Fragments in eIC

S.White 6/5/10

- Forward physics at colliders

  http://arxiv4.library.cornell.edu/abs/1003.4252

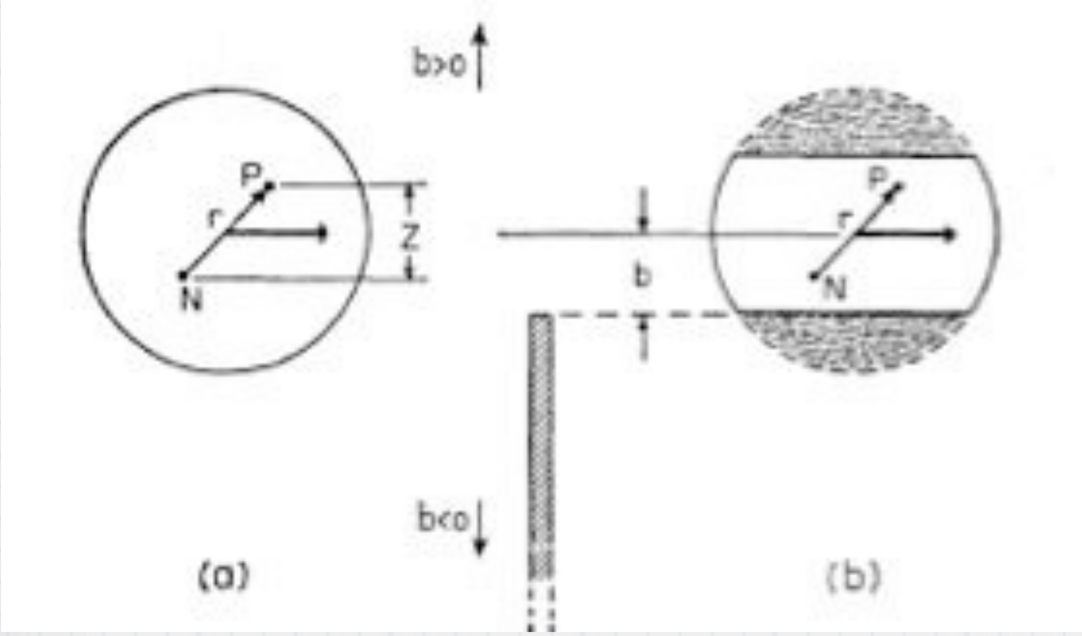
  http://indico.cern.ch/conferenceDisplay.py?confId=94115

- measurement of fragments
- Experience from RHIC/LHC
- the machine

"Diffraction at eIC"

R. Glauber, 1955

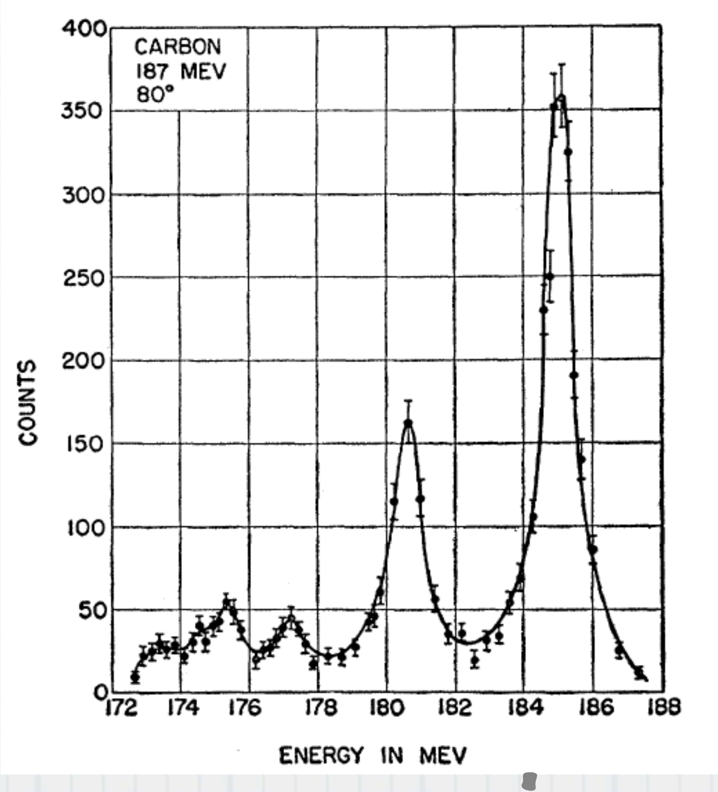
"free dissociation" of deuterons

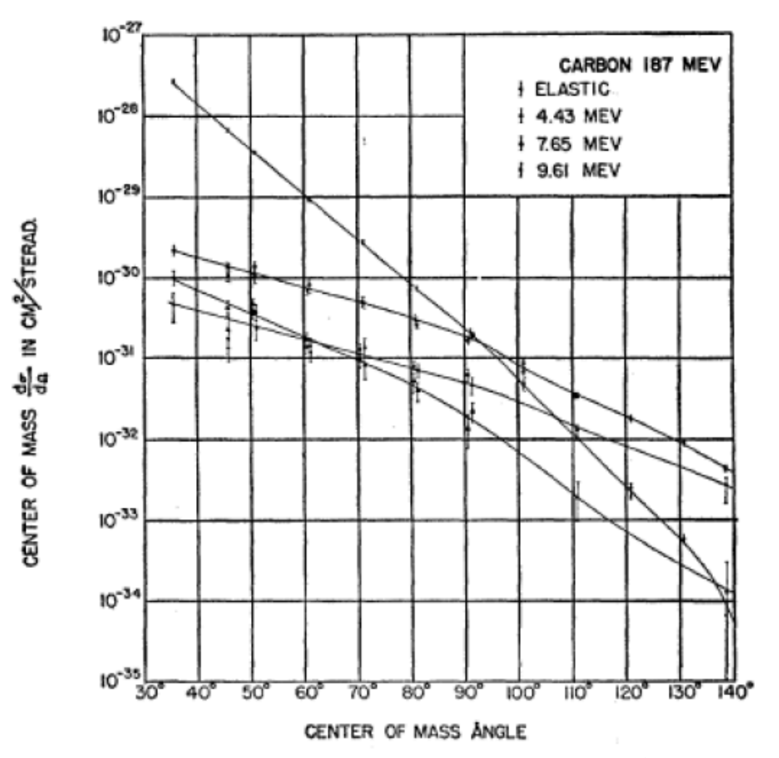


first (and possibly only) calculation of diffraction dissociation

R. Hofstadter, 1953

the electron scattering method for nuclear or proton structure





very precise measurements of e′ to insure coherence

Coherence tag is critical for several eIC measurements

analog to Hofstadter

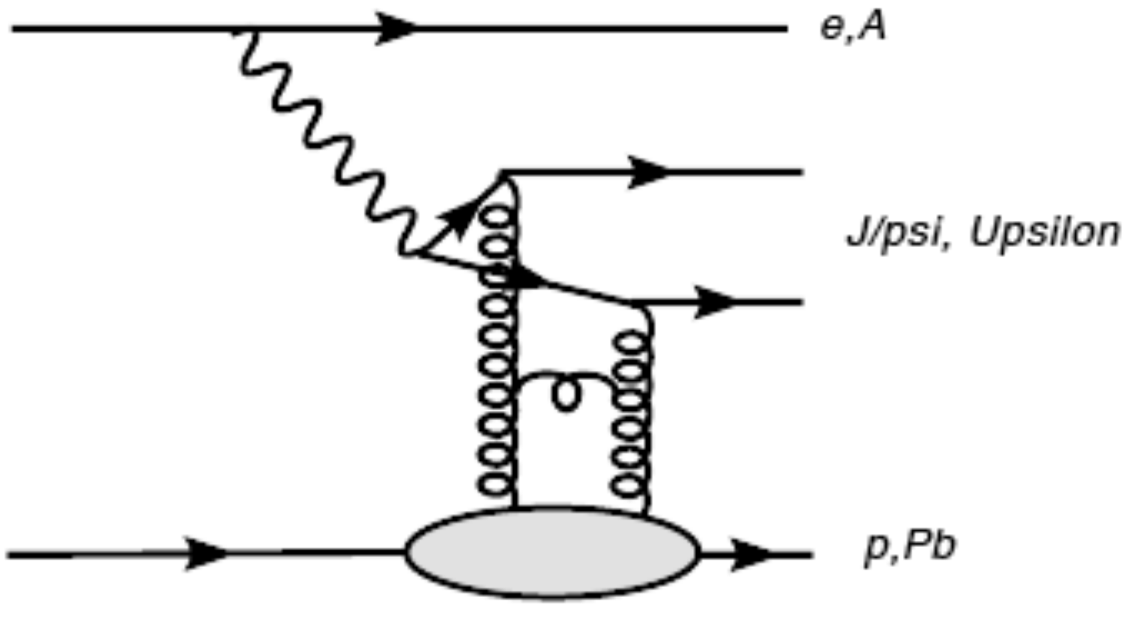


Figure 2: Diffractive Vector Meson production.

diffractive structure
in black disc regime

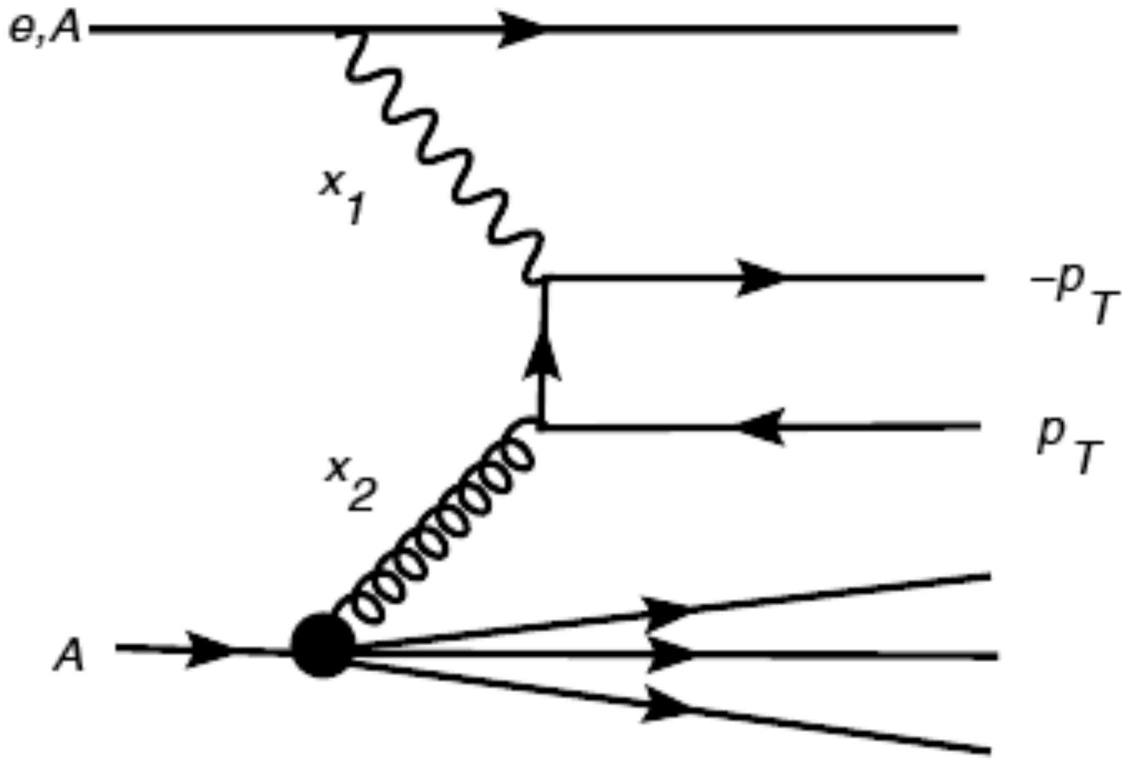
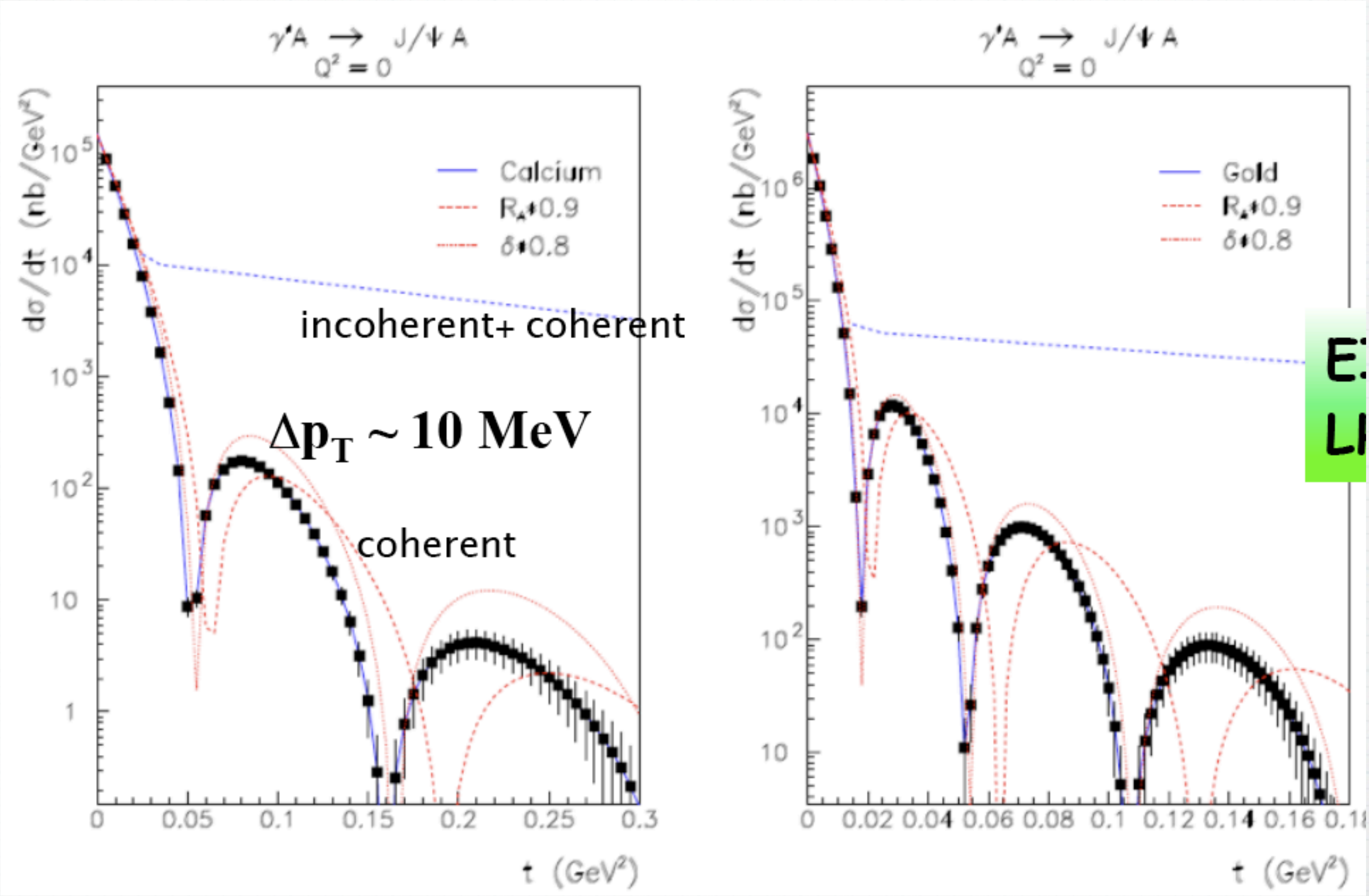


Figure 3: Hard jet photoproduction.

Incoherent is a non-negligible background



incoherent+ coherent

$\Delta p_T \sim 10$ MeV

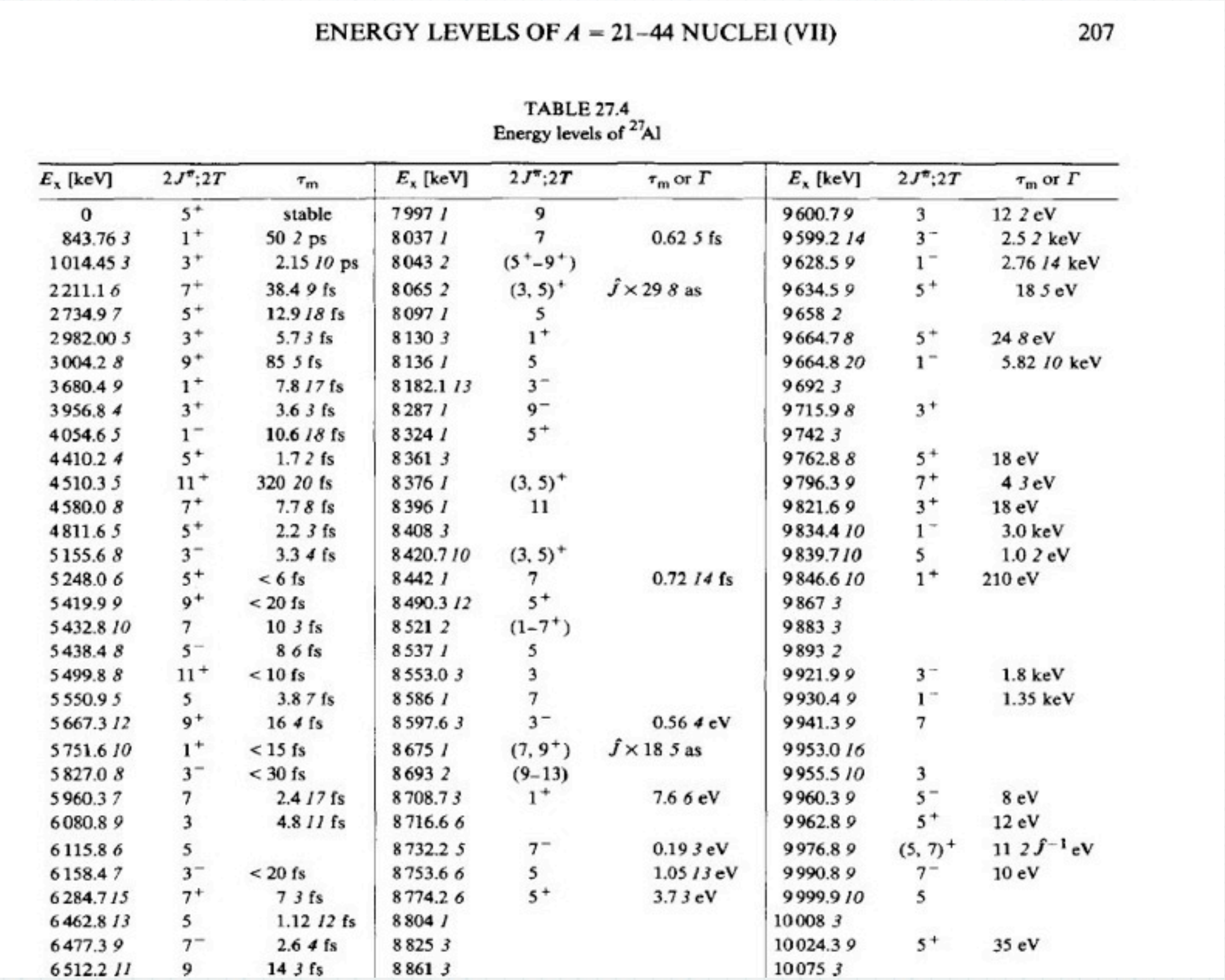
coherent

components of Fragmentation

- Gammas. Few MeV in nucleus frame->100-400 MeV in Lab. ~10 mrad in lab frame.
- neutrons. Several components to momentum distribution in HI. evaporation, Fermi step or Feshbach-Huang, tail due to SRC.
- protons, deuterons. None observed. Mostly due to Coulomb barrier suppression

Gammas: there are lots of them

partial list
for
Aluminum

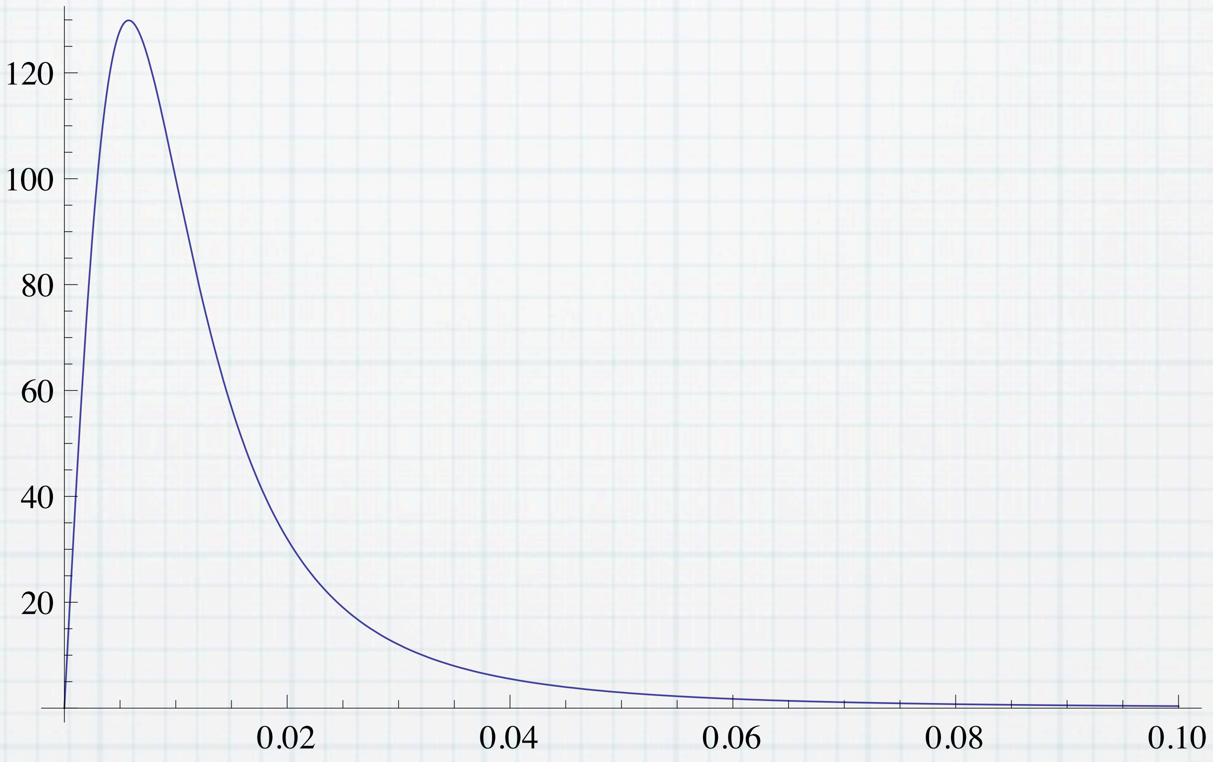


ENERGY LEVELS OF $A = 21$–44 NUCLEI (VII) 207

TABLE 27.4
Energy levels of ^{27}Al

E_x [keV]	$2J^\pi;2T$	τ_m	E_x [keV]	$2J^\pi;2T$	τ_m or Γ	E_x [keV]	$2J^\pi;2T$	τ_m or Γ
0	5^+	stable	7997 *1*	9		9600.7 *9*	3	12 *2* eV
843.76 *3*	1^+	50 *2* ps	8037 *1*	7	0.62 *5* fs	9599.2 *14*	3^-	2.5 *2* keV
1014.45 *3*	3^+	2.15 *10* ps	8043 *2*	(5^+-9^+)		9628.5 *9*	1^-	2.76 *14* keV
2211.1 *6*	7^+	38.4 *9* fs	8065 *2*	$(3, 5)^+$	$\hat{J} \times$ 29 *8* as	9634.5 *9*	5^+	18 *5* eV
2734.9 *7*	5^+	12.9 *18* fs	8097 *1*	5		9658 *2*		
2982.00 *5*	3^+	5.7 *3* fs	8130 *3*	1^+		9664.7 *8*	5^+	24 *8* eV
3004.2 *8*	9^+	85 *5* fs	8136 *1*	5		9664.8 *20*	1^-	5.82 *10* keV
3680.4 *9*	1^+	7.8 *17* fs	8182.1 *13*	3^-		9692 *3*		
3956.8 *4*	3^+	3.6 *3* fs	8287 *1*	9^-		9715.9 *8*	3^+	
4054.6 *5*	1^-	10.6 *18* fs	8324 *1*	5^+		9742 *3*		
4410.2 *4*	5^+	1.7 *2* fs	8361 *3*			9762.8 *8*	5^+	18 eV
4510.3 *5*	11^+	320 *20* fs	8376 *1*	$(3, 5)^+$		9796.3 *9*	7^+	4 *3* eV
4580.0 *8*	7^+	7.7 *8* fs	8396 *1*	11		9821.6 *9*	3^+	18 eV
4811.6 *5*	5^+	2.2 *3* fs	8408 *3*			9834.4 *10*	1^-	3.0 keV
5155.6 *8*	3^-	3.3 *4* fs	8420.7 *10*	$(3, 5)^+$		9839.7 *10*	5	1.0 *2* eV
5248.0 *6*	5^+	< 6 fs	8442 *1*	7	0.72 *14* fs	9846.6 *10*	1^+	210 eV
5419.9 *9*	9^+	< 20 fs	8490.3 *12*	5^+		9867 *3*		
5432.8 *10*	7	10 *3* fs	8521 *2*	$(1-7^+)$		9883 *3*		
5438.4 *8*	5^-	8 *6* fs	8537 *1*	5		9893 *2*		
5499.8 *8*	11^+	< 10 fs	8553.0 *3*	3		9921.9 *9*	3^-	1.8 keV
5550.9 *5*	5	3.8 *7* fs	8586 *1*	7		9930.4 *9*	1^-	1.35 keV
5667.3 *12*	9^+	16 *4* fs	8597.6 *3*	3^-	0.56 *4* eV	9941.3 *9*	7	
5751.6 *10*	1^+	< 15 fs	8675 *1*	$(7, 9^+)$	$\hat{J} \times$ 18 *5* as	9953.0 *16*		
5827.0 *8*	3^-	< 30 fs	8693 *2*	(9–13)		9955.5 *10*	3	
5960.3 *7*	7	2.4 *17* fs	8708.7 *3*	1^+	7.6 *6* eV	9960.3 *9*	5^-	8 eV
6080.8 *9*	3	4.8 *11* fs	8716.6 *6*			9962.8 *9*	5^+	12 eV
6115.8 *6*	5		8732.2 *5*	7^-	0.19 *3* eV	9976.8 *9*	$(5, 7)^+$	11 *2* J^{-1} eV
6158.4 *7*	3^-	< 20 fs	8753.6 *6*	5	1.05 *13* eV	9990.8 *9*	7^-	10 eV
6284.7 *15*	7^+	7 *3* fs	8774.2 *6*	5^+	3.7 *3* eV	9999.9 *10*	5	
6462.8 *13*	5	1.12 *12* fs	8804 *1*			10008 *3*		
6477.3 *9*	7^-	2.6 *4* fs	8825 *3*			10024.3 *9*	5^+	35 eV
6512.2 *11*	9	14 *3* fs	8861 *3*			10075 *3*		

Gammas: angular distribution in the lab

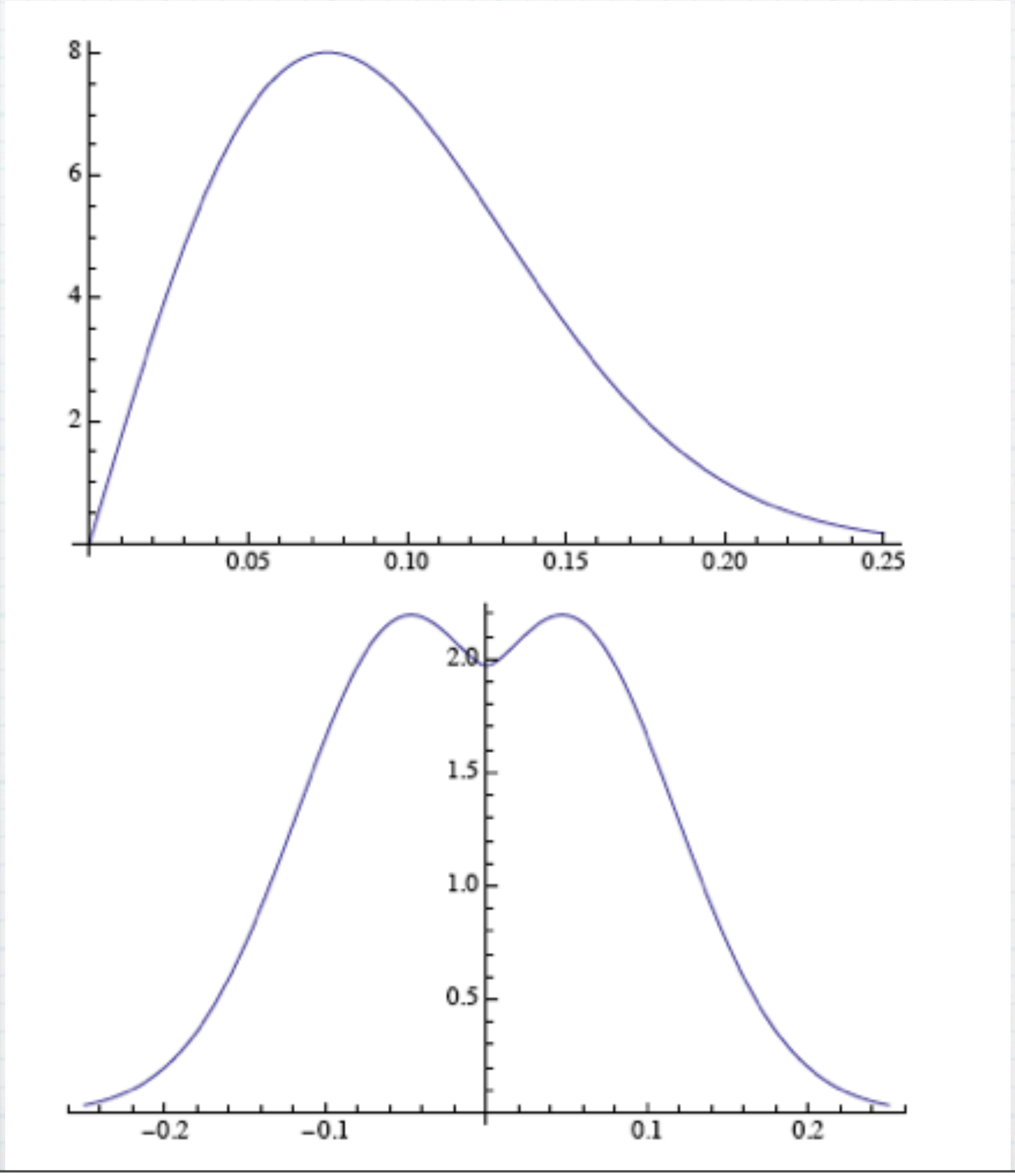


Neutrons.

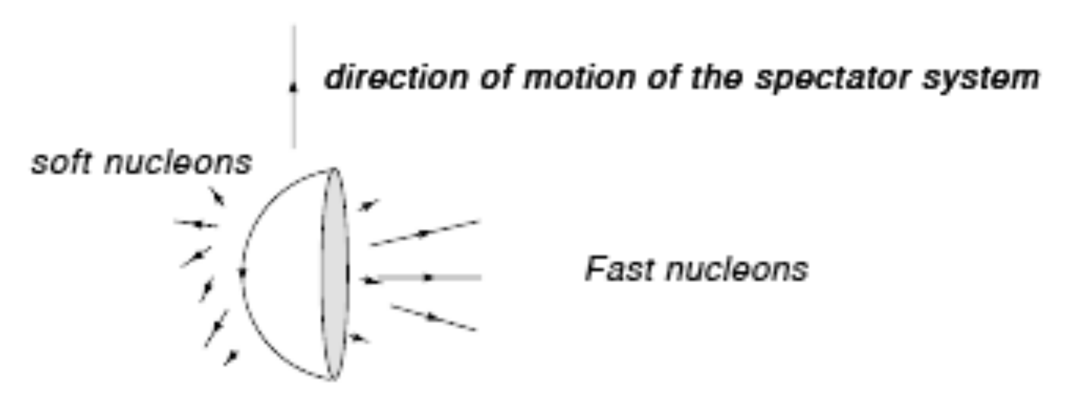
Evaporation component critical for diffraction in eA

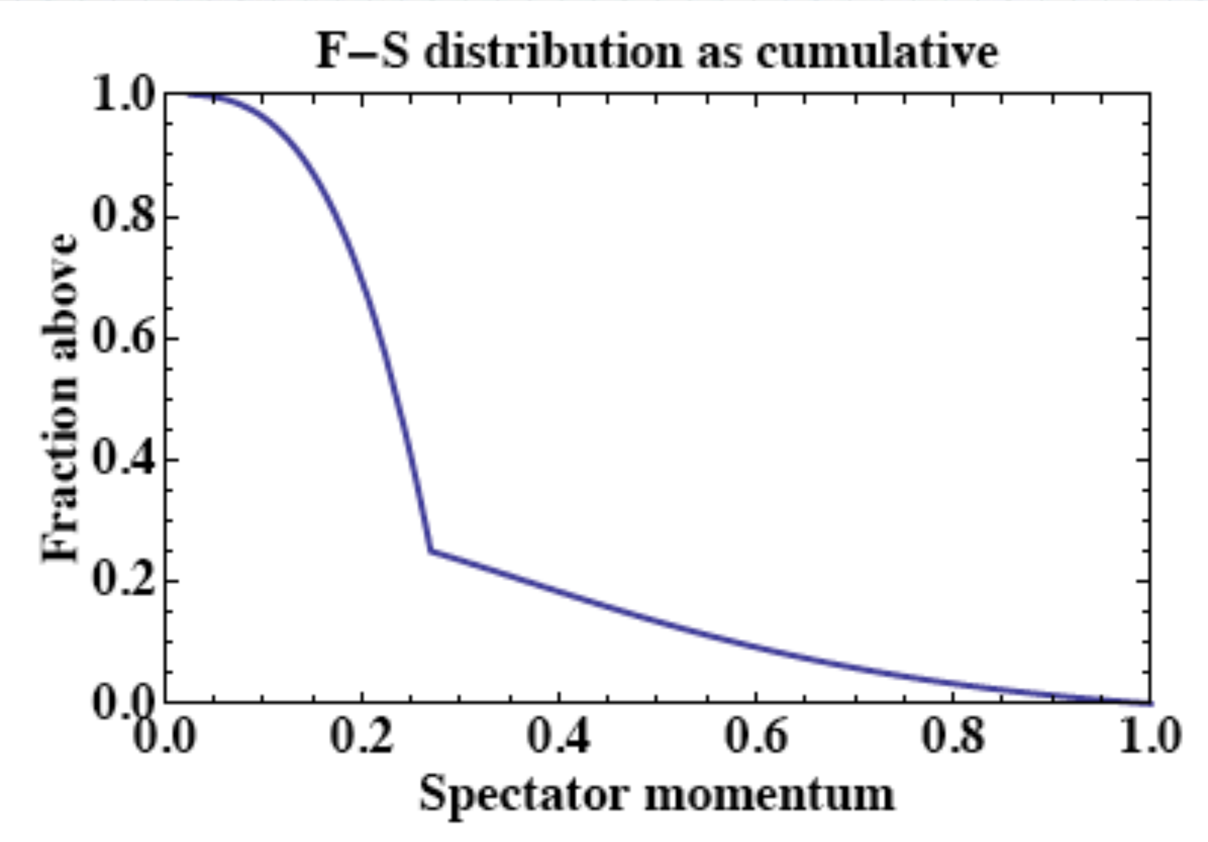
pT(Mev)

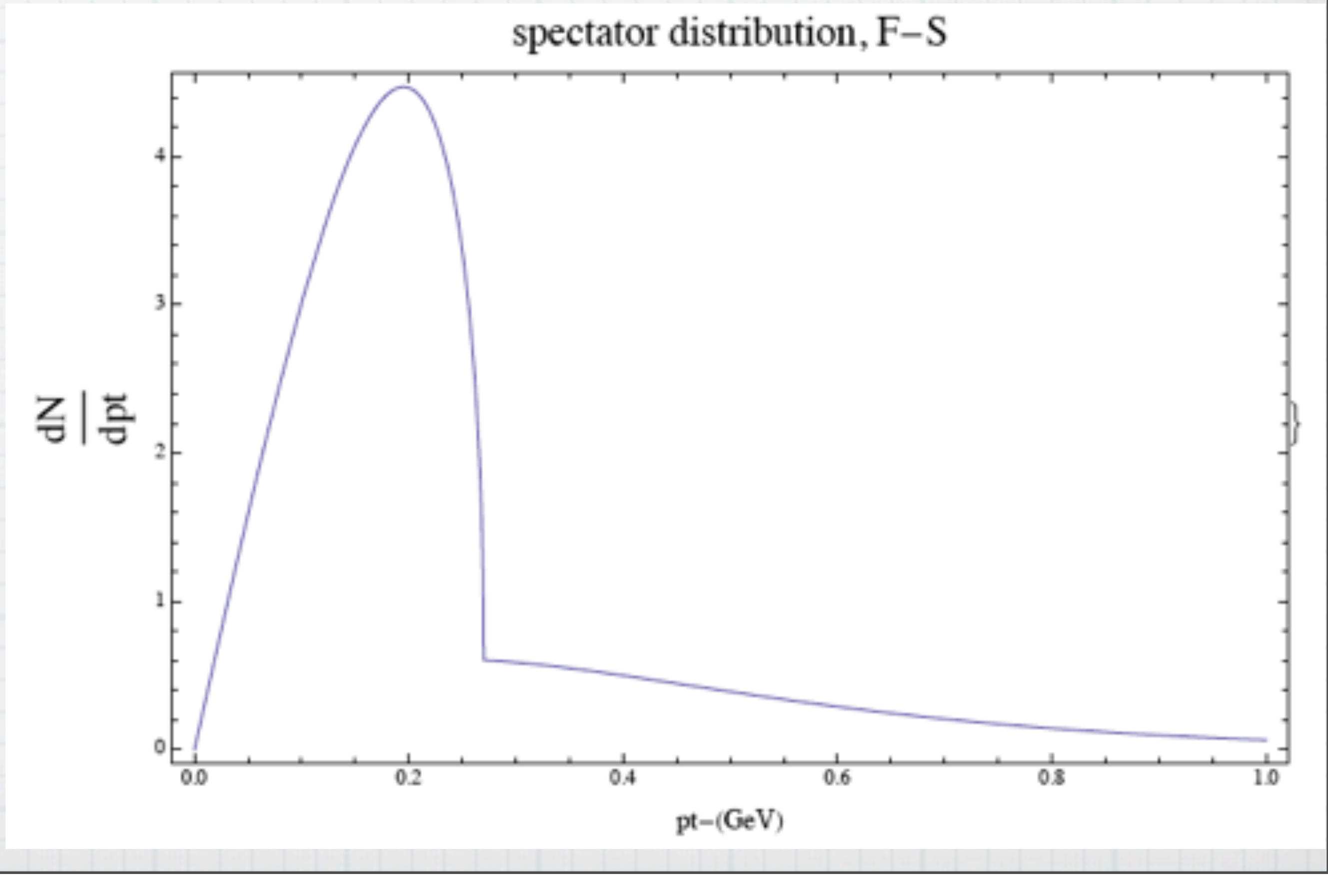
pT(x projection)

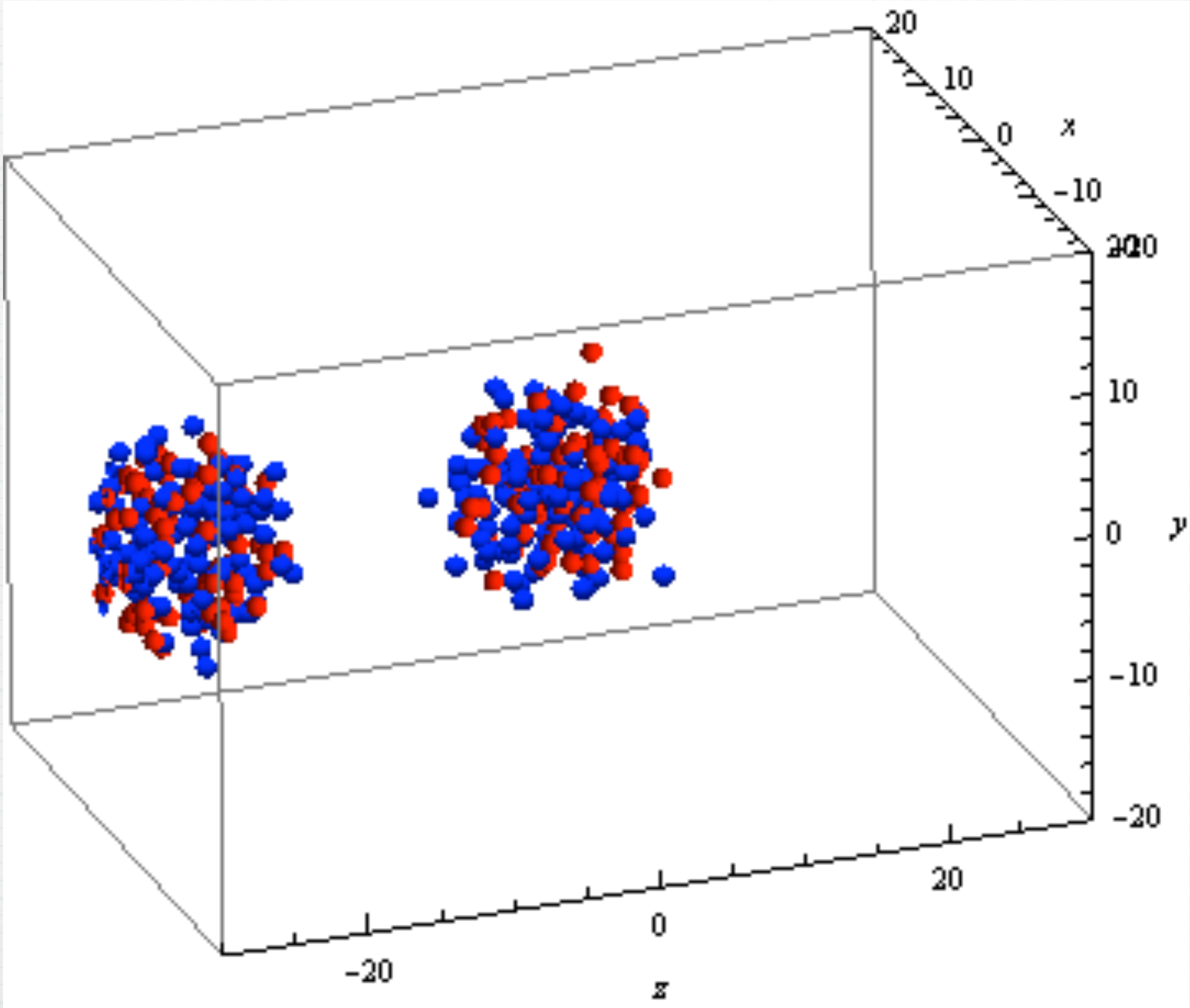


we produced modified HIJING with critical aspects of fragmentation





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20
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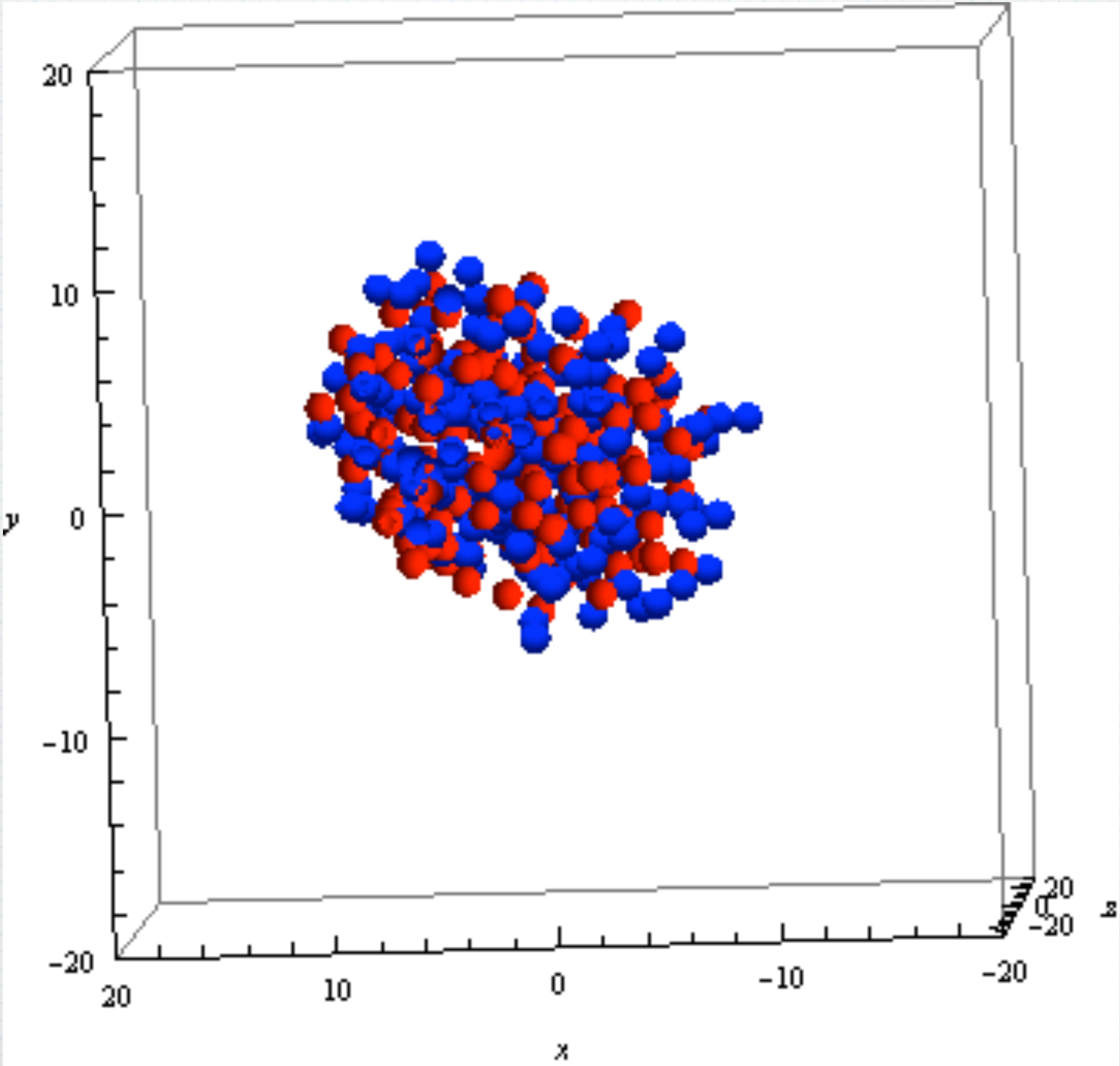
20
z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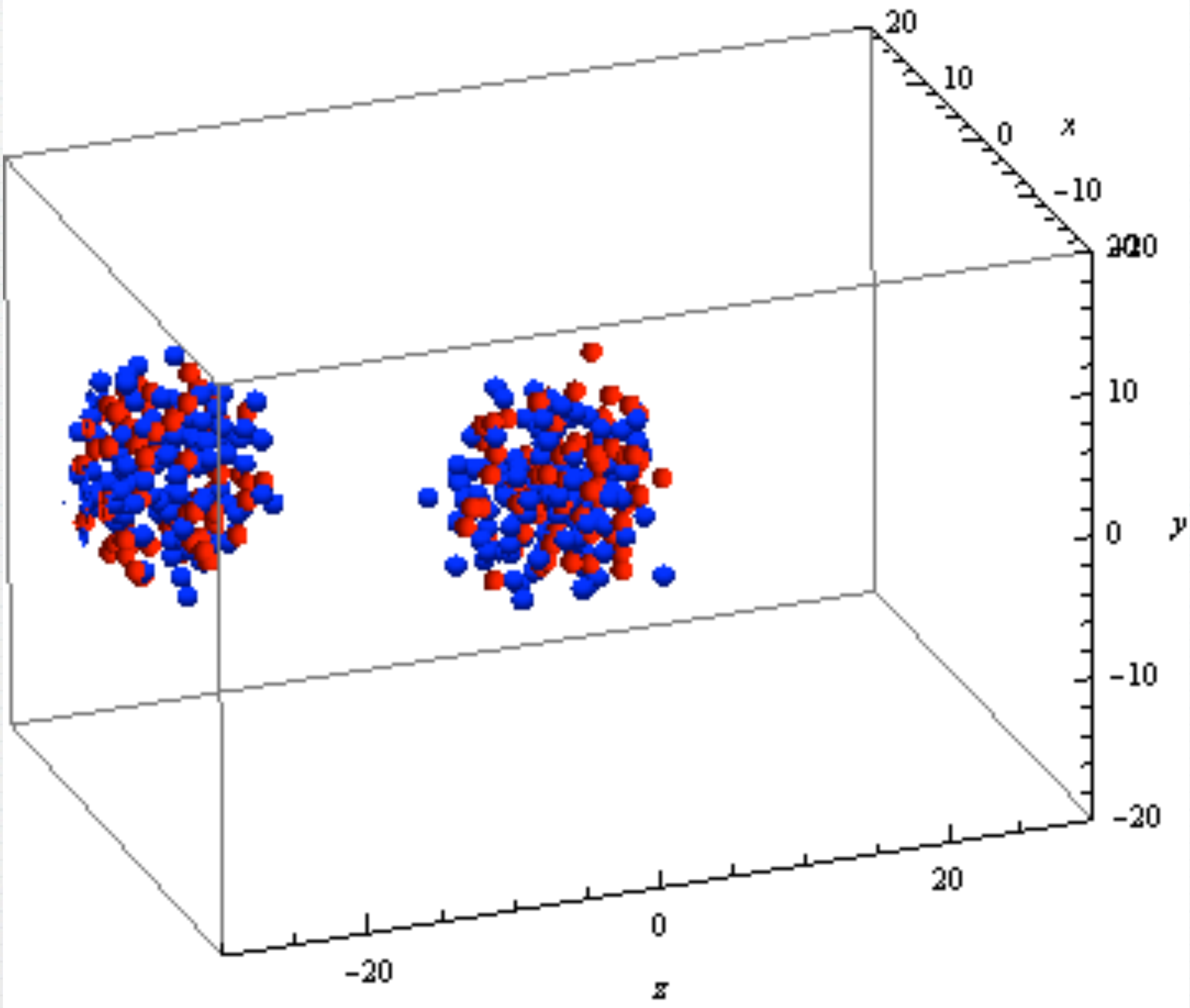
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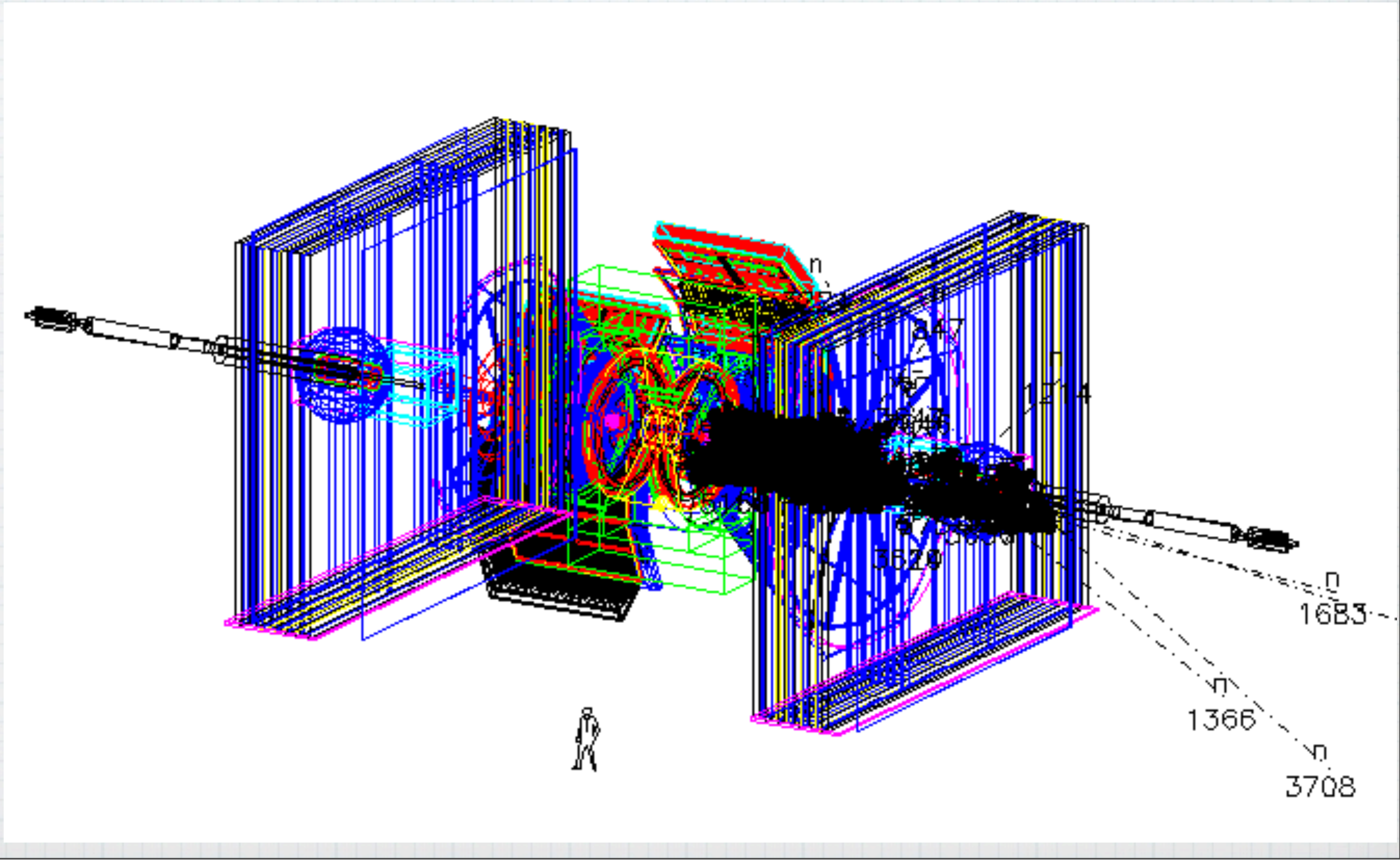
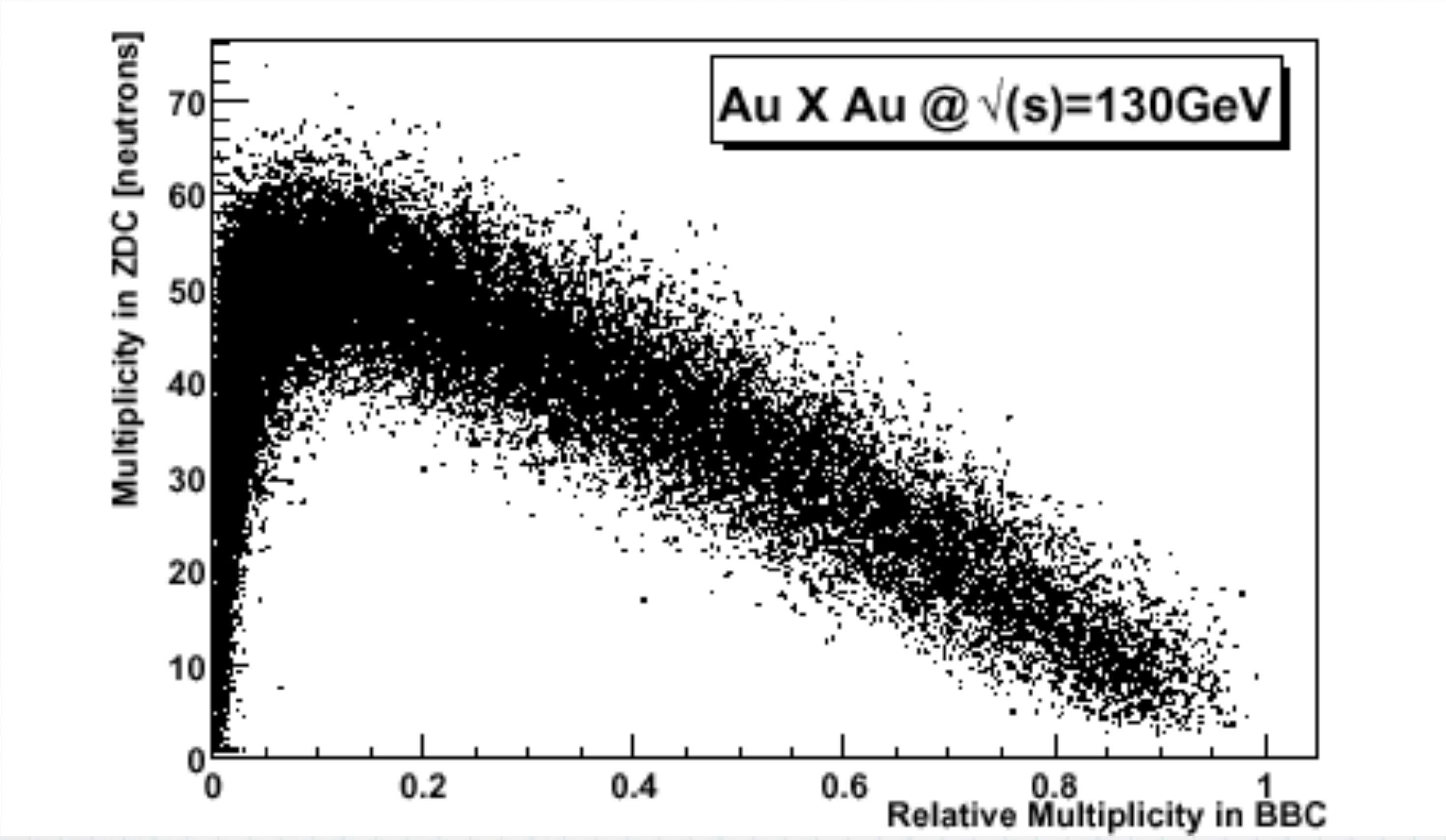
SNW, Mark Strikman, Tamas Csorgo, Massi Alvioli, Marton Vargyas

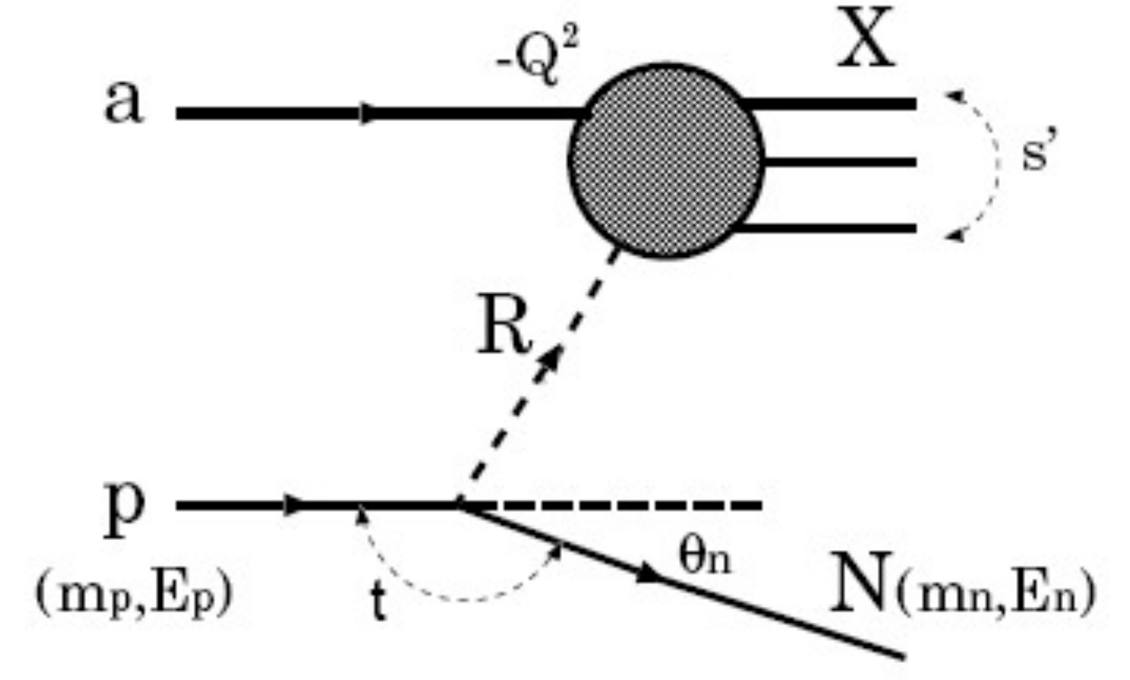


Leading neutrons basis of much physics in PHENIX and ATLAS

in Heavy nuclei

in pp



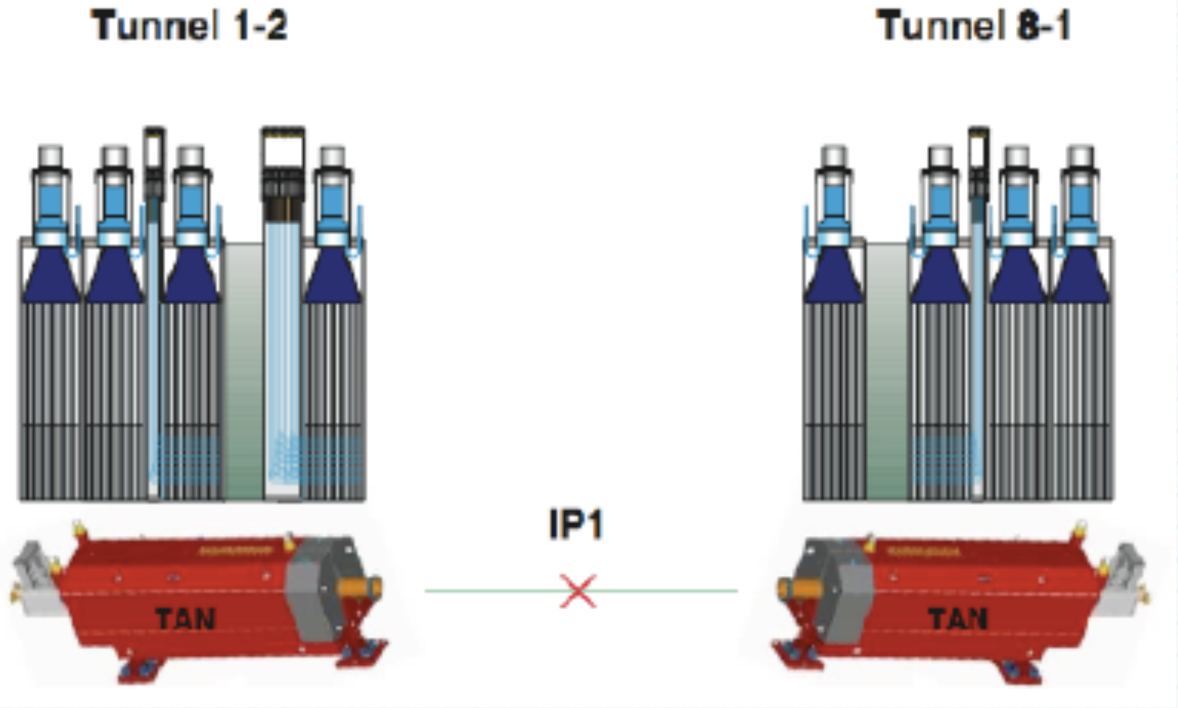


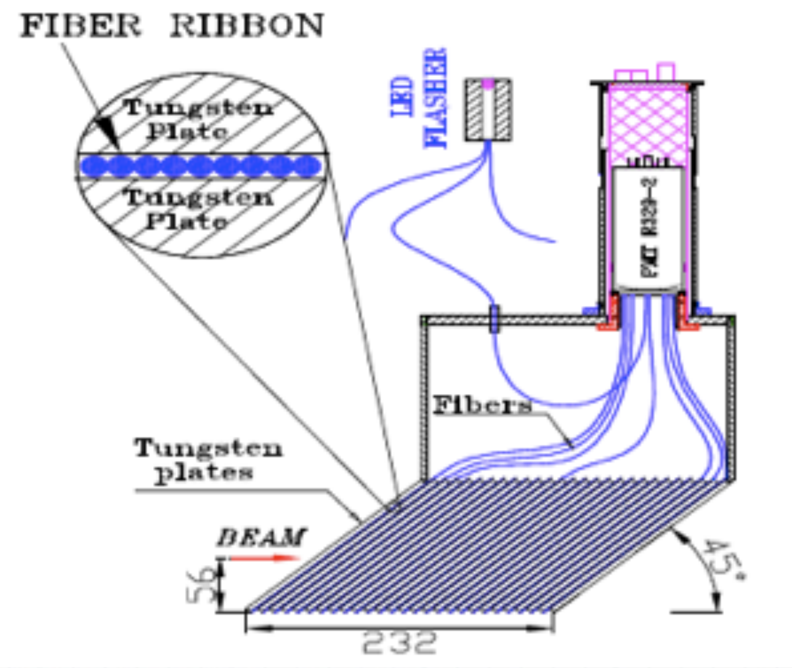
BBC similar to MBTS
multiplicity anticorrelated to ZDC energy

usually, ie RAPGAP,
R= pi+

Forward Instrumentation @ion colliders

- There are many challenges:
  - space constraints
    - @RHIC & LHC only 10cm for ZDC
    - window to limit material-> rf impedence
  - machine dictates field geometry
  - LHC dumps 200Watts into ZDC (>5Grad)
  - PMT aging seen at RHIC (but not rad damage)





ATLAS ZDC's

RHIC ZDC's

but many overcome @ RHIC&LHC

- we achieved excellent results for EM and Hadronic showers in both

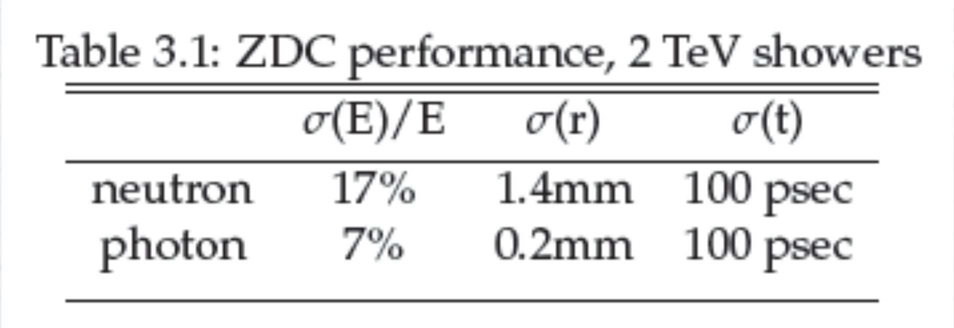


Table 3.1: ZDC performance, 2 TeV showers

	$\sigma(E)/E$	$\sigma(r)$	$\sigma(t)$
neutron	17%	1.4mm	100 psec
photon	7%	0.2mm	100 psec

- Surprisingly, ZDC is one of cleanest detectors in ATLAS ("signal energy" is orders of mag. above most bkg.). Unique 1-arm van derMeer.
- In PHENIX the ZDC is key to triggering and analysis for EM processes (ie coherent J/Psi)
- ALICE also installed a "proton ZDC" with good results.
- CDF BSC's may be a good way to extend rapidity coverage for tags.

Roman Pots+

- used in HEP to measure protons at very small angles and when $1-x<0.05$ (note acceptance is in narrow window at $x=2.5$ with ion beams)
- several factors limit their relevance at an electron nucleus collider

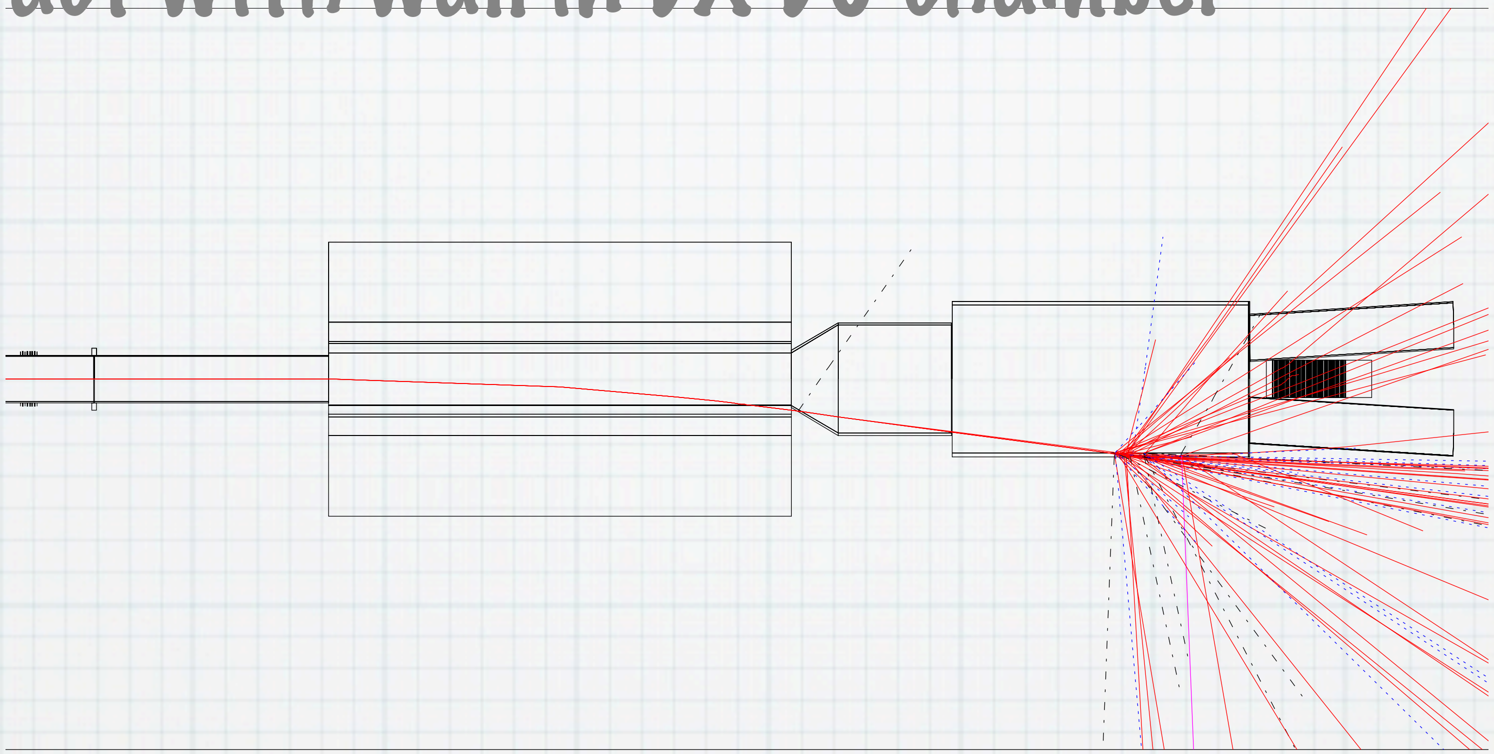
+ (I worked with Roman Pots for 5 yrs on CDF)

pertinent factors:

- nuclei don't evaporate protons (Coulomb barrier)
- protons differ in magnetic rigidity by a factor of 2.5(A/Z) from the beam
  - they don't get into the beamline
  - the dispersion in a realistic accelerator beamline kills them
- impact on rf impedence
- sensors too sensitive for nuclear beams
- pots usually in dedicated runs

trajectory of final state protons at RHIC

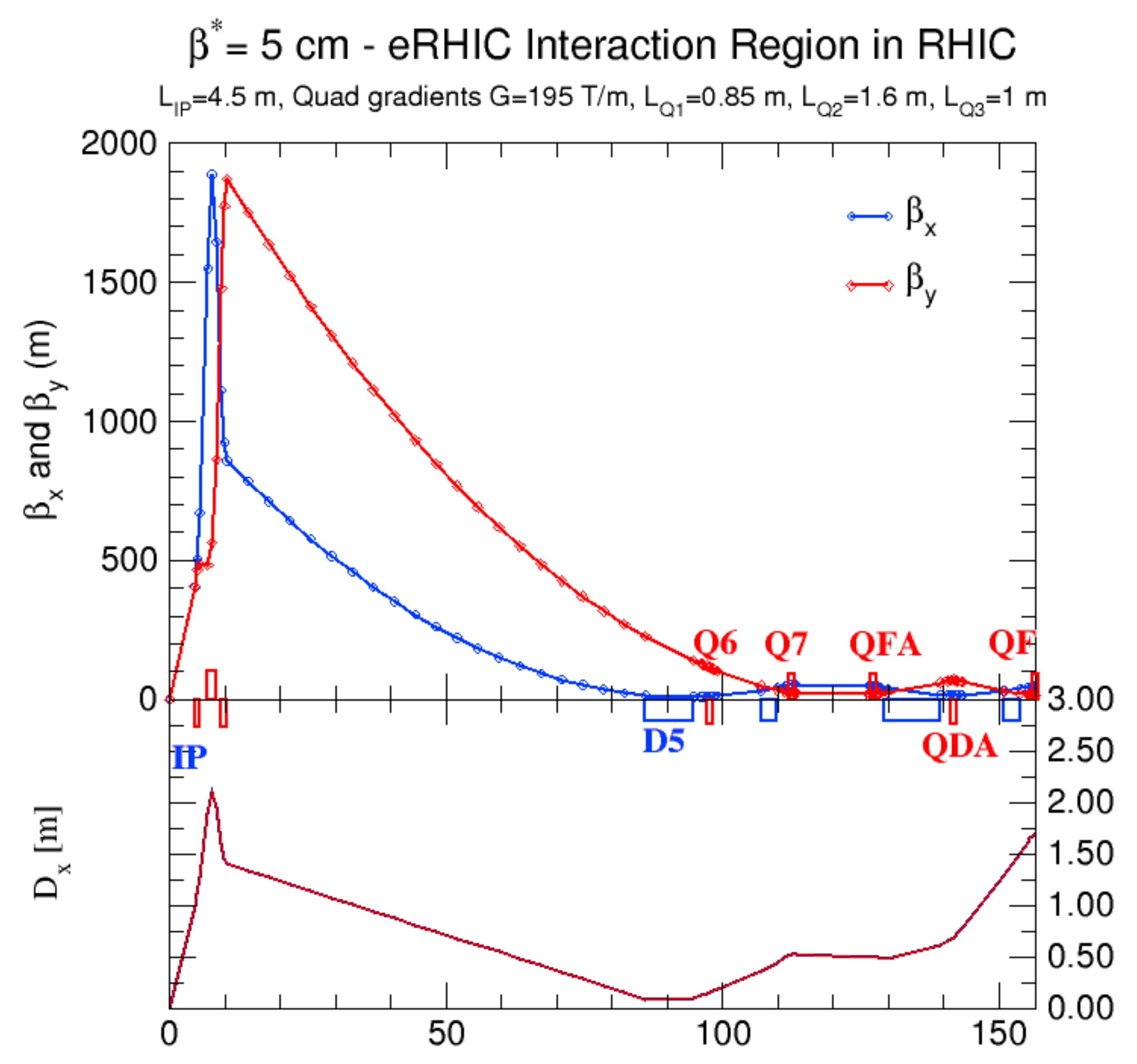
- a fraction interacts with wall in DX magnet
- the rest interact with wall in DX-D0 chamber



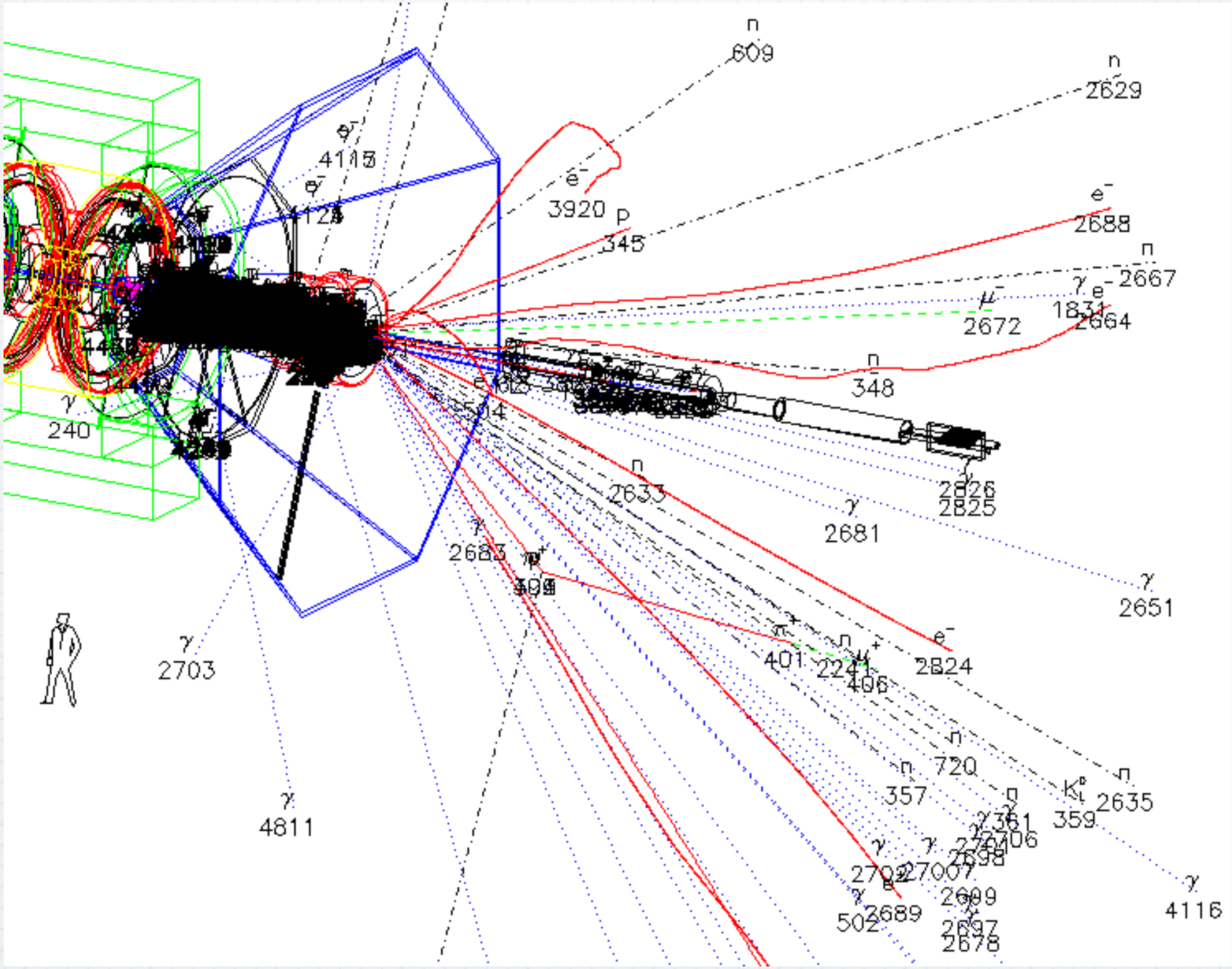
this location has highest rf impedence at RHIC (~rf cavity)

impedence minimized by lining it with rf screens

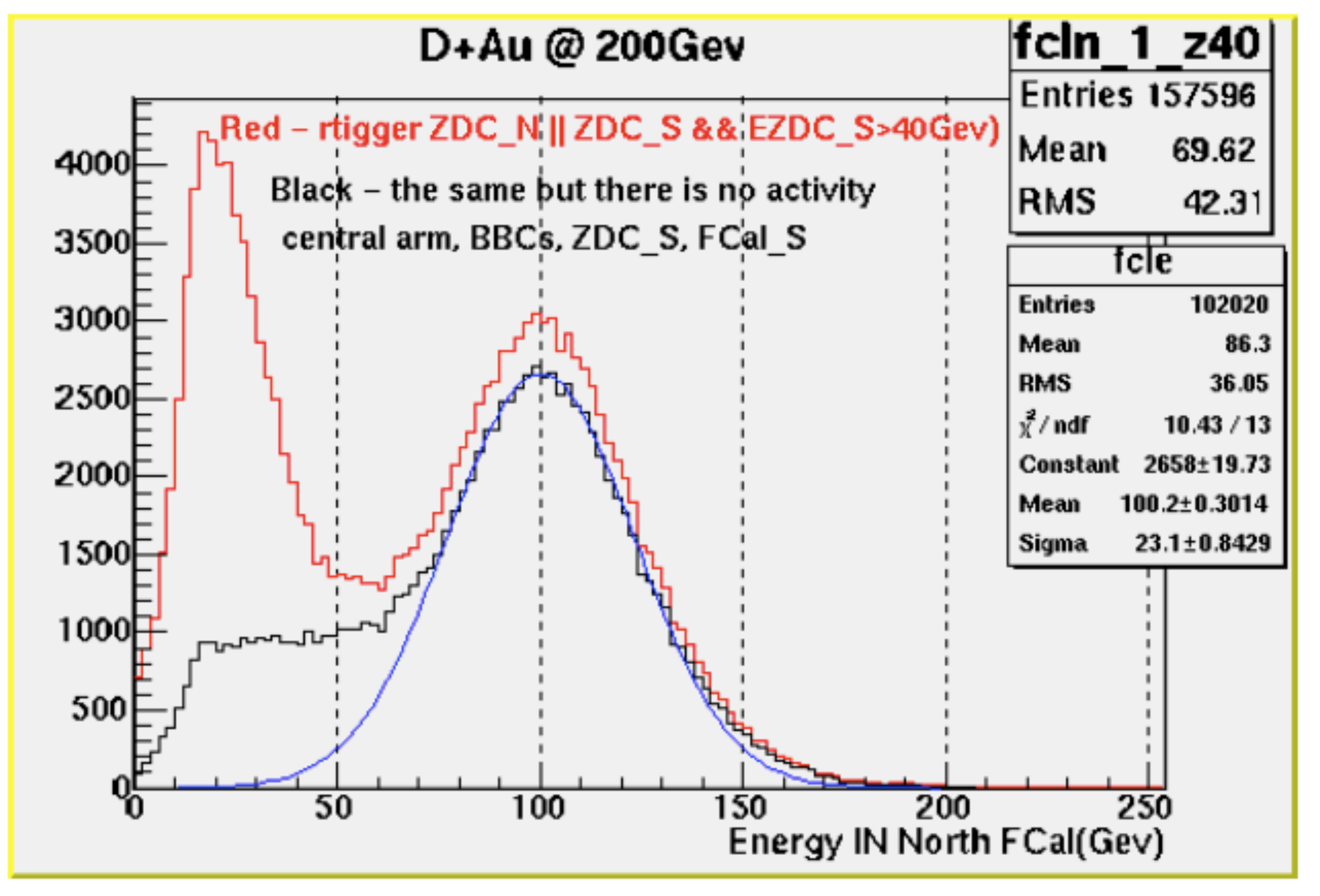
- typical RHIC dispersion function exceeds 0.5 meters (not sure which lattice this one is)
- even a 2.5(A/Z)*0.5m radius aperture would be a very expensive accelerator



if you look for hit in a silicon detector in forward direction you usually find one at an ion collider



for some physics it would be useful to measure protons- particularly with large xF coverage.
PHENIX did this successfully with a hadron calorimeter



magnet elements around ip determine possible measurements this shows RHIC geometry which is a good one for fragment measurement

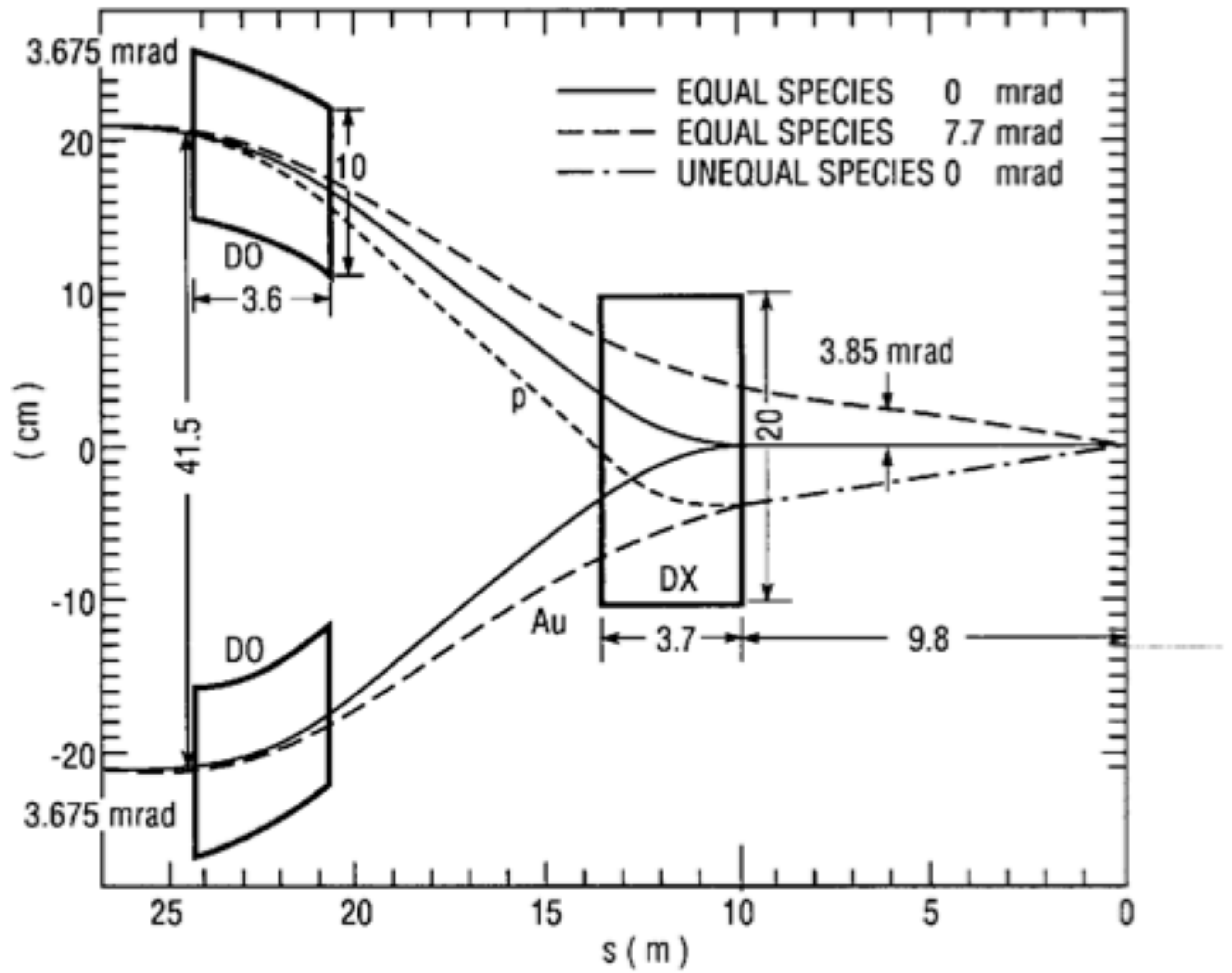
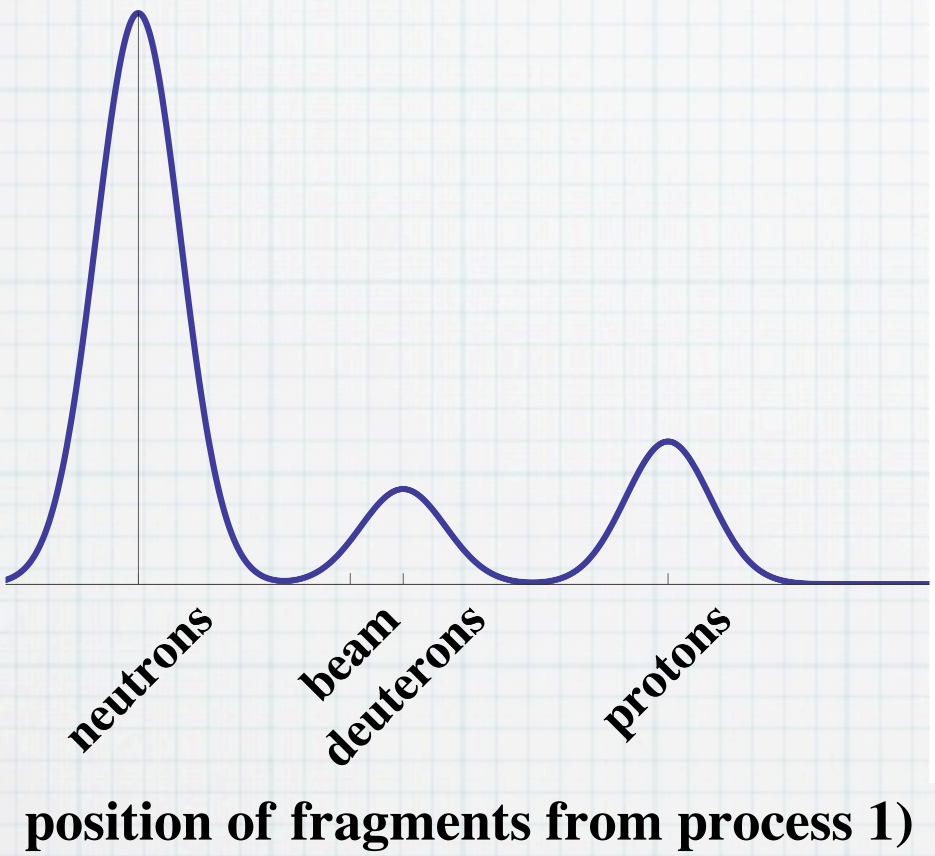


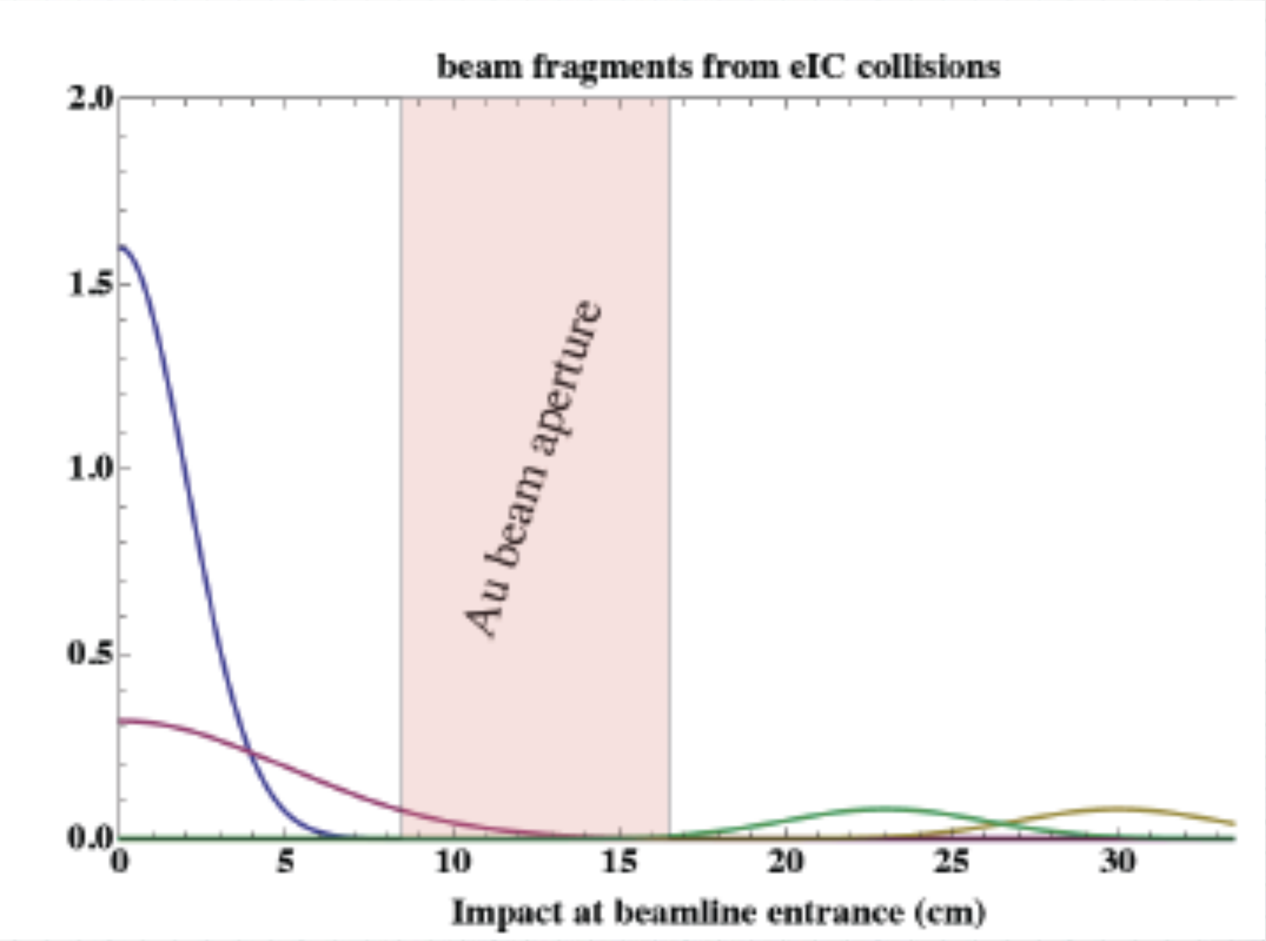
Fig. 11-7. Beam crossing geometry (magnetic lengths are shown).

```
Etot[x_] := Energy[1, x] * Mult[[1]] +
  Energy[2, x] * Mult[[2]] + Energy[3, x] * Mult[[3]] + Energy[4, x] * Mult[[4]]
Plot[Etot[x], {x, -5, 30}, PlotStyle → Thick, PlotRange → {{-5, 30}, {0, 3}},
 Frame → {True, False, False, False}, Ticks → { Automatic, None},
 FrameTicks → {{All, None}, {Mynames[45], None}},
 FrameLabel → {Style["position of fragments from process 1)", 18],
   Style["", 18], Style["Energy Distribution at 4*10^9", 18]},
 LabelStyle → Directive[Black, Bold, FontSize → 18]]
```

```
{12, 0, 2, 3}

{0, 0.4, 0.5, 1.}
```

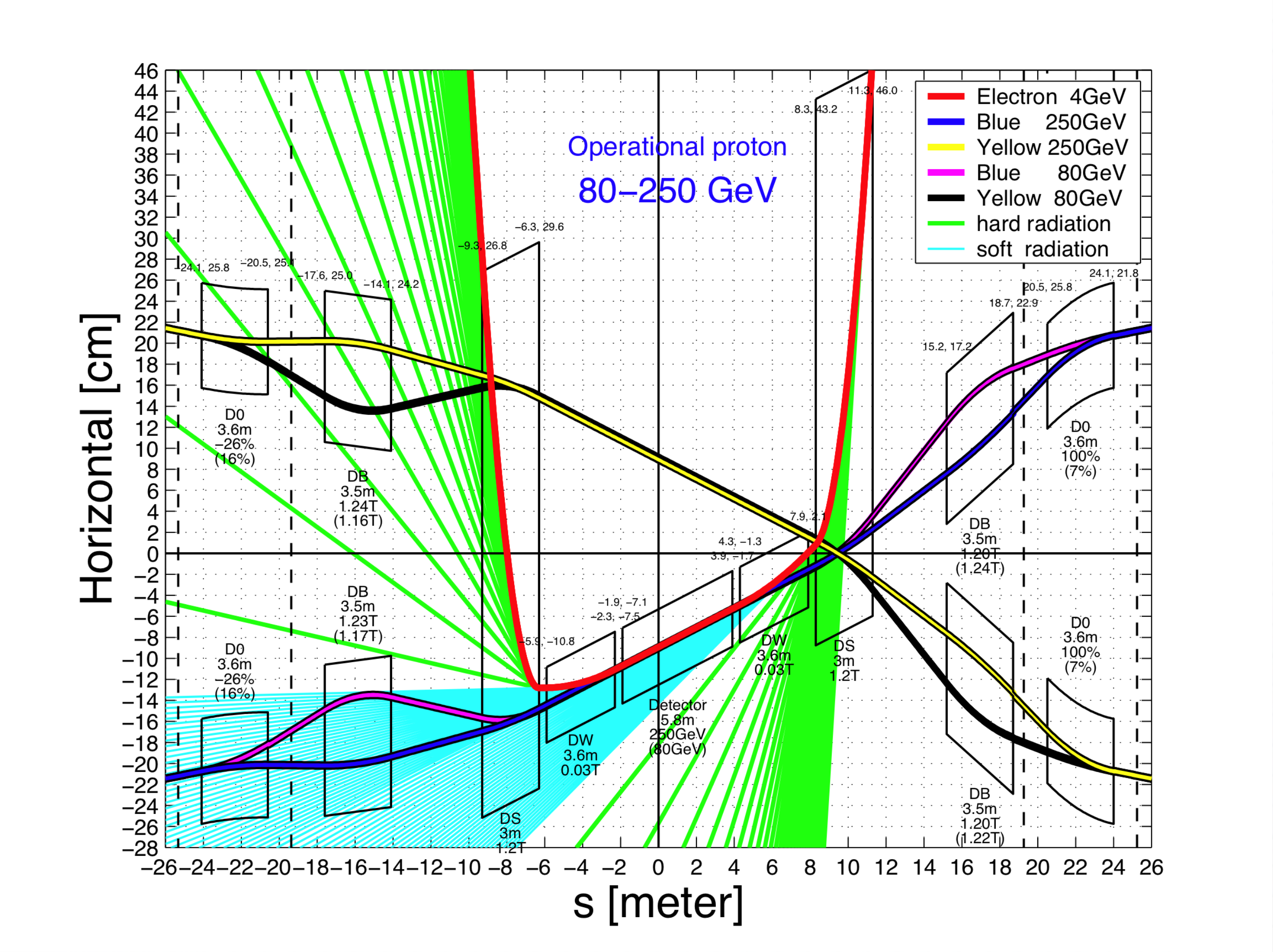


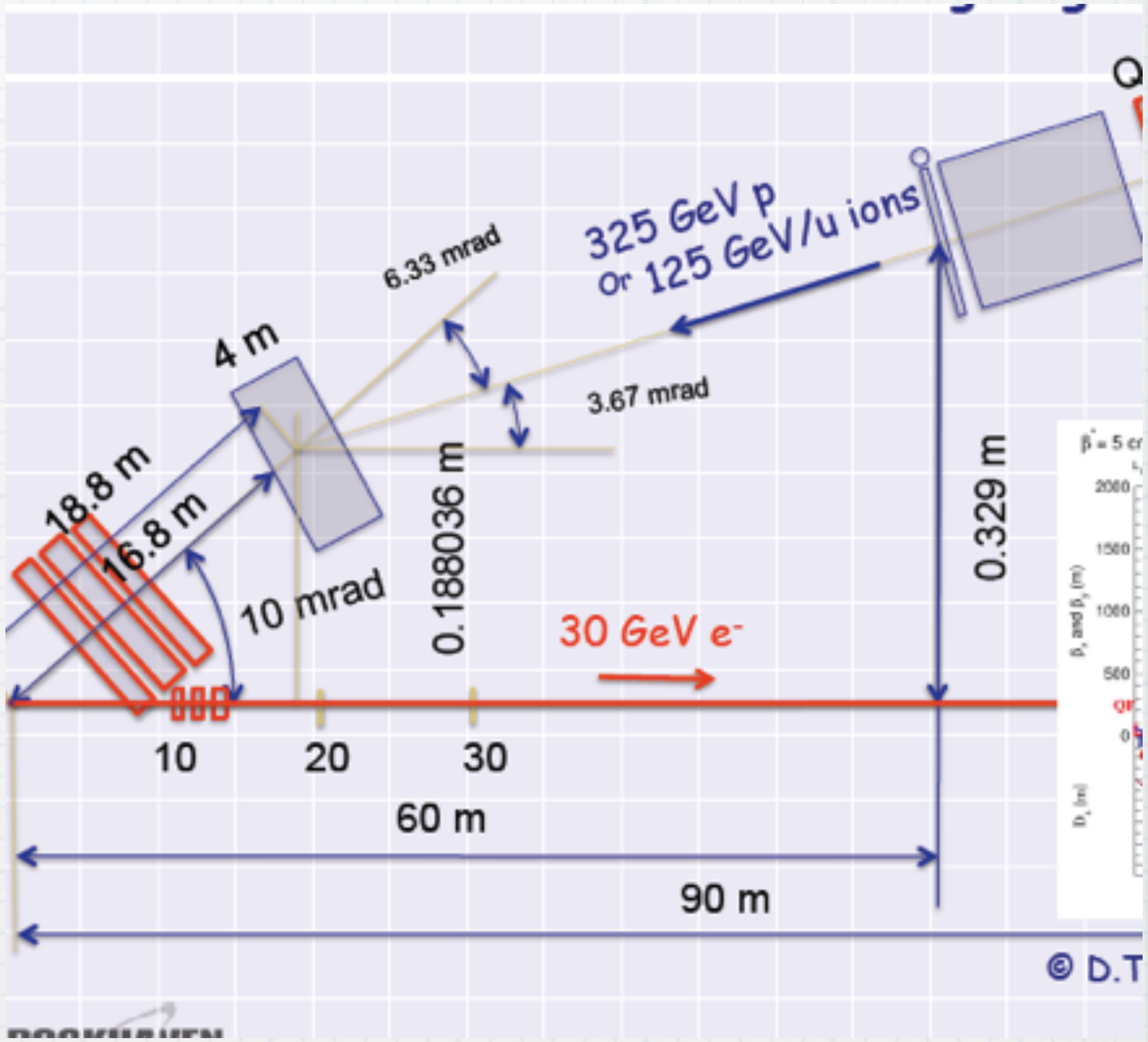


eRHIC designs have smaller bend angle than RHIC

~4 mrad

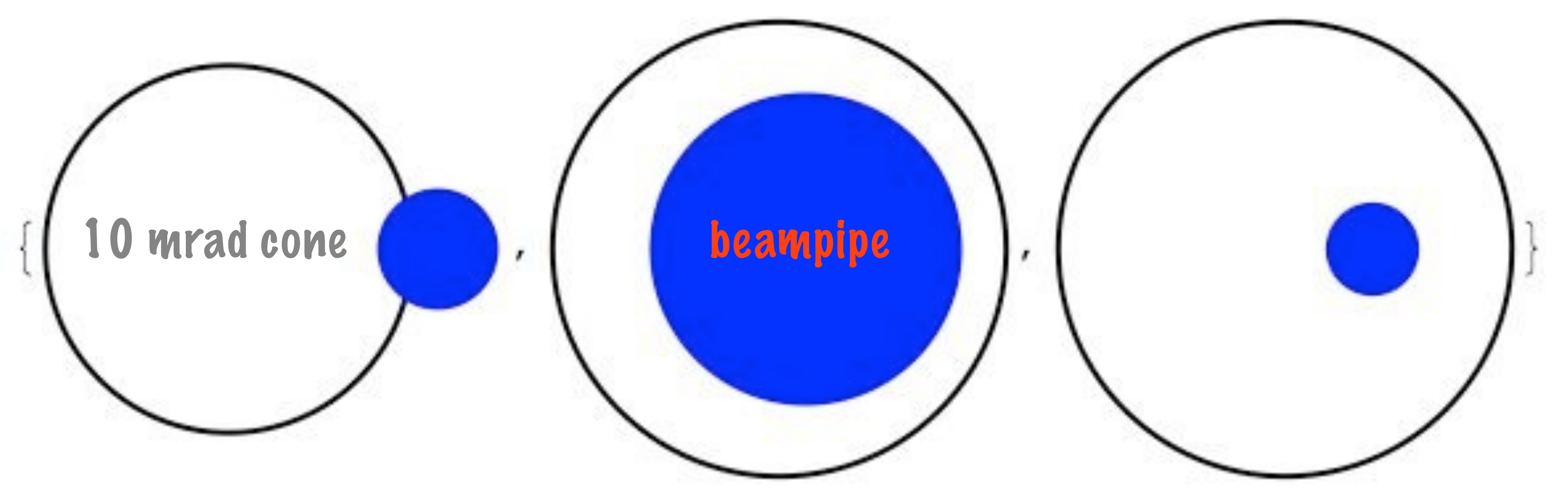
6.3 mrad



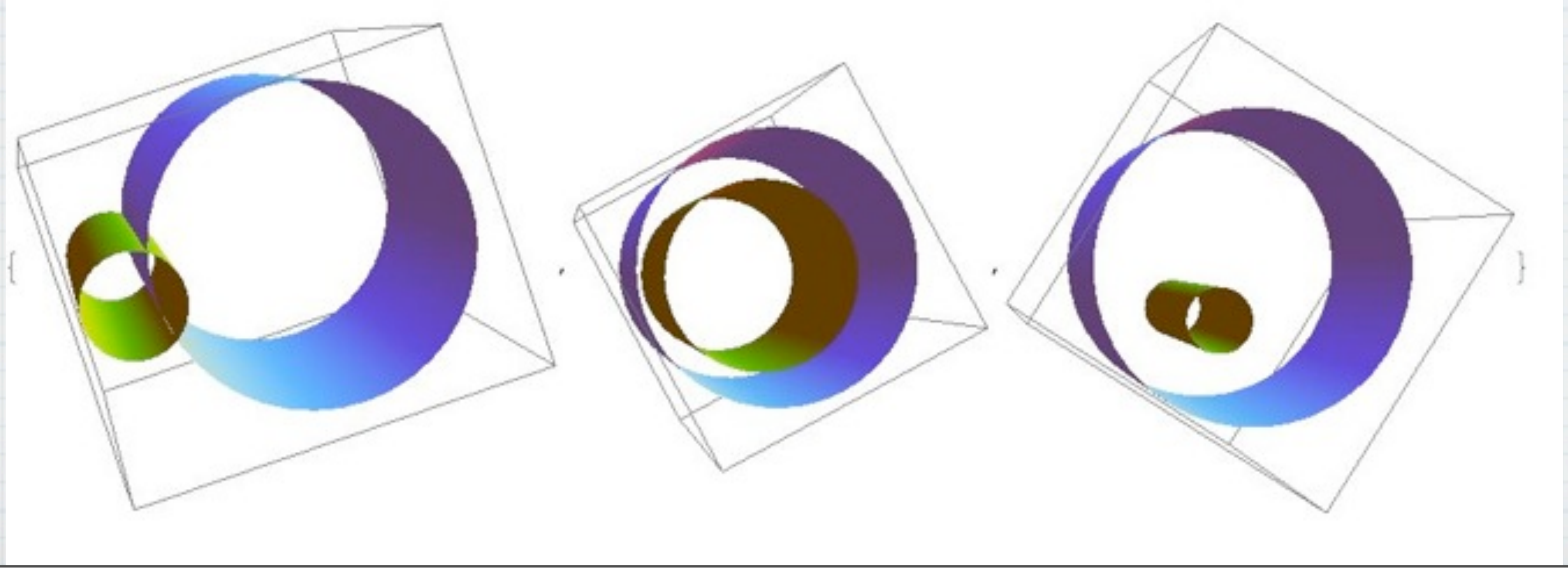


IR geometry , magnetic field determine possible forward coverage.

Consider forward 10 mrad cone (black circle) containing most of fragmentation neutrons and ~1/2 of gammas:



RHIC 4mr bend 6.3 mr bend



Summary

- there is a lot of interesting physics with fragments
- proper integration of machine design with detector challenges clearly worth the effort.