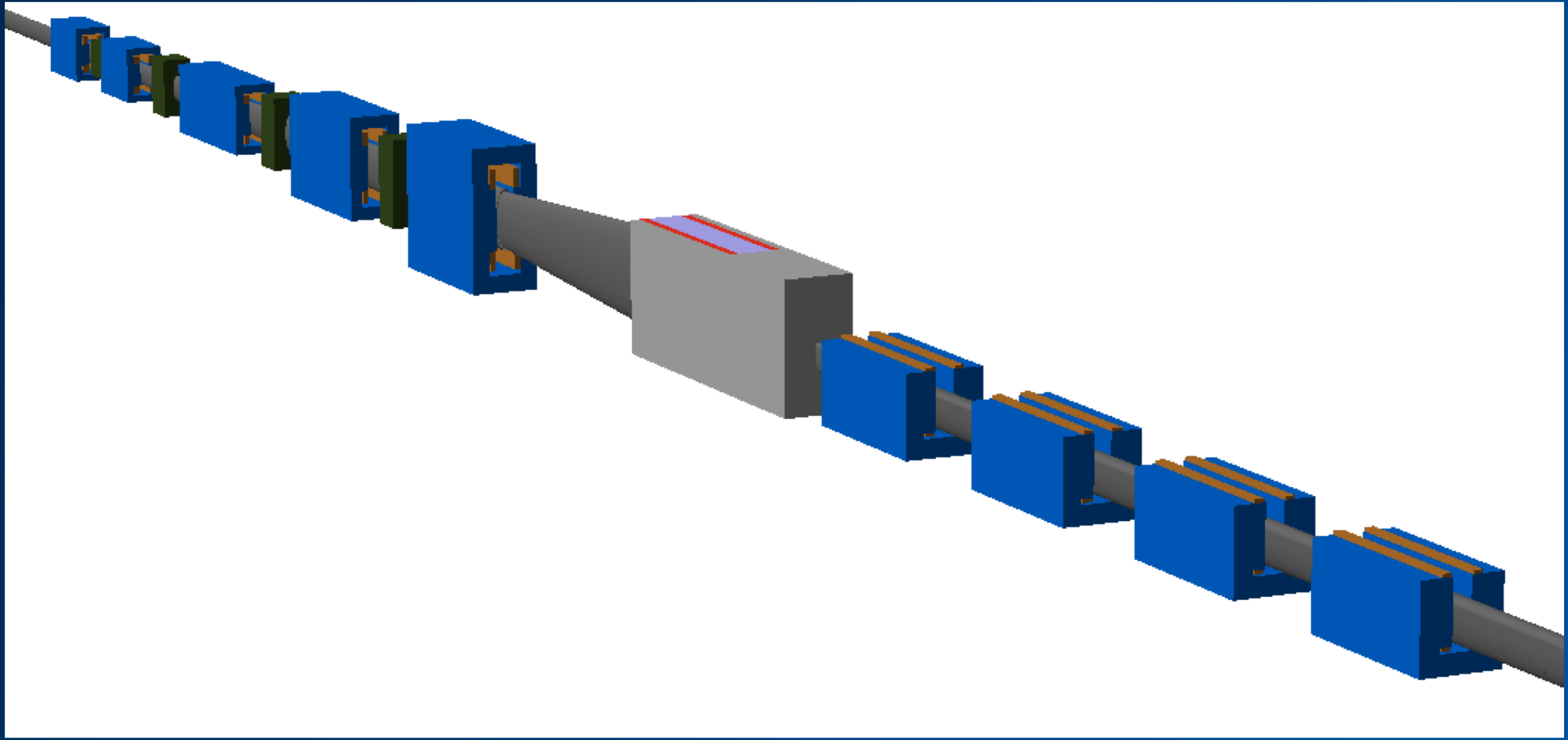


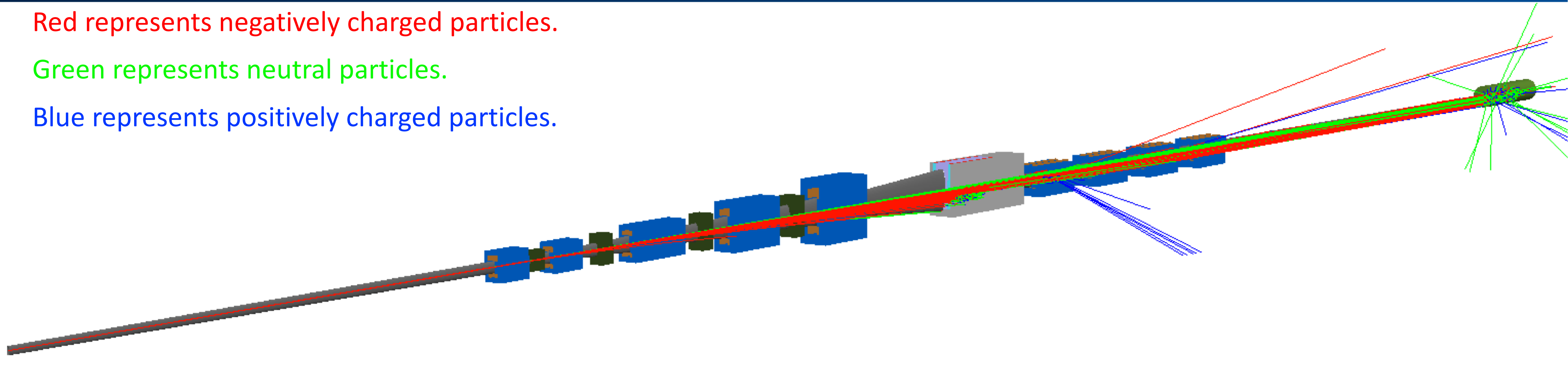
Now for the Simulations

Screenshot of interactive simulation

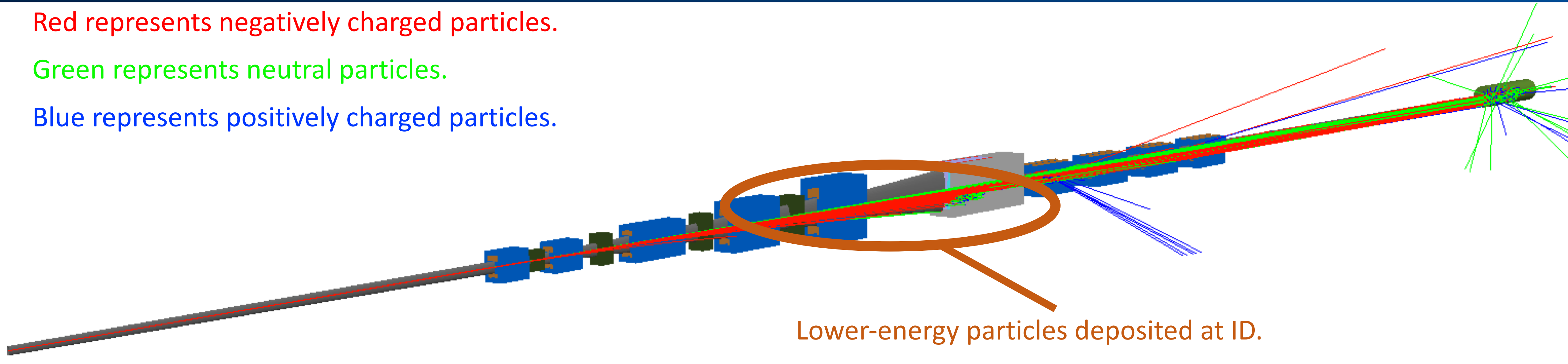
Red represents negatively charged particles.

Green represents neutral particles.

Blue represents positively charged particles.



Screenshot of interactive simulation



Screenshot of interactive simulation

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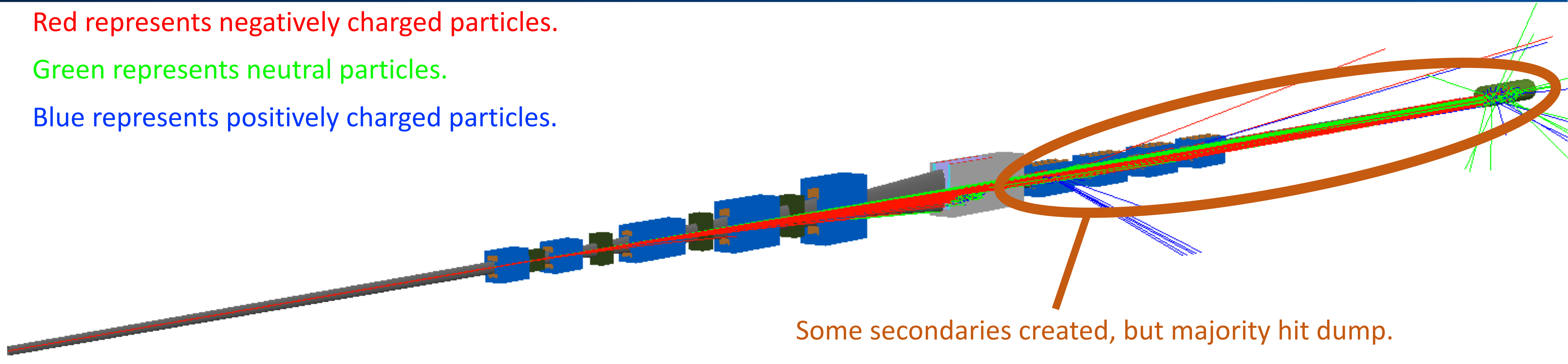
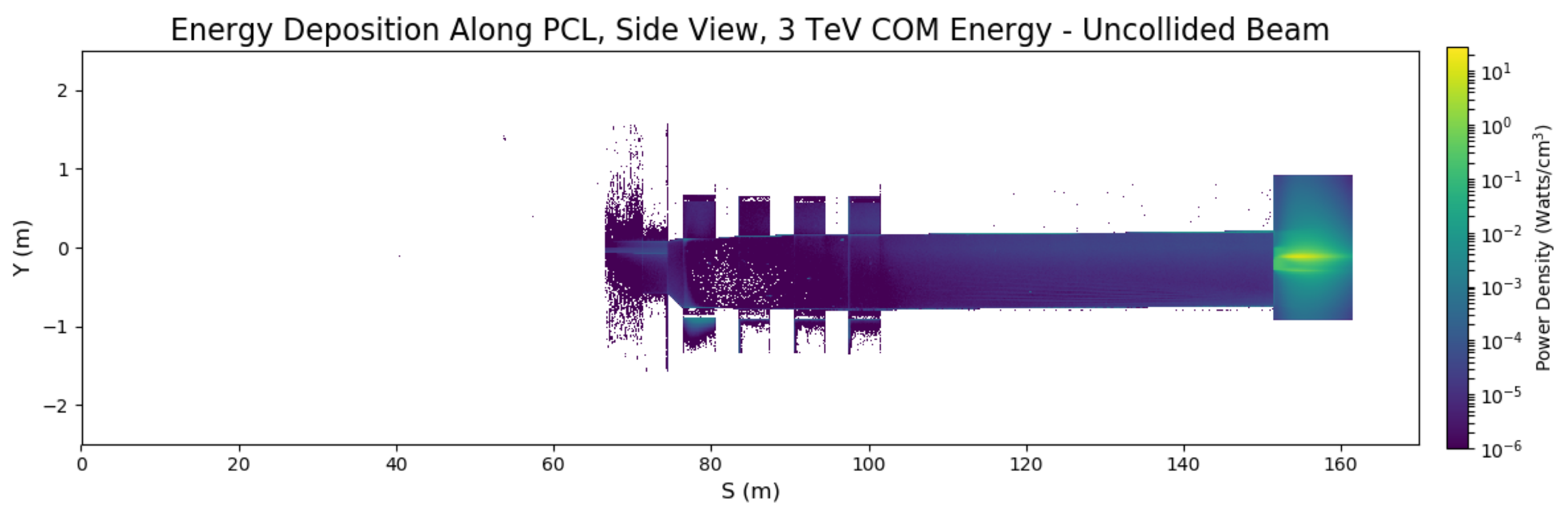


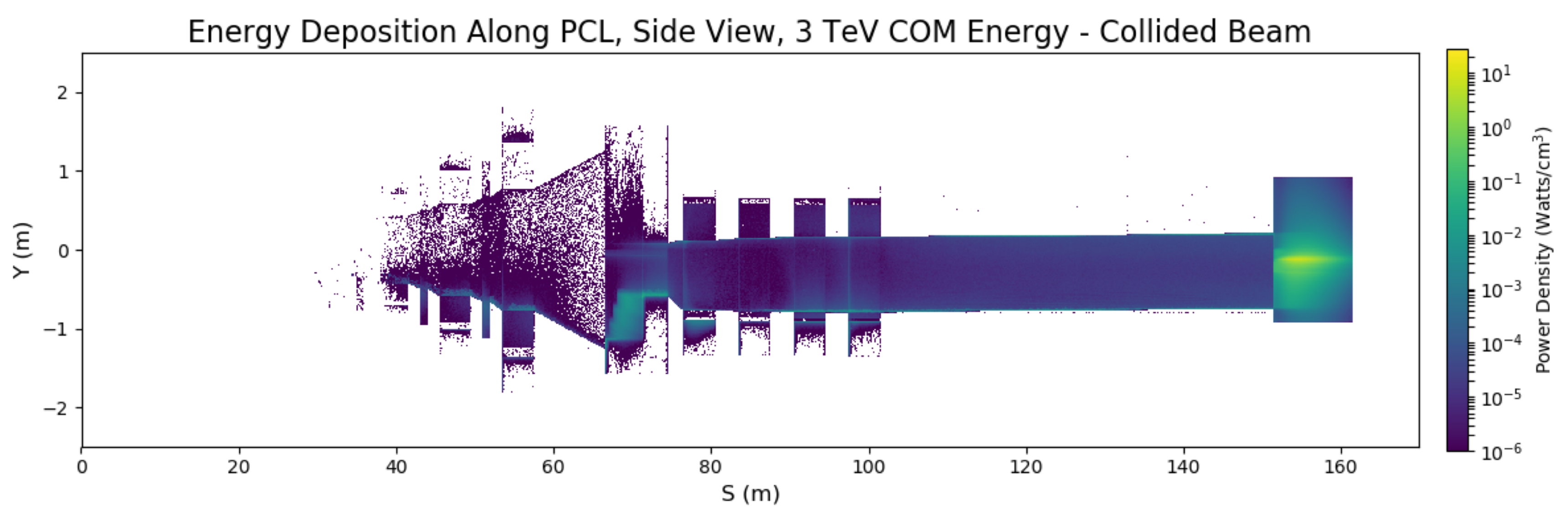
Some secondaries created, but majority hit dump.

Once happy, move to batch

- Simulate ~1,000,000 particles
- Beam data from Beam-beam interactions group (GUINEA-PIG)
- Energy cuts at 20 MeV, secondaries cut below 1 cm
- Primary analysis performed during simulation (ROOT)
  - Requires a bit of foresight
- Data not copied back, only histograms
  - This is by choice. 1 TB of data can be created easily by these simulations
  - Use pybdsim utilities for further analysis of histograms

Some results!


Energy Deposition Along PCL, Side View, 3 TeV COM Energy - Uncollided Beam
Y (m)
S (m)
Power Density (Watts/cm³)


Energy Deposition Along PCL, Side View, 3 TeV COM Energy - Collided Beam
Y (m)
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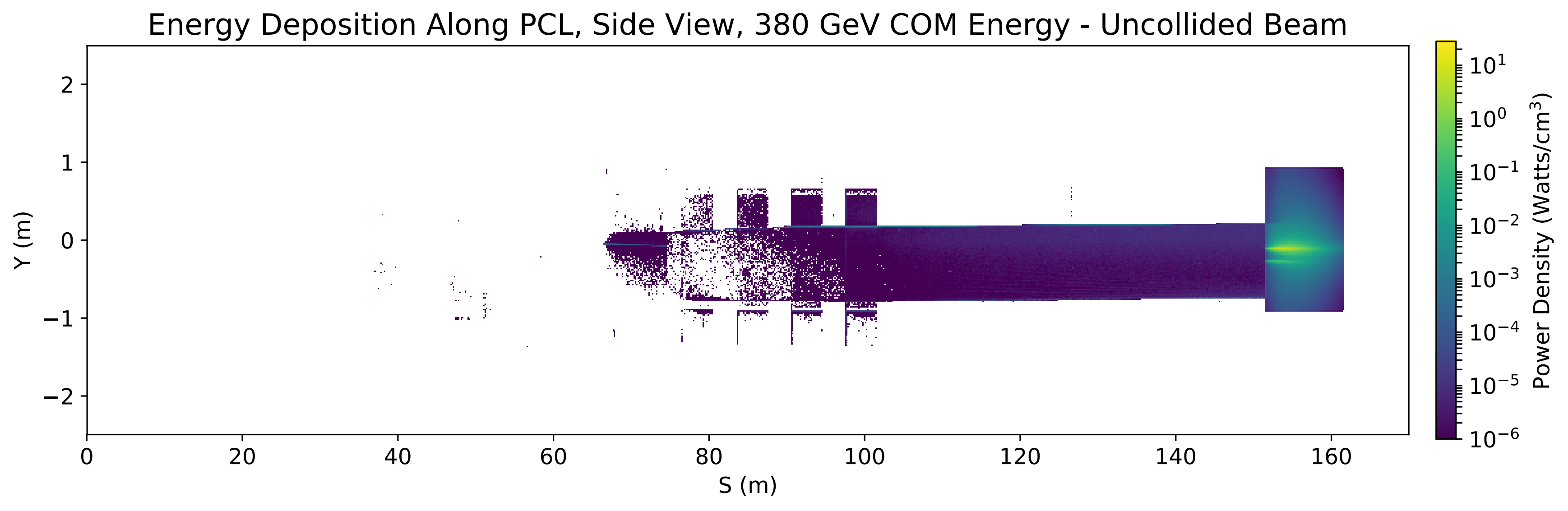
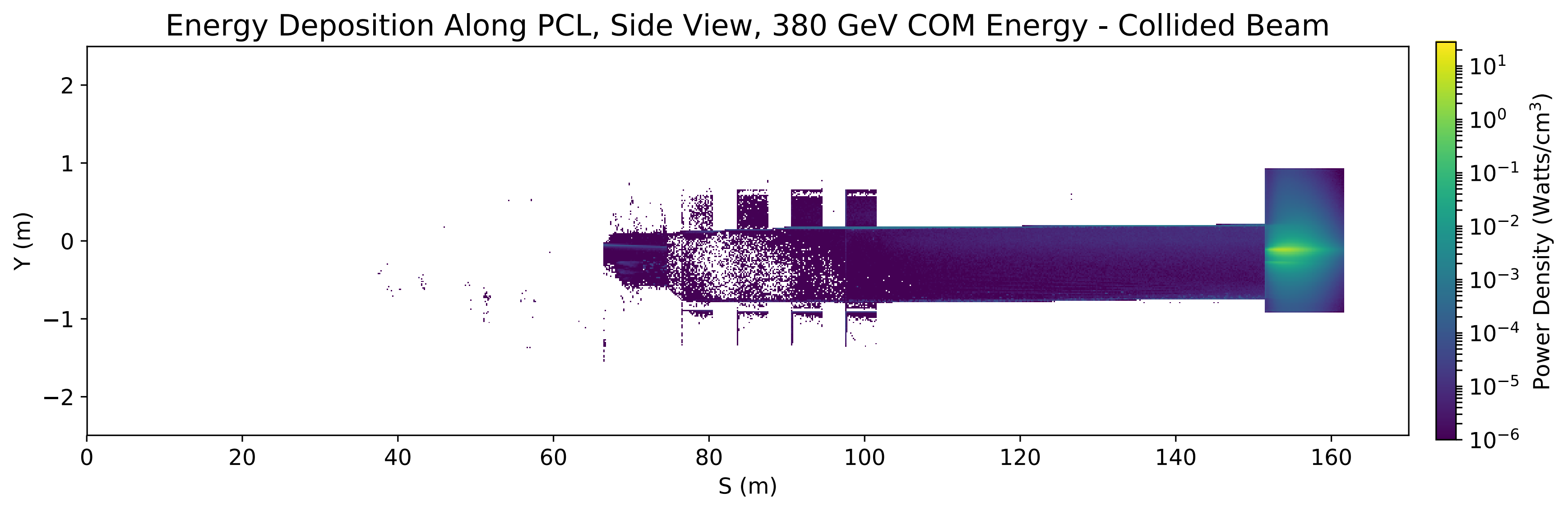
Power Density (Watts/cm³)





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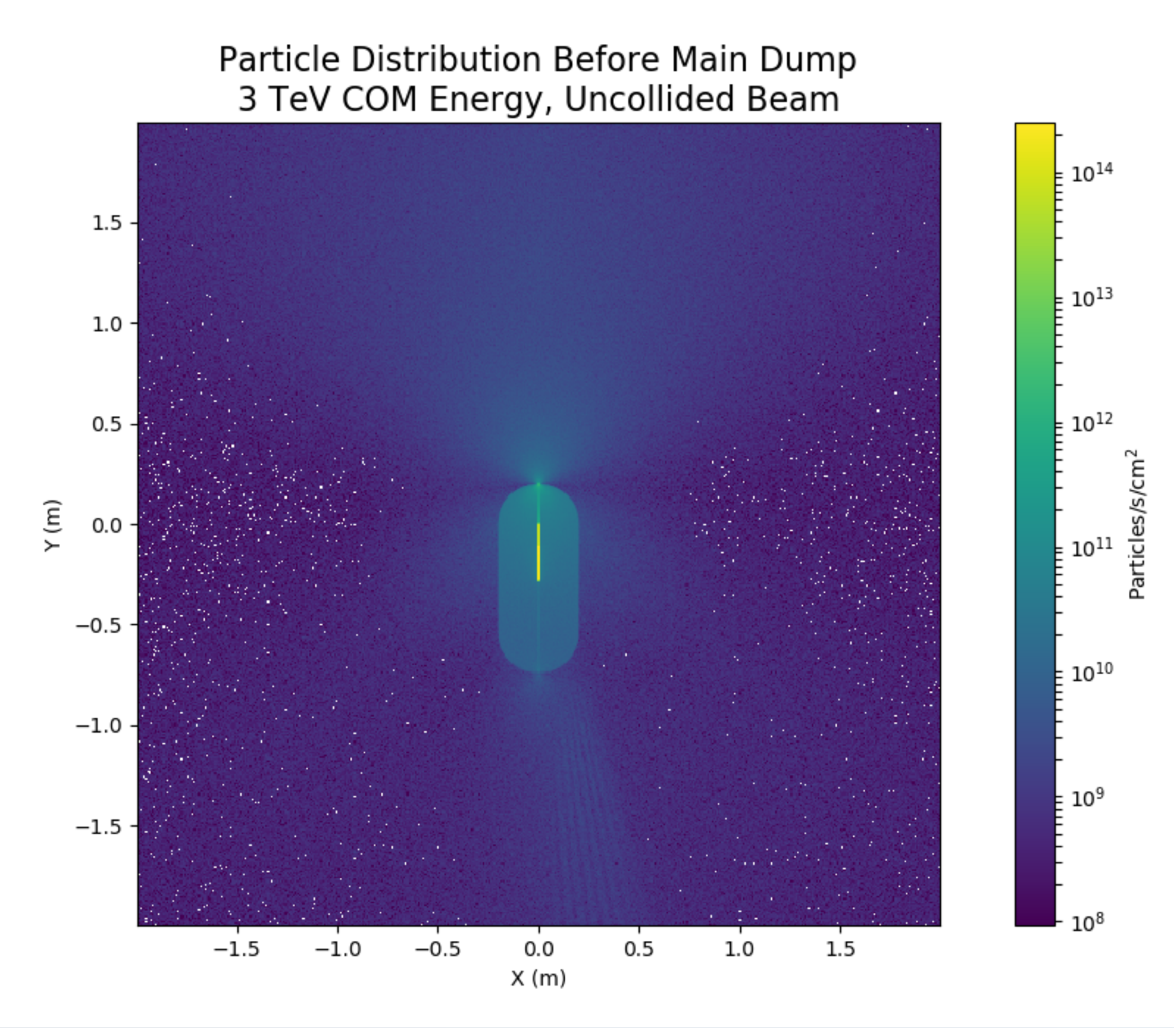
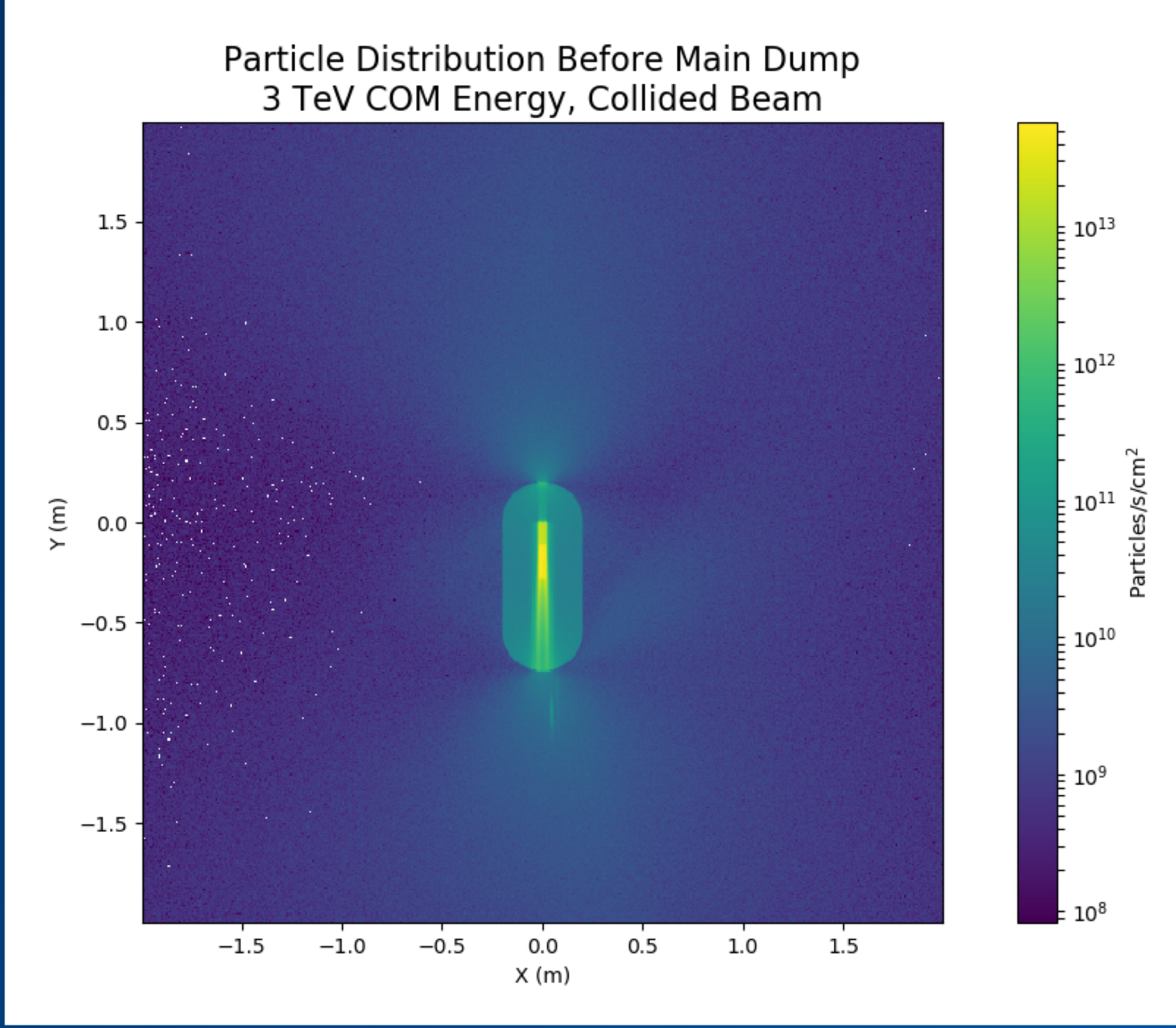
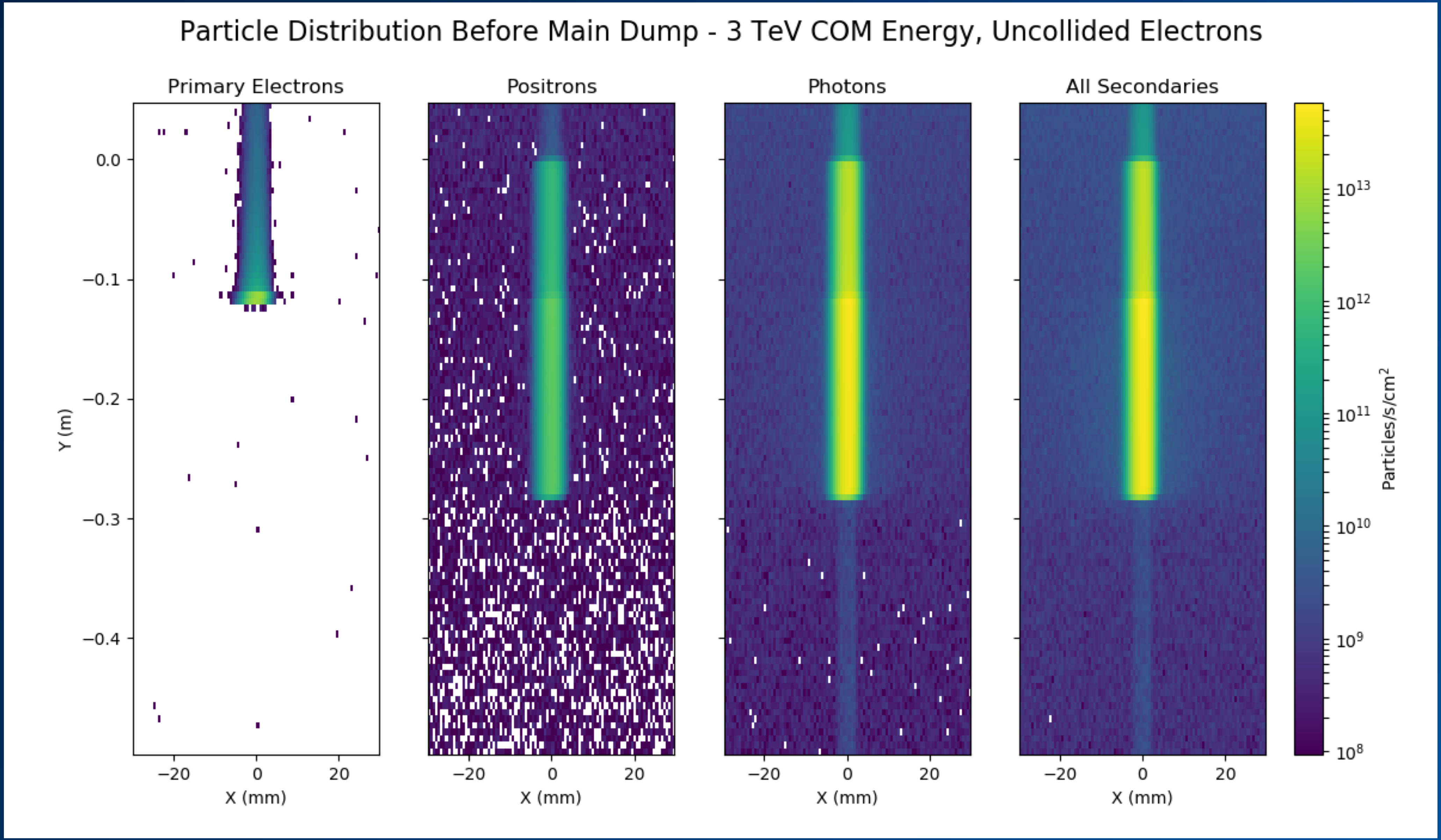
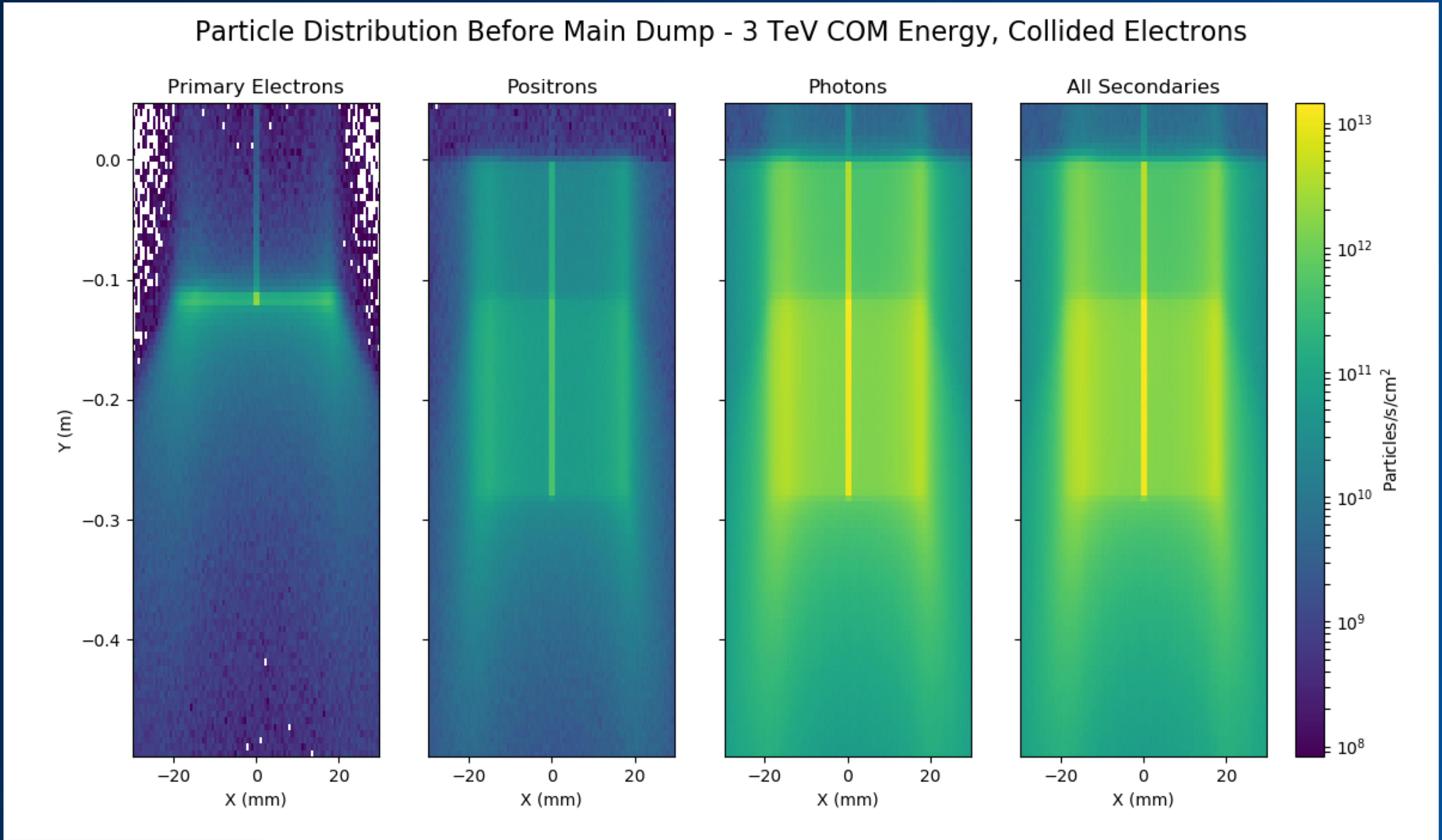

Particle Distribution Before Main Dump
3 TeV COM Energy, Uncollided Beam
Y (m)
X (m)
Particles/s/cm^2
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}


Particle Distribution Before Main Dump
3 TeV COM Energy, Collided Beam
Y (m)
X (m)
Particles/s/cm^2
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}



Particle Distribution Before Main Dump - 3 TeV COM Energy, Uncollided Electrons
Primary Electrons
Positrons
Photons
All Secondaries
Y (m)
0.0
−0.1
−0.2
−0.3
−0.4
X (mm)
−20
0
20
Particles/s/cm^2
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}



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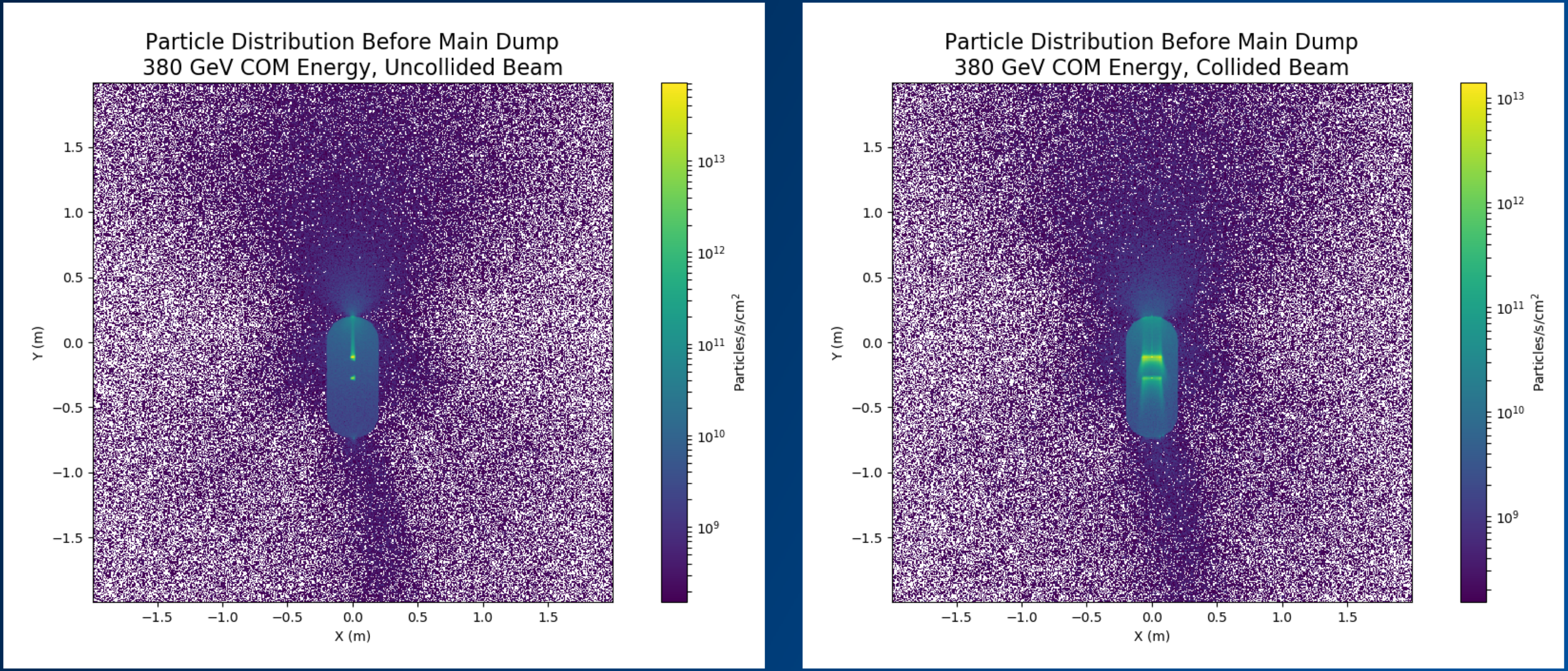

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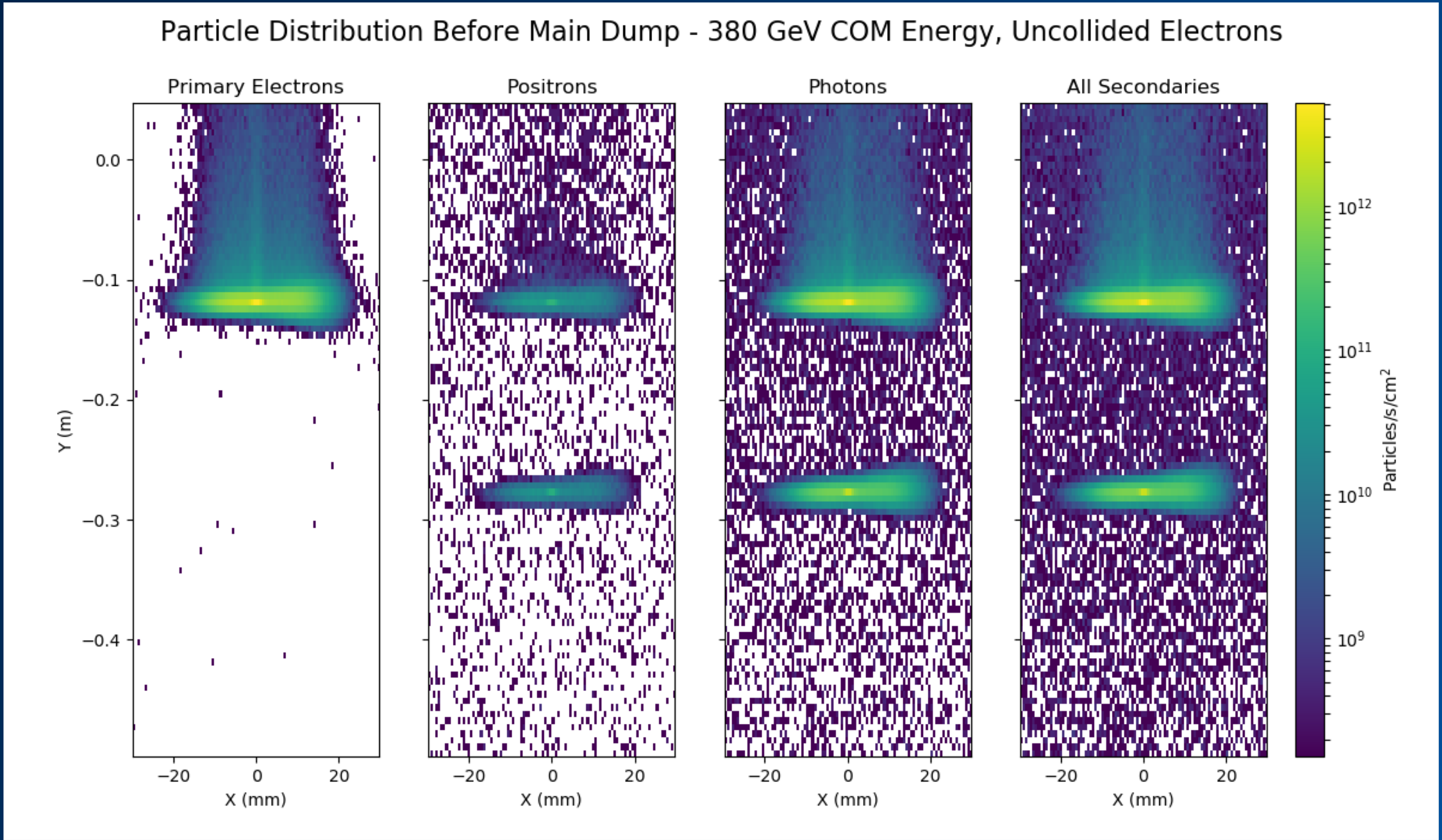

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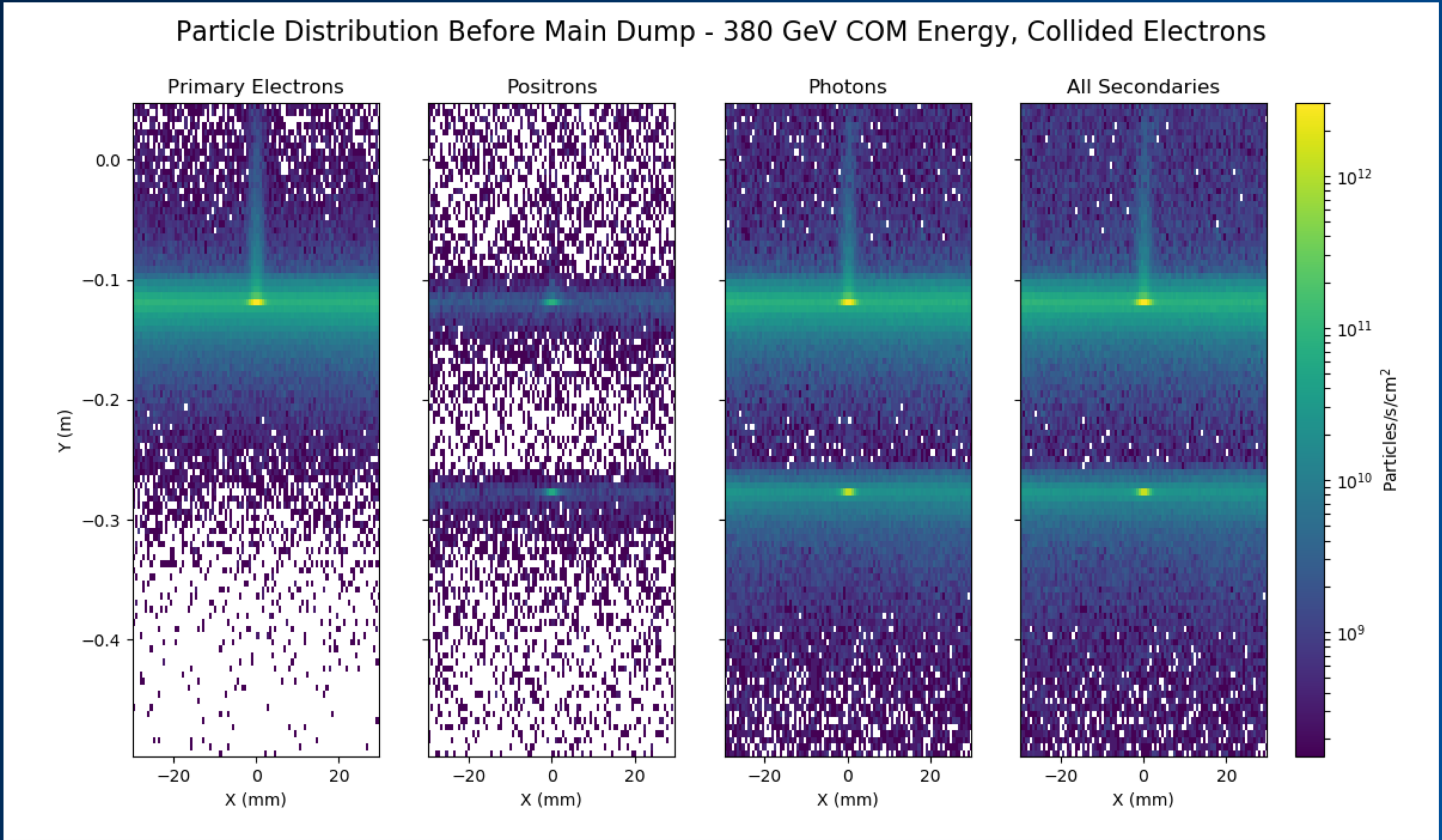
Particle Distribution Before Main Dump - 380 GeV COM Energy, Collided Electrons
Primary Electrons
Positrons
Photons
All Secondaries
Y (m)
0.0
−0.1
−0.2
−0.3
−0.4
−20
0
20
X (mm)
10^{12}
10^{11}
10^{10}
10^{9}
Particles/s/cm^2

Project Implementation Plan

- Results appear in PIP
- It appears scaling from 0.8 T to 0.1 T will work for the PCL
- There are improvements that can be made

Power Deposition (MW) in Key PCL Elements

	Intermediate Dump	Final Drift	Main Dump
3 TeV Uncollided	2.10×10^{-4}	1.97×10^{-2}	13.6
3 TeV Collided	3.67×10^{-2}	2.96×10^{-2}	10.2
380 GeV Uncollided	5.19×10^{-5}	4.08×10^{-3}	2.91
380 GeV Collided	7.77×10^{-5}	4.23×10^{-3}	2.70

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What’s next?

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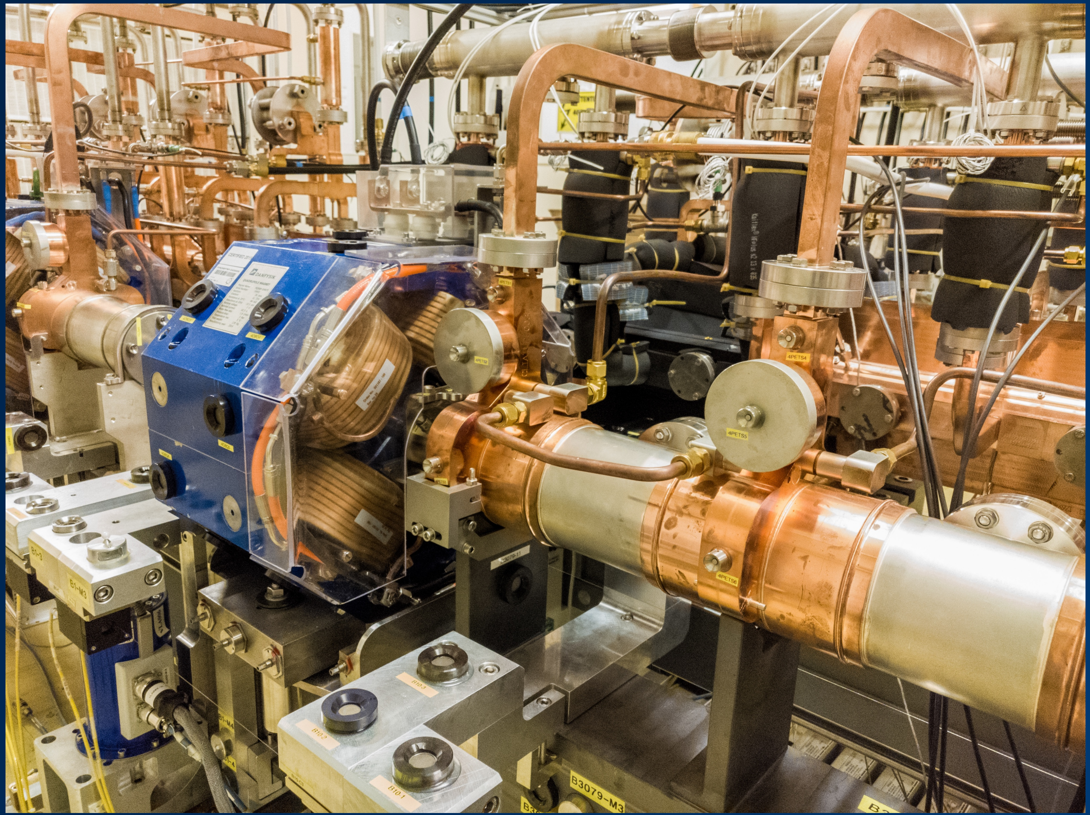
Actually, quite a bit!

- Only ran electrons
  - Need to run positrons, beamstrahlung, incoherent pairs, muons, others?
- Check option to use fewer magnets at 380 GeV
  - Instead of scaling each to 0.1 T, turn off some and use larger field
- Look at final drift length
  - Two options: ~50 m and ~210 m. I used 50 m for PIP
- Look at carbon-based mask apertures
- Perhaps instrumentation?

Thanks!



[CV and Publications (January 2019)]

Currently searching for permanent/tenure-track positions.

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