On the Potential Use of Zero Degree Calorimeters for LHC Luminosity Monitoring

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The ATLAS ZDC

- Role of ZDC in Heavy Ion Program(s)
- Potential Role as an LHC Commissioning tool
- Expected Rates/Background at LHC
- ZDC design and Prototype status

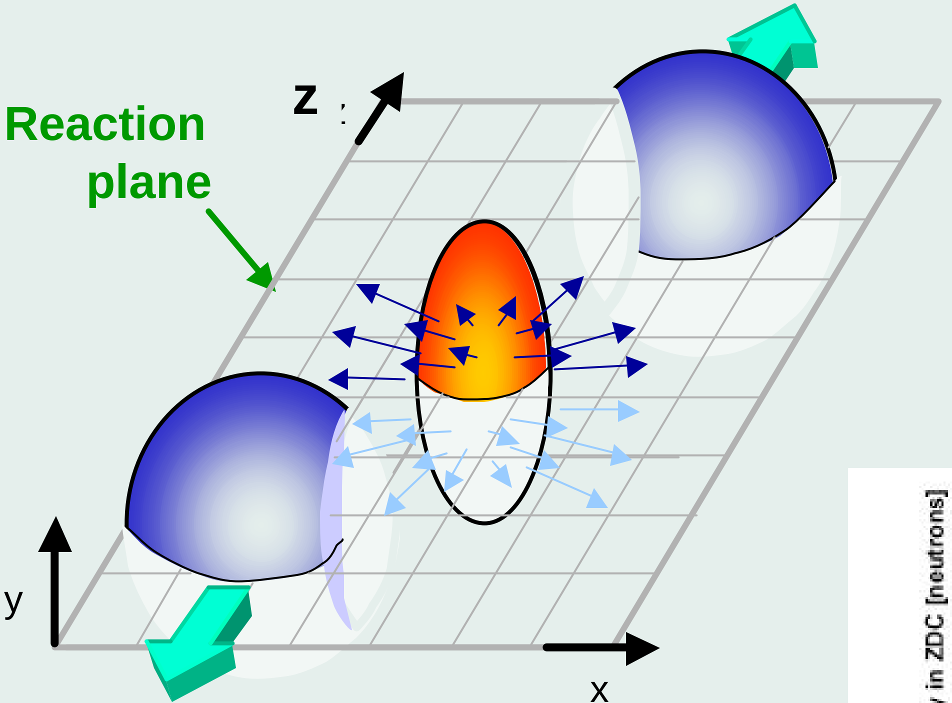
Role of ZDC in Heavy Ion Program(s)

- Anticipated
  - Heavy Ion absolute / relative Luminosity
  - HI Event Characterization
- Evolving
  - HI Reaction Plane(v1)
  - HI tag / trigger for Diffractive Physics
  - d-Au,pp (and AuAu) diffractive Physics
  - pp commissioning and Lumi monitoring
  - Polarimetry(PHENIX)

=> Critical to LHC program of Deep Inelastic Photoproduction (strong overlap with HERAII goals)

Event characterization using forward detectors

>>Direction and magnitude of impact parameter, b



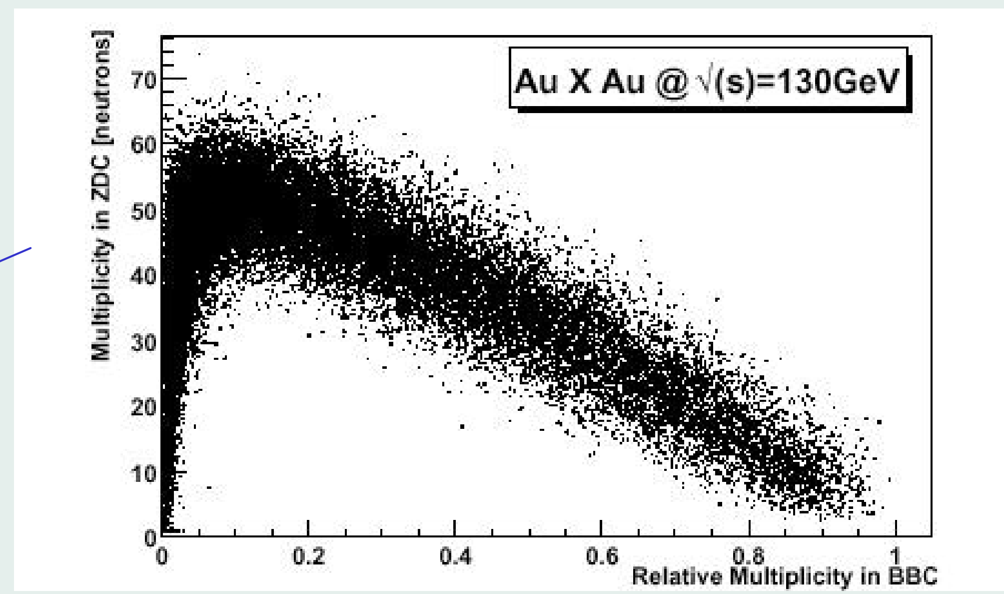
Magnitude from complementary parameters

$N_{participant}=2*A-N_{spectator}$

Spectator neutrons

- **measure centrality,**
- **Min_min_bias trigger**

(Calorimeter@q<2mr.)



Beam-Beam Counter Mult/1000

Topics in Diffraction

- Total Cross Sections
  - RHIC methodology uses calculable EM cross sections to calibrate (eg Coulomb Dissociation, γ+d->n+p)
- "Peripheral γ-A interactions"
  - Diffractive Vector meson production
  - $\gamma\gamma \rightarrow e^+e^-$
- Deep inelastic γ-A interactions
  - -dijet, jet+γ, Heavy Flavor production
- Other Forward Physics, eg pp->n+X

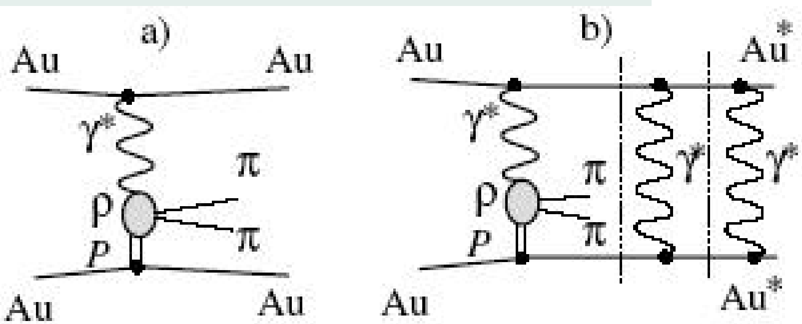
Tagged photon spectrum

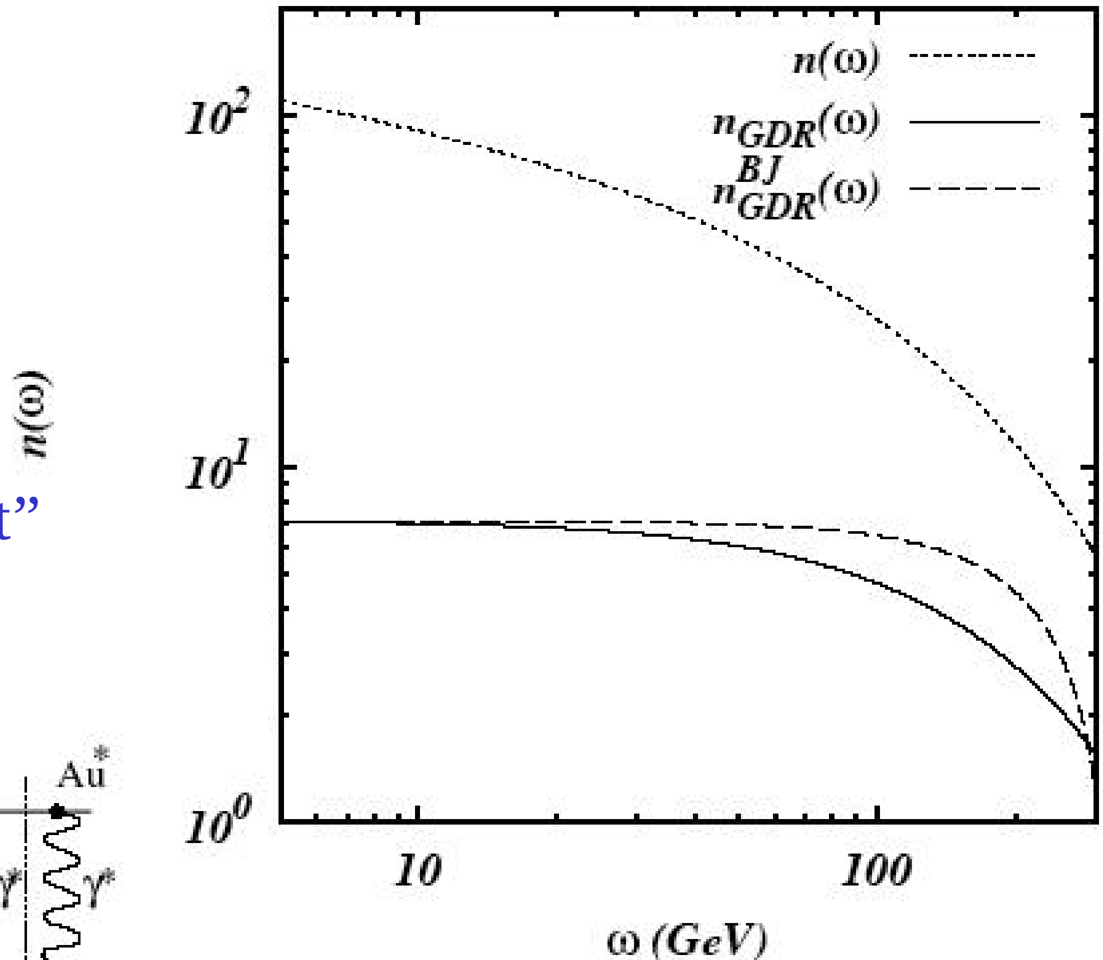
Strength of interaction

$$\eta = \frac{Z_1 Z_2 e^2}{\hbar v} \approx Z_1 Z_2 \alpha$$

2^{nd} γ exchange leads to hardened photon beam (implemented in "STARlight" not yet in "DPEMC")

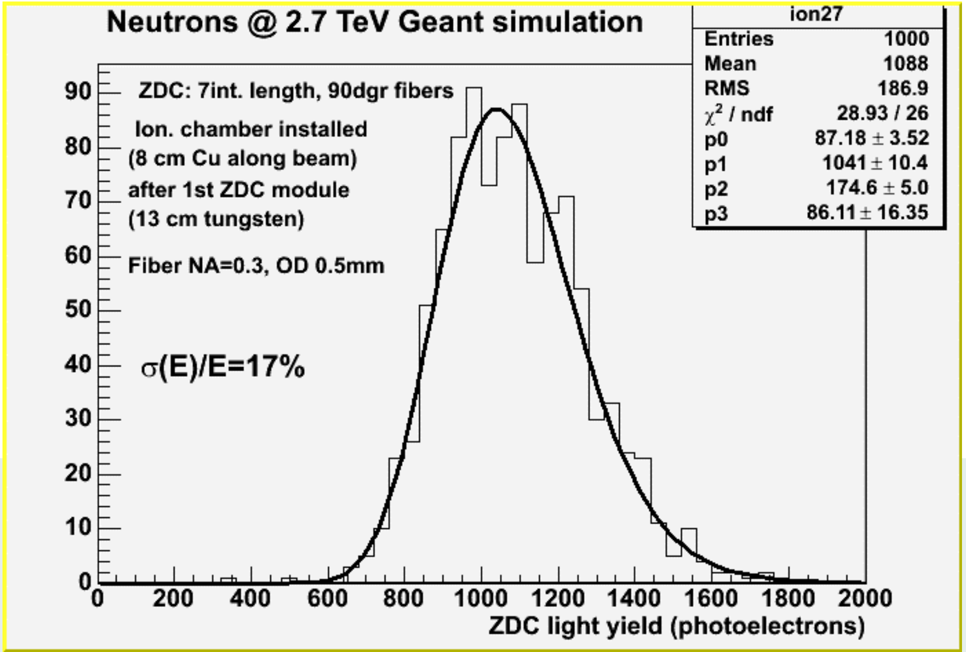
(seeG.Baur et al. Nucl-th/03070310)

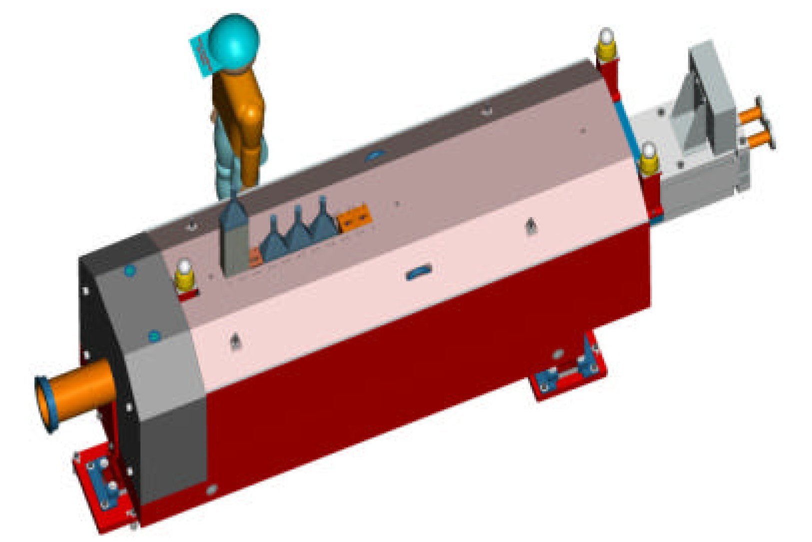




Towards the LHC

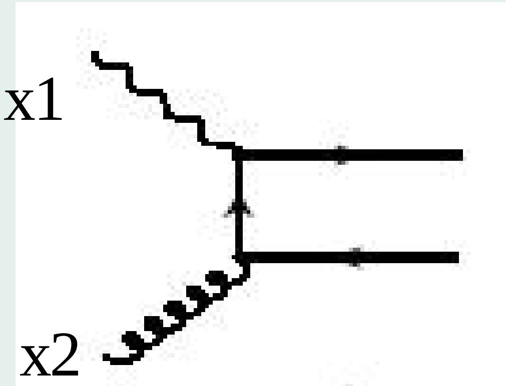
- ATLAS Coverage
- Forward Instrumentation
- ATLAS reach in jj and γj



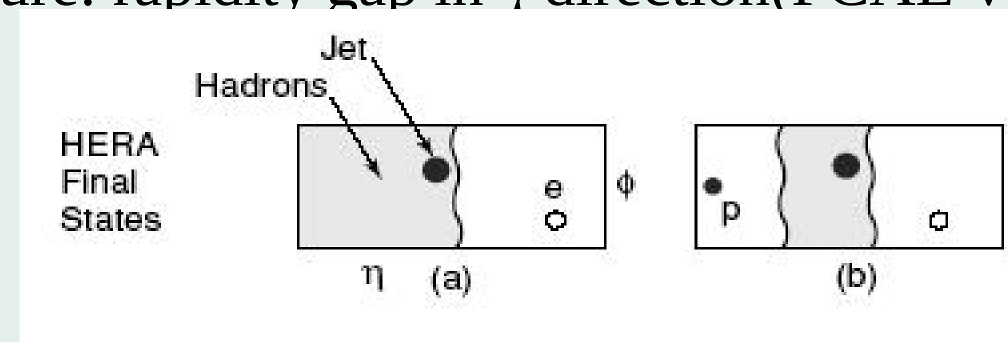


Pro-E model of ZDC for ATLAS and full simulation of Energy response

Probing small x structure in the Nucleus with γN->jets, heavy flavor.

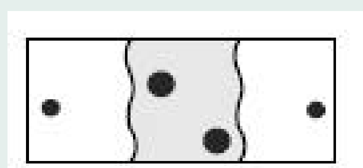


di-jet photoproduction-> parton distributions,x2
by γ with momentum fraction, x1
$4p_t^2/s=x1*x2$
$<y> \sim -1/2*\ln(x1/x2)$
Signature: rapidity gap in γ direction(FCAL veto)

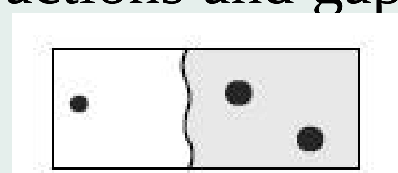


ATLAS coverage to
$|\eta|<5$ units. P_t ~2 Gev
“rapidity gap” threshold

Analogous upc interactions and gap structure



diffractive

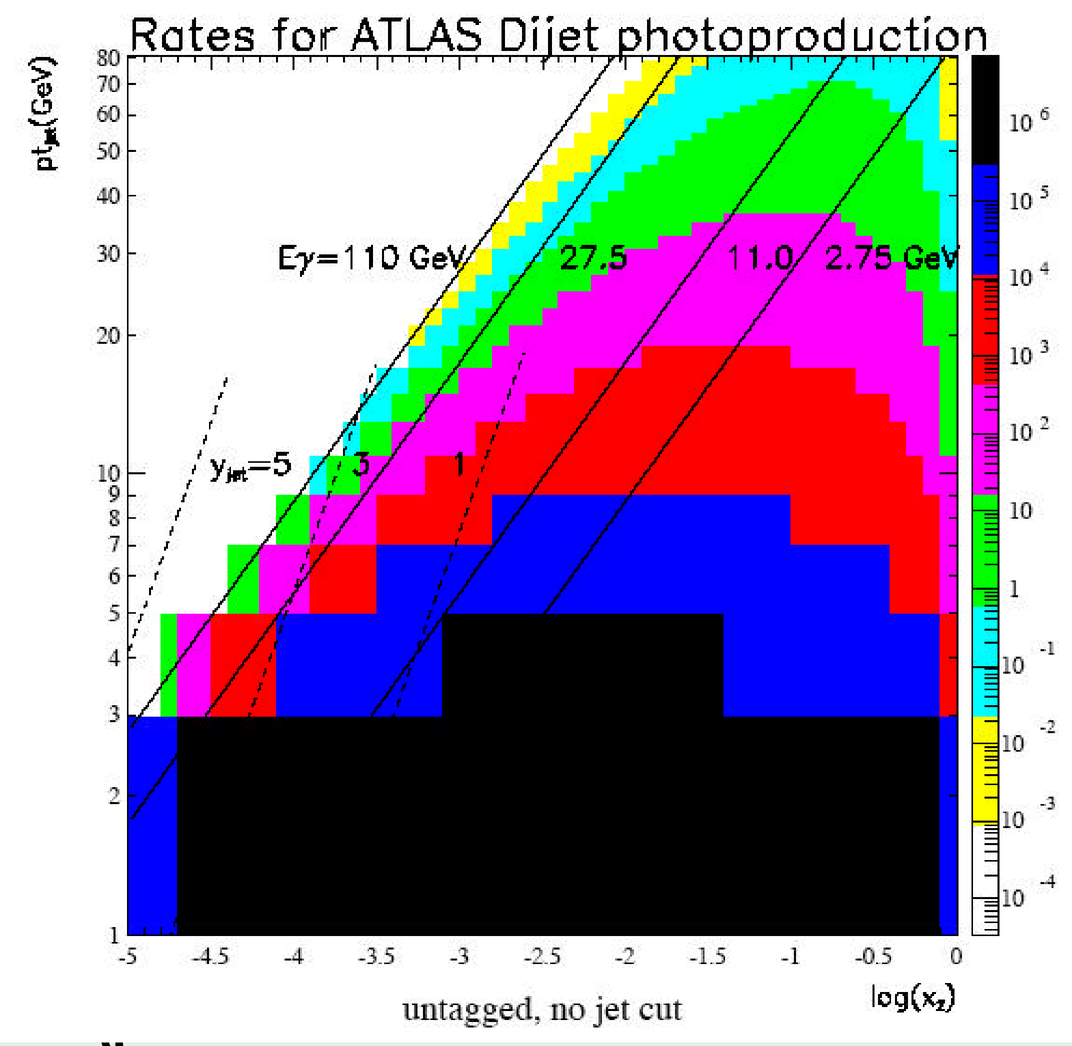


Non-diffractive

Rates and Kinematics

Event yields from a 1 month HI (Pb-Pb) run at nominal Luminosity.
Counts per bin of δpt=2 GeV δx2/x2=+/- 0.25

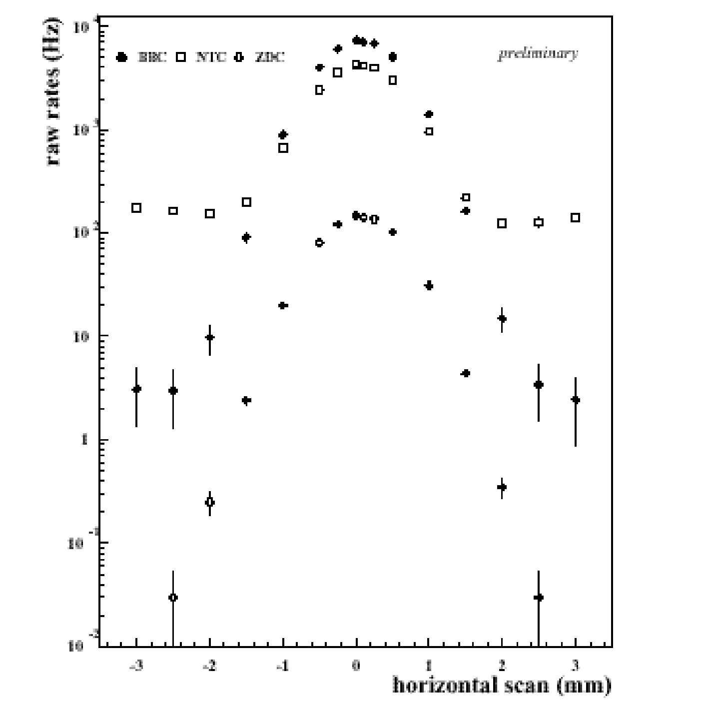
With R. Vogt and M. Strikman
(PRL draft in preparation)



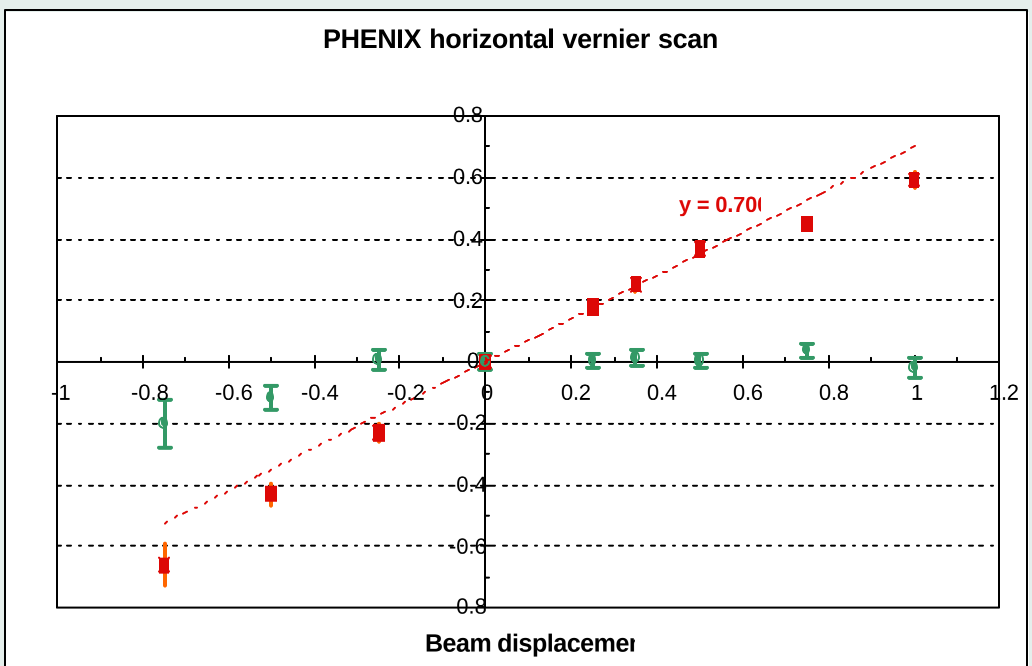
Role of ZDC as a commissioning tool

- Assume existence of LBNL ion Chambers (based on integrated flux @1.4Λ_I =>IαL at High Luminosity)
- Segmentation of Ion Chamber now de-emphasized
- ZDC adds coincidence constraint with ~18% σ_E / E
- Low background useful (required) for commissioning
- ~2 cms vertex resolution from timing.

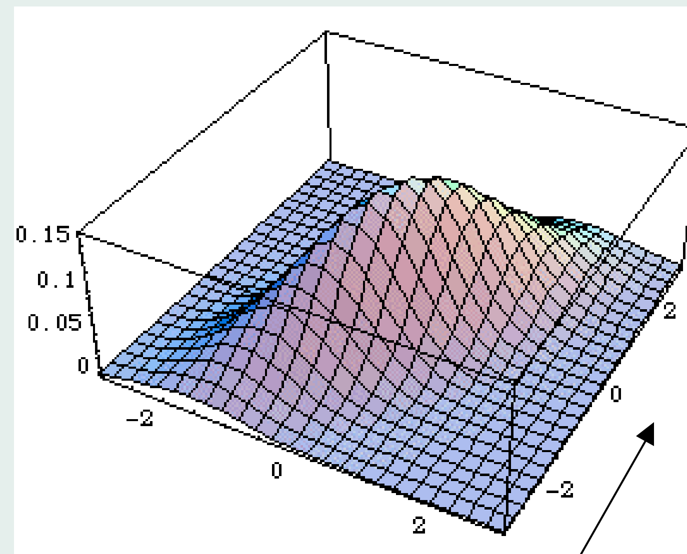
(this addresses need to measure crossing angle)



Why the accelerator Dept. can't do without us!!



rate



Measured Beam x(mm)

Vernier bump

QuickTime™ and a
decompressor
are needed to see this picture.

Can we extrapolate RHIC case to LHC?

- Distances from I.p.:RHIC(18m)=>140m
- Lorentz Boost:RHIC(100)=>7,000

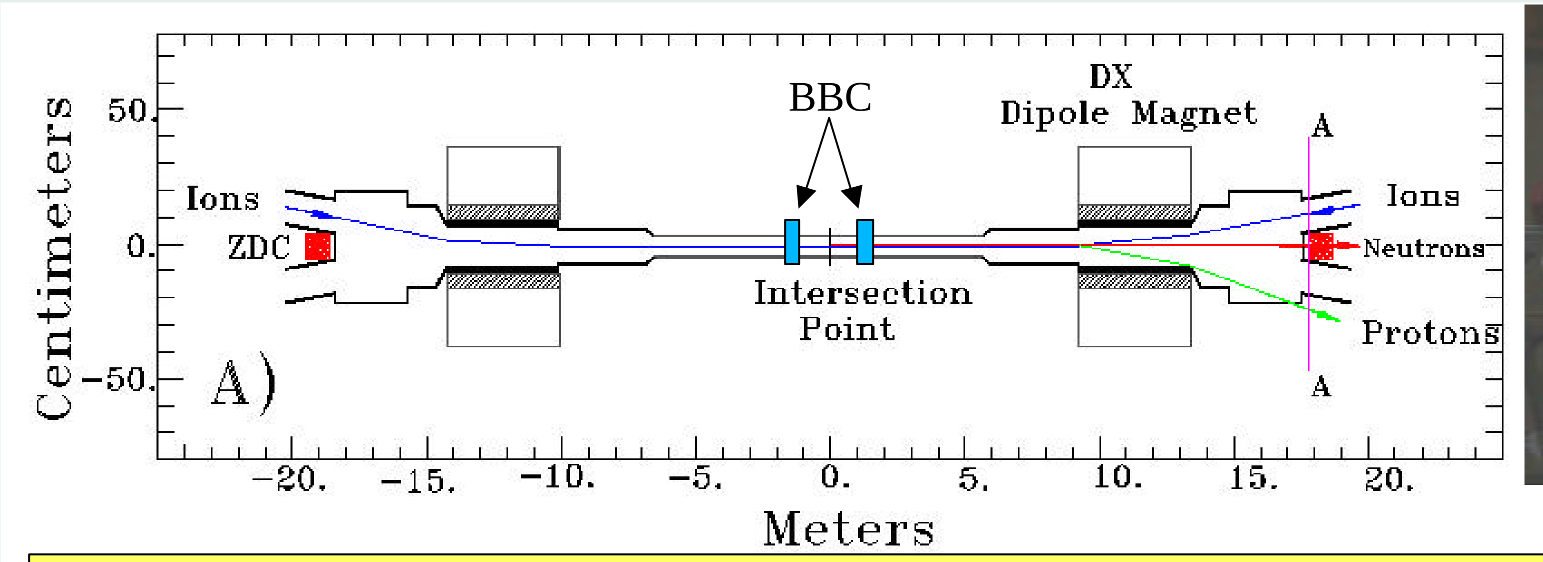
=>dΩ increase by $(70/10)^2$~50

=><t> of leading proton increase~$(p\theta)^2$~50

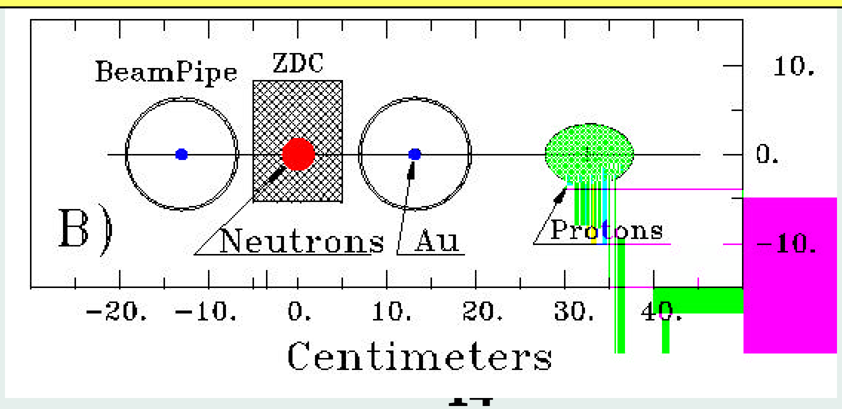
- And physics should mostly scale as ~ln(s)
- Rough Agreement w. data=>generator level

adequate for projection to LHC

Location, Location, Location



- All of the action is at forward rapidities
- In collider geometry access to all spectators limited to outside beamtube
- We sample participants through 128 chann hodoscope at 3<η<4
    - Spatial Distribution of n and Charged Particles shown below
- Large Separation = Easy Timing = Very Clean Trigger against Beam Gas and Beam Scrape



Pythia Statistics(3<|η_{BBC}|<4)

elastic scattering events:

Fraction of BBC triggered events: 0%

Fraction of ZDCN triggered events: 0.79358%

Fraction of ZDCNS triggered events: 0%

double diffractive events:

Fraction of BBC triggered events: 18.8746%

Fraction of ZDCN triggered events: 9.55965%

Fraction of ZDCNS triggered events: 1.01887%

Fraction of ZDCNS&&BBC triggered events: 0.12026%

fraction of ZDCNS&&BBC/BBC: 0.637154%

fraction of ZDCNS&&BBC/ZDCNS: 11.8033%

single diffractive events:

Fraction of BBC triggered events: 5.69839%

Fraction of ZDCN triggered events: 6.98964%

Fraction of ZDCNS triggered events: 0.20909%

Fraction of ZDCNS&&BBC triggered events: 0.00486%

fraction of ZDCNS&&BBC/BBC: 0.0852872%

fraction of ZDCNS&&BBC/ZDCNS: 2.32436%

non diffractive events:

Fraction of BBC triggered events: 60.891%

Fraction of ZDCN triggered events: 5.02369%

Fraction of ZDCNS triggered events: 0.27898%

Fraction of ZDCNS&&BBC triggered events: 0.13947%

fraction of ZDCNS&&BBC/BBC: 0.229049%

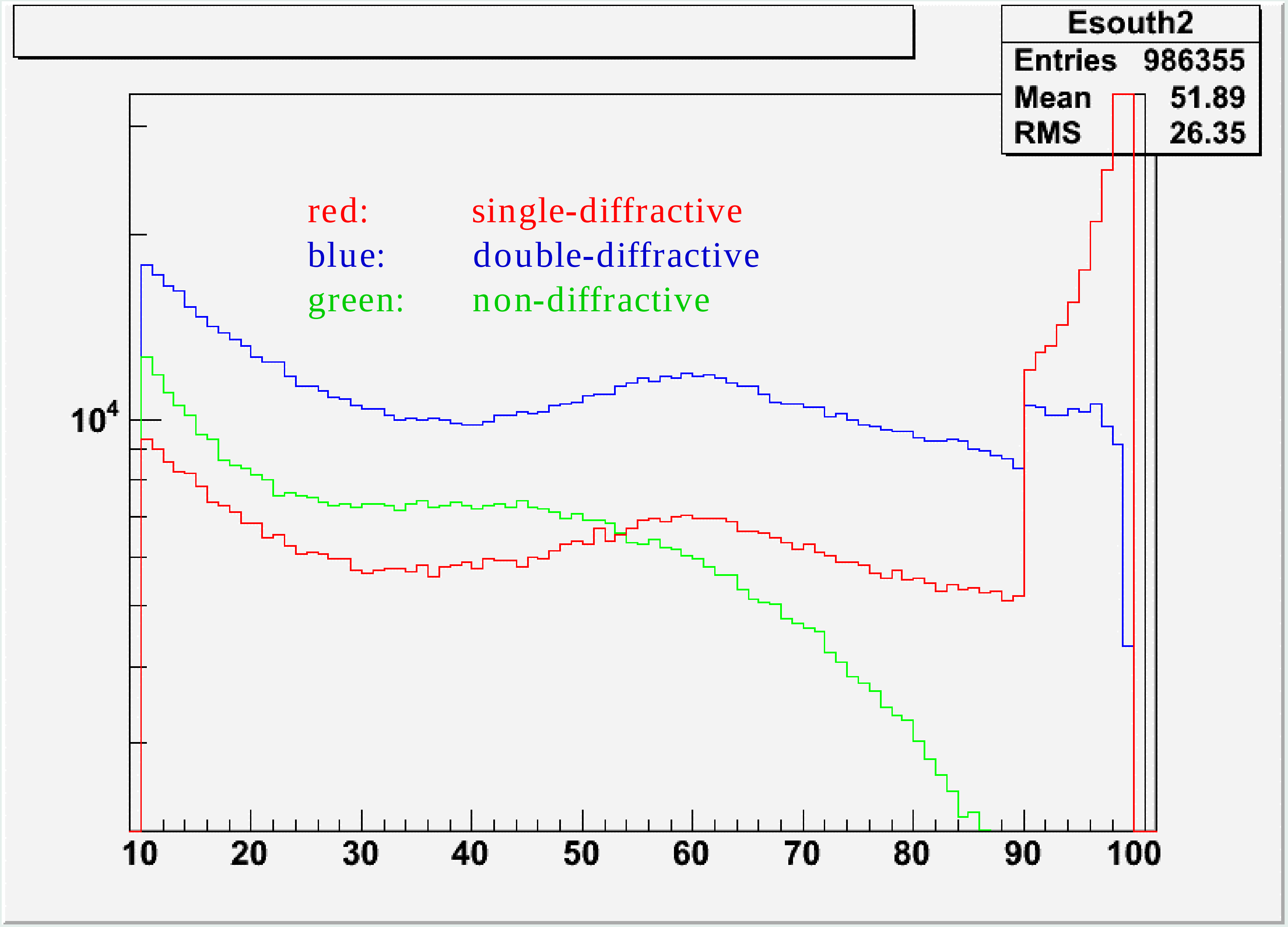
fraction of ZDCNS&&BBC/ZDCNS: 49.9928%

Simple Exercise with event topologies. data consistent with Pythia

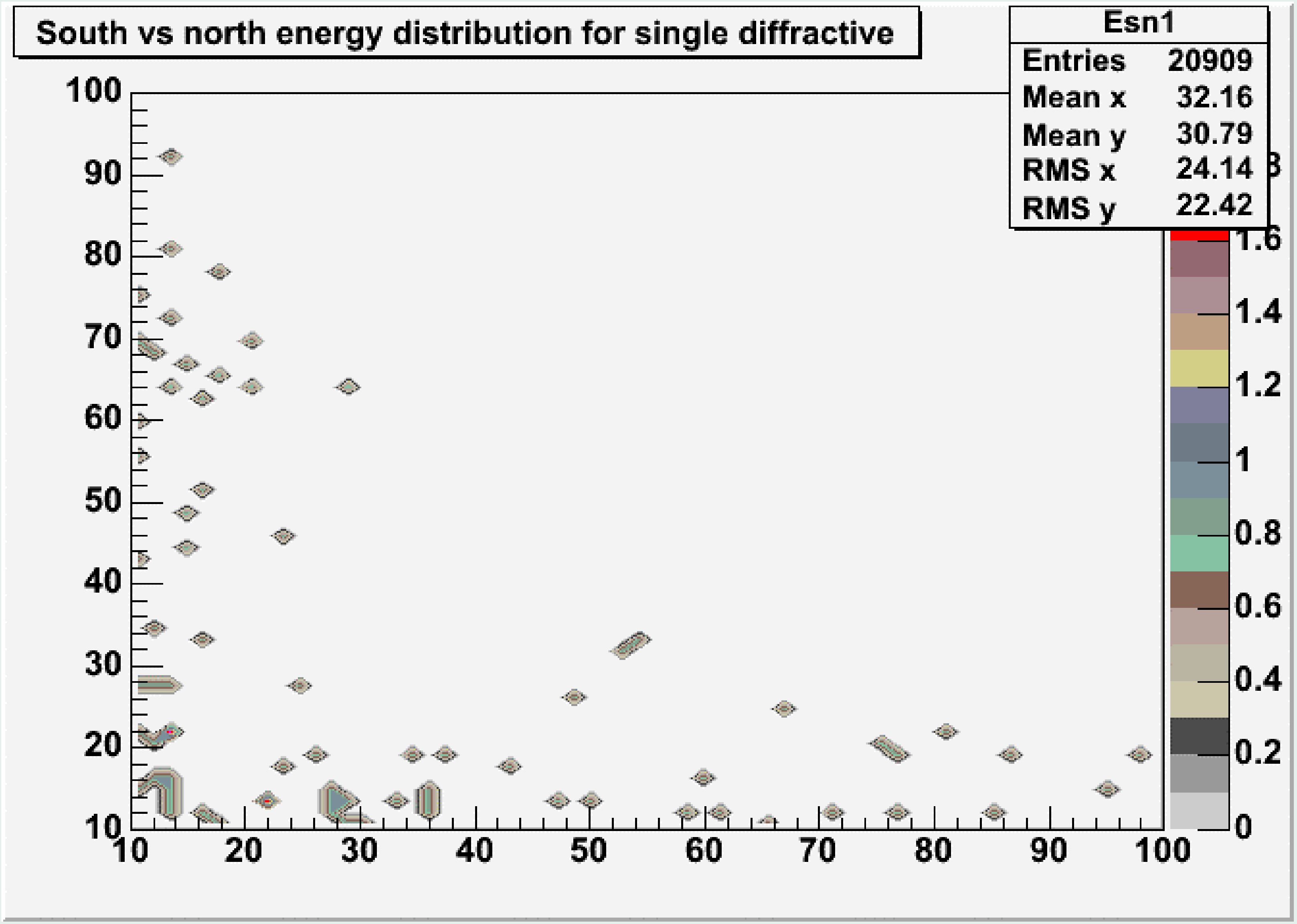
w. Mate Csanad

	Pythia s*acceptance		expected Ratios (ZDC*BBC)/ZDC	PHENIX pp data
elastic	σ(mb)	10		
	bel(GeV-2)	13		
	bsd(GeV-2)	6		
Single Diff	σ(mb)	14		
Double diff	σ(mb)	1		
non-Diff	σ(mb)	25		
Single Diff	σ(mb),ZDC	0.03	2.30%	\
Double diff	σ(mb),ZDC	0.01	12%	22%
non-Diff	σ(mb),ZDC	0.08	50%	/
	σZDC/σnondif	**0.50%**		**0.36%**

ZDC energy distribution



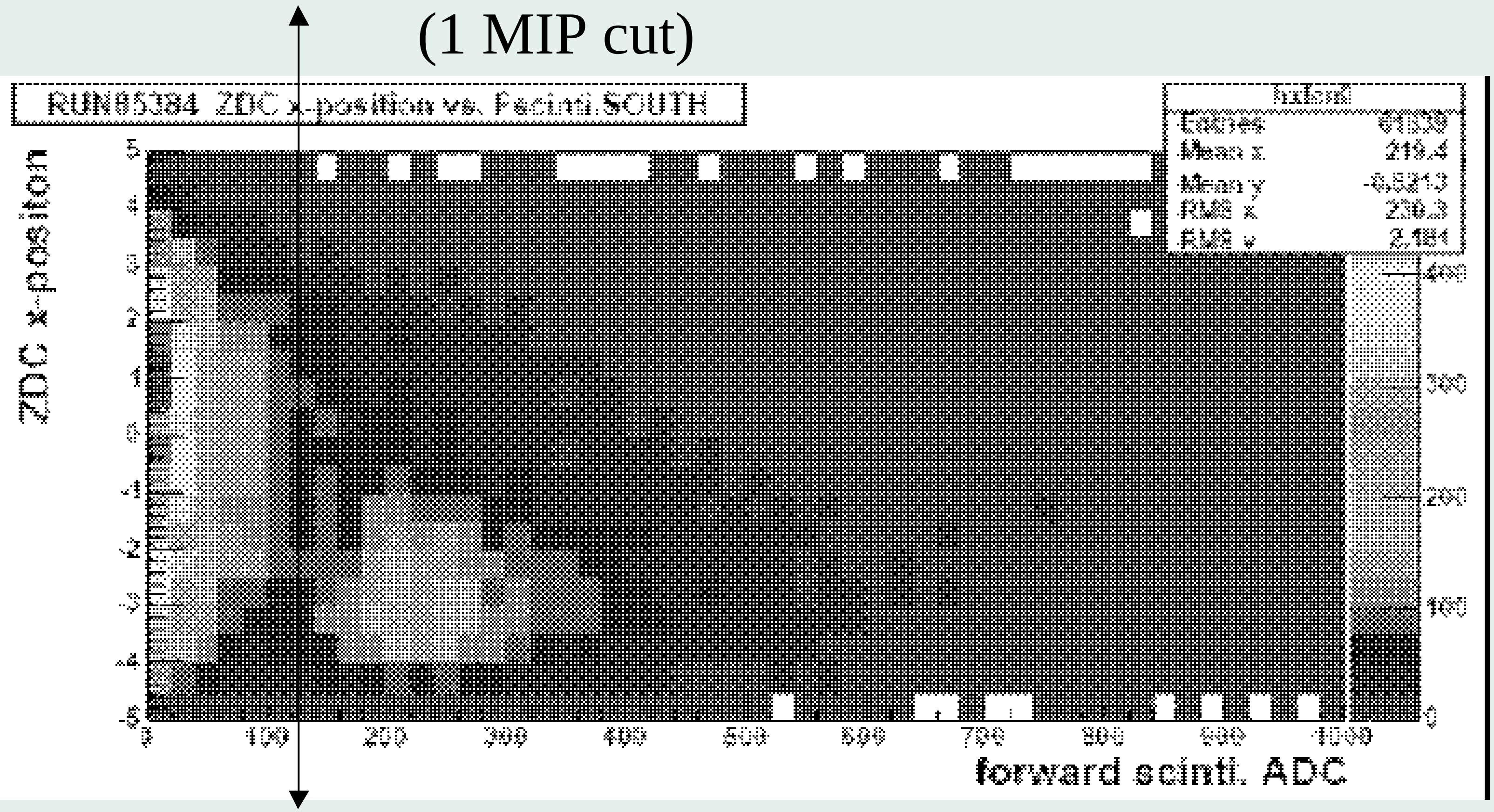
2D ZDCN vs ZDCS energy for for sdiff



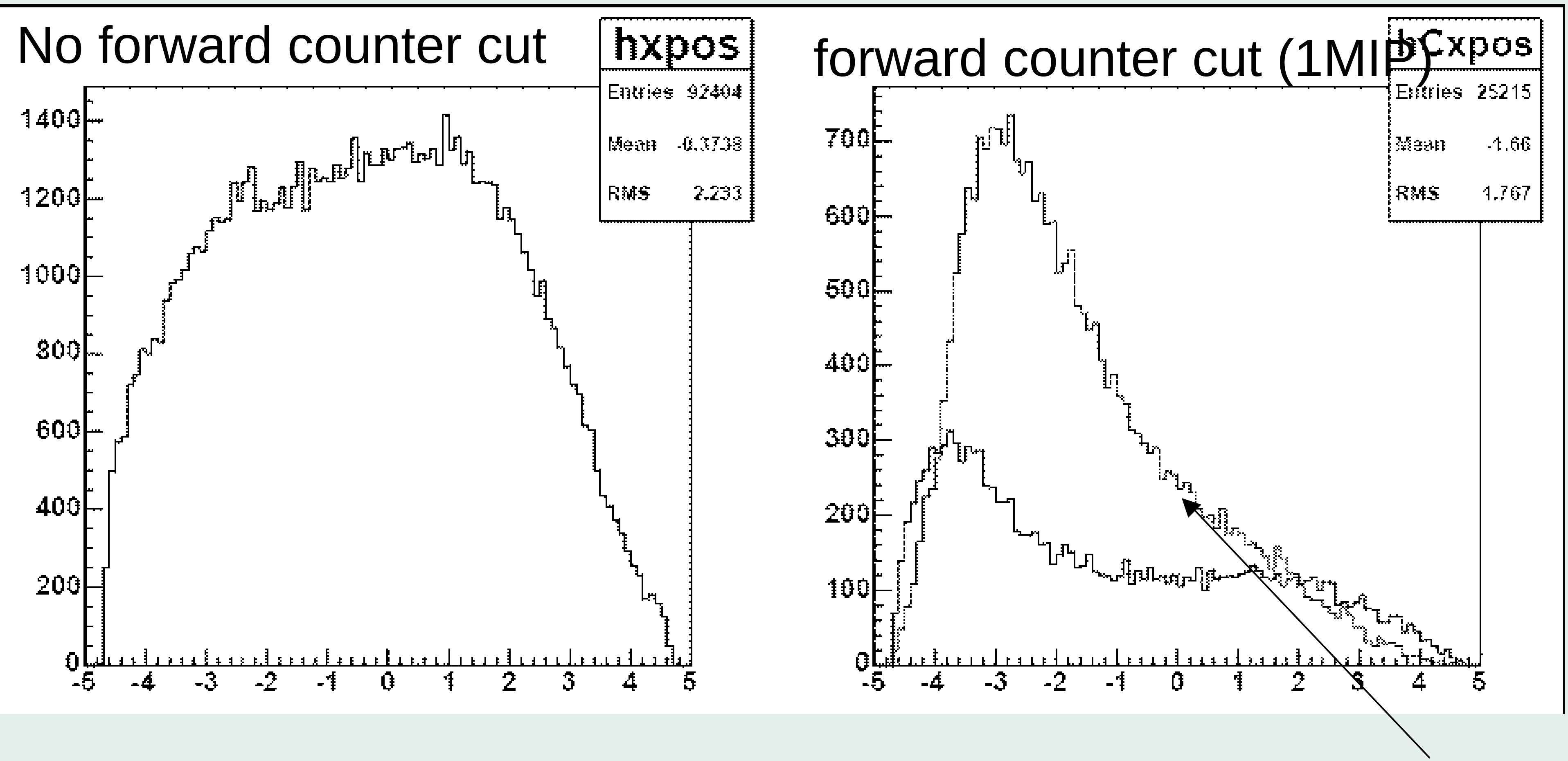
What is the physics behind pp ZDC measurements?

Part is pp-p+X (ie single diffraction dissociation

(1 MIP cut)



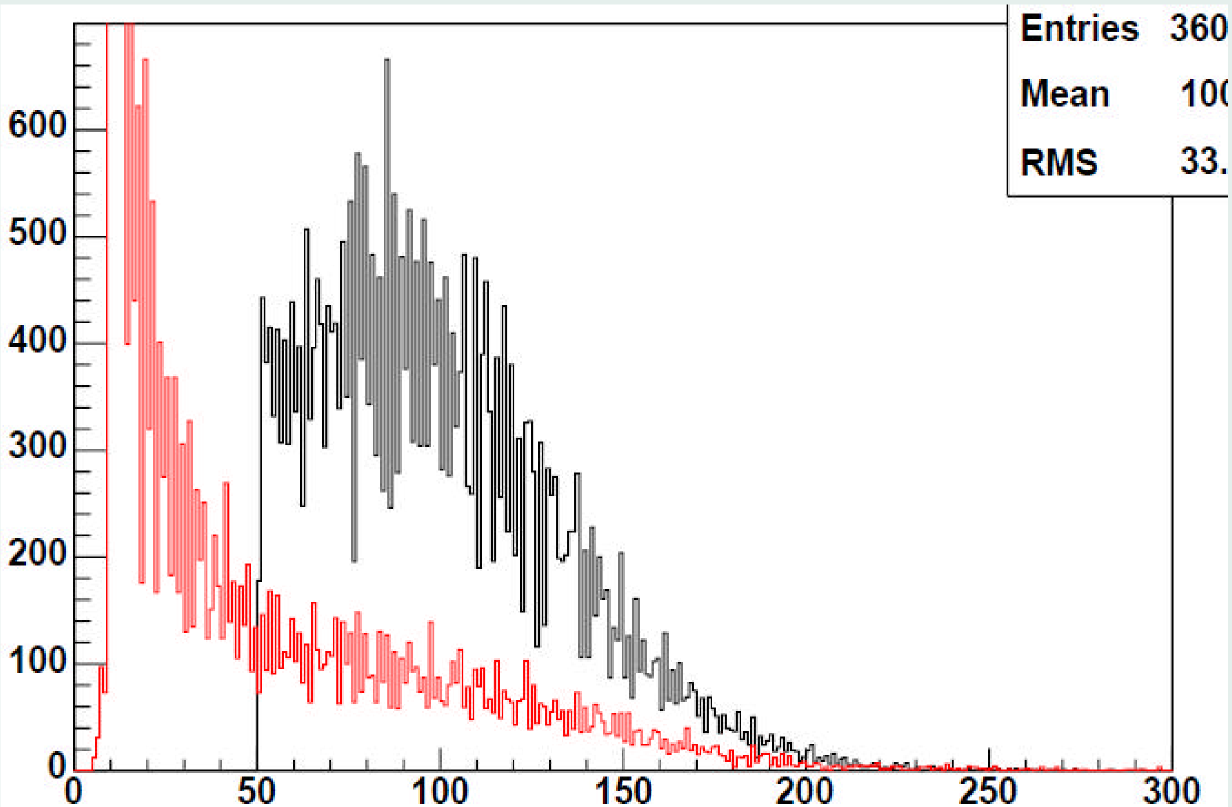
X-position



Cut less/more than 50 with ZDC energy

Red > 50 blue < 50

Proton in 1 arm (black) balances more complicated multiparticle final state **(red)**



Corresponding Acceptance at LHC

Fractions in elastic scattering events:
BBC triggered events: 0%
ZDCN triggered events: 0%
ZDCNS triggered events: 0%

Fractions in single diffractive events:
BBC triggered events: 21.7%
ZDCN triggered events: 23.4%
ZDCNS triggered events: 0.013%

$$s^{ZDC}_{LHC} \sim s^{inel} * 9\%$$

Fractions in double diffractive events:

BBC triggered events: 21.69%

ZDCN triggered events: 48.72%

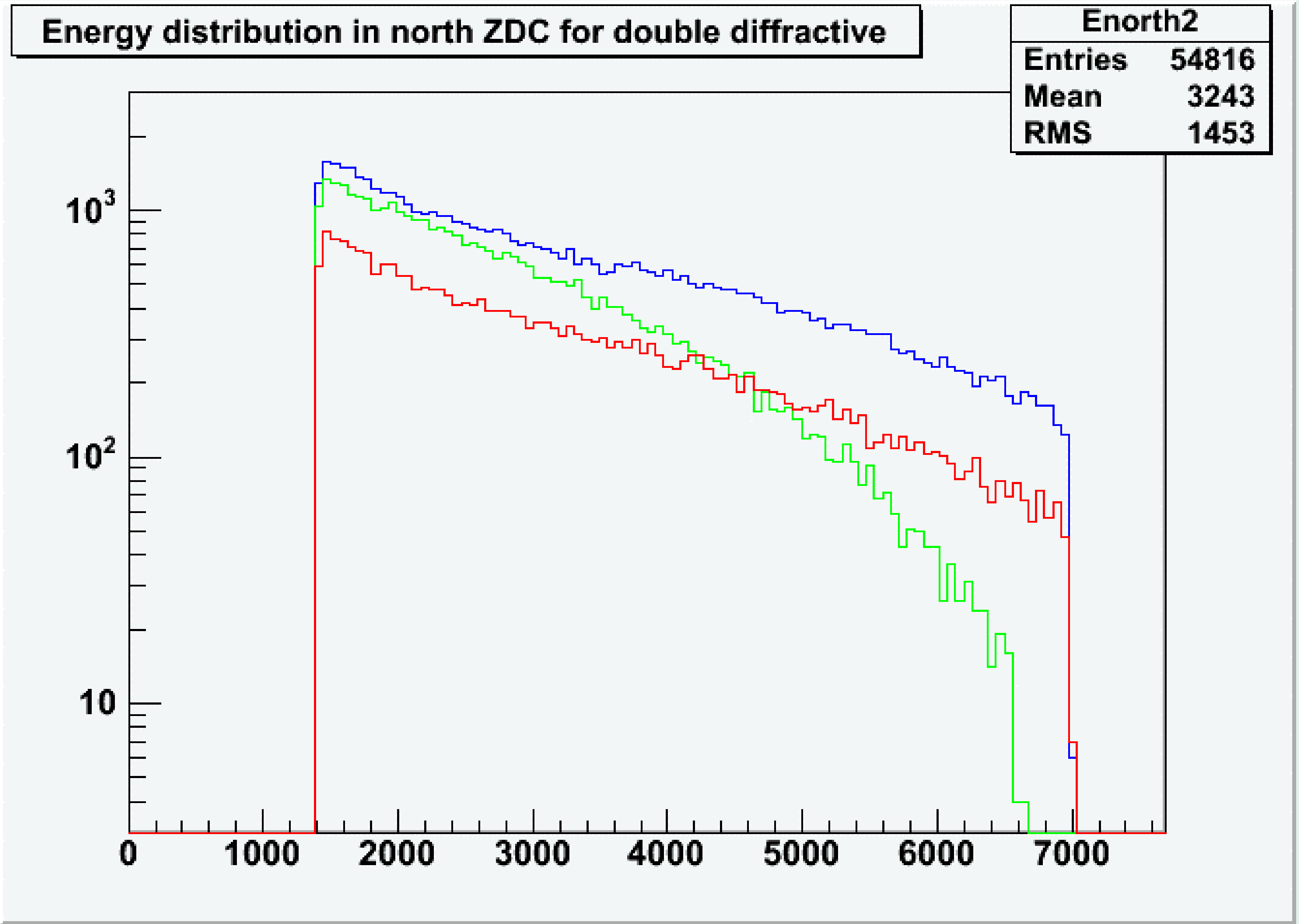
ZDCNS triggered events: 23.6%

ZDCNS&&BBC trig events: 5.05%

ZDCNS&&BBC/BBC: 23.29%
ZDCNS&&BBC/ZDCNS: 21.4%

Fractions in non diffractive events:
BBC triggered events: 97.8%
ZDCN triggered events: 34.6%
ZDCNS triggered events: 11.9%
ZDCNS&&BBC triggered events: 11.7%
ZDCNS&&BBC/BBC: 11.9%
ZDCNS&&BBC/ZDCNS: 97.6%

Energy Distribution in ZDC at LHC



Implications for LHC commissioning

Relative Luminometry Dynamic Range:

•ZDC rate is linear to L>10^{33} (where pileup ~20%)

•At startup Luminosity backgrounds are negligible and can in any case be easily computed from singles rates.

Absolute Luminometry(1):

•Large dynamic range is useful for year 2 precision measurements of absolute luminosity (which run at ~ 10^{28}) ie TOTEM/ATLAS

Absolute Luminometry(2):

Calculated cross sections for PbPb@LHC

A.J.Baltz, C.Chasman and SNW NIM A417(1998)p.1

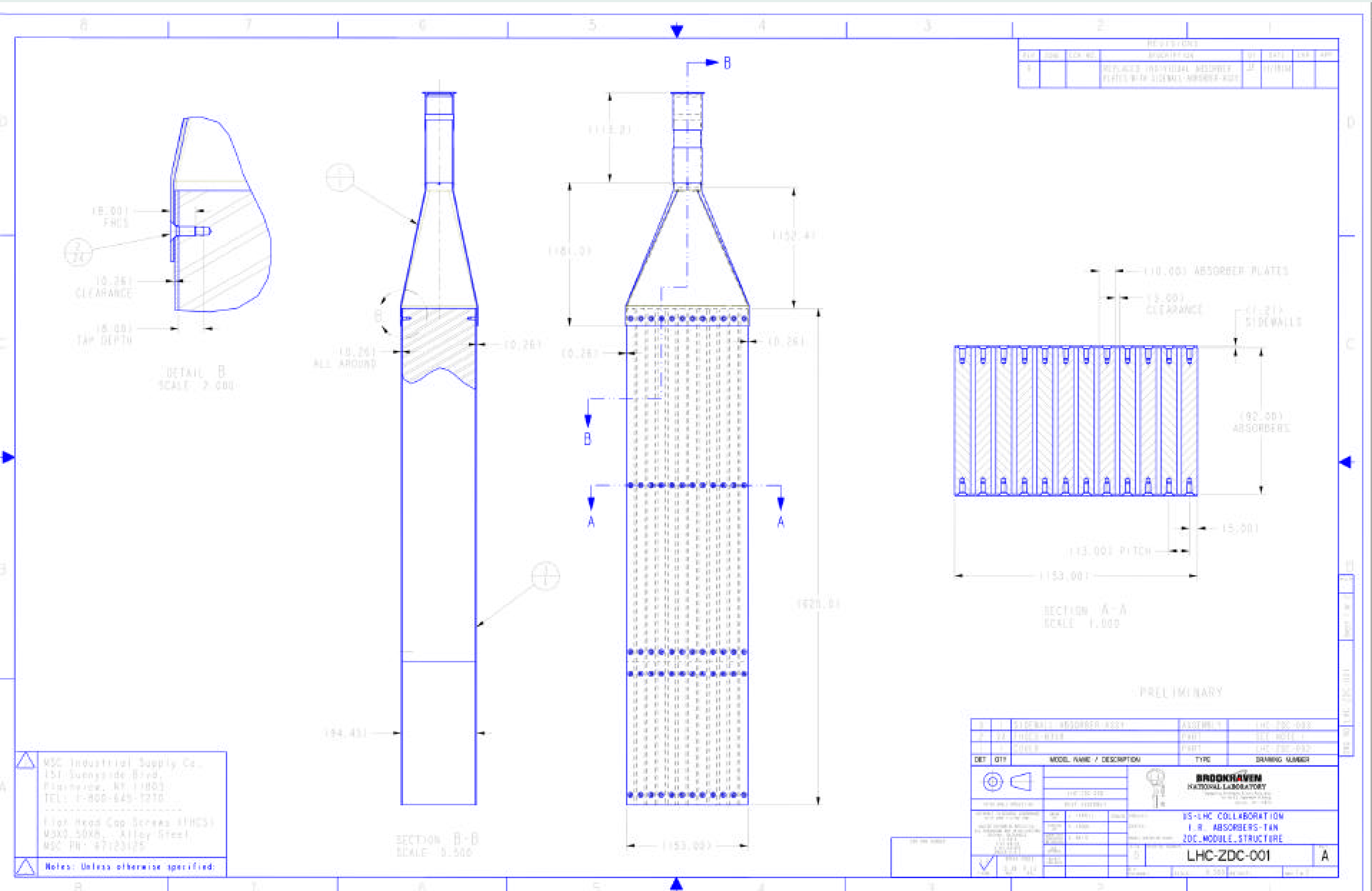
(errors can be inferred from above RHIC discussion)

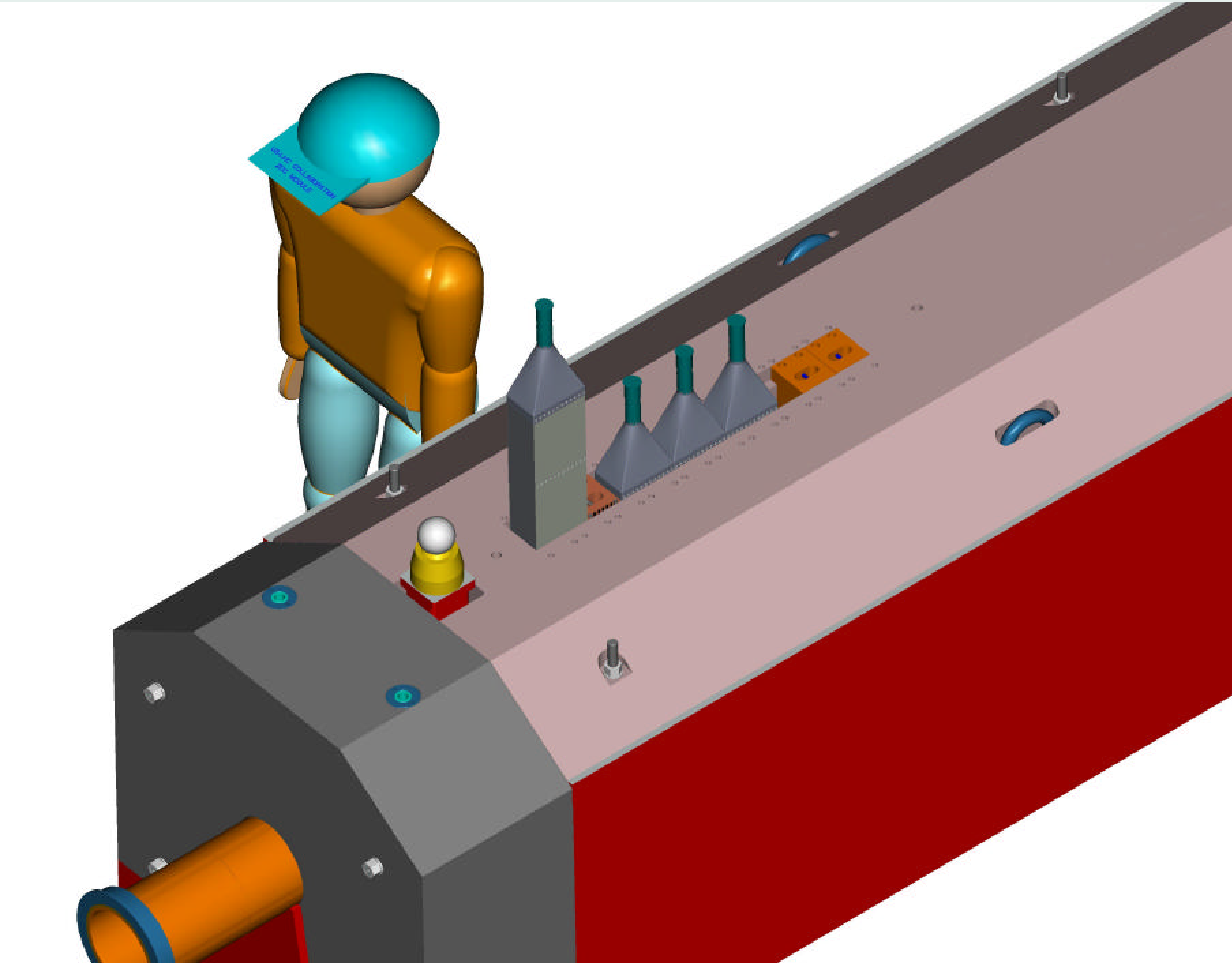
$\sigma_{1n,1n}$	0.537 barns
$\sigma_{1n,xn}$	1.897
$\sigma_{xn,xn}$	14.75
σ_{xn}	227.3

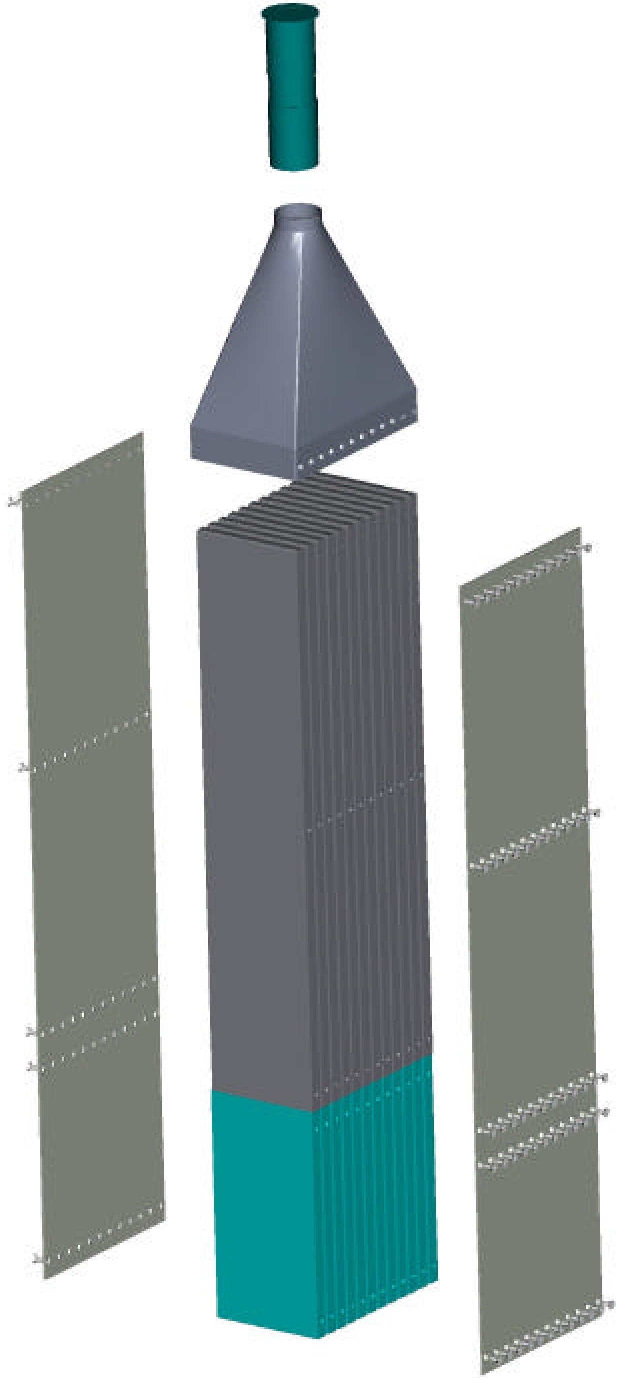
Calculable large EM cross sections calibrate LHC Heavy Ions

This has potential to do so also for LHC pp

ATLAS ZDC Prototype Design(Materials: Tungsten Alloy and SS)







ATLAS ZDC COST sheet (less contingency and personnel cost)

	Unit Cost($)	Quantity	total	time from t0(wks)
Module Structure and Absorber				
Quote from Starck(1 prototype)	$11,700	1	11700	
Delivery Estimate				8
Fiber for Prototype				
Quote from CeromOptec	1.5	1435.2	2152.8	
Delivery Estimate				4
Mesh PMT from Hamamatsu(R5924)				
Cost Estimate(22mm Diam, FM PMT)	4500	1	4500	
Delivery Estimate				6
Trim, Polish Quartz, Fab Ribbons				
Estimate for Work @ IHEP	5000	1	5000	
Delivery Estimate				4
Fabricate PMT Mount& LED flasher				
Estimate of BNL Tech time	75	40	3000	
Time to Complete				2
Assemble Module and checkout				
Estimate of Cost for Equipment	2000	1	2000	
Time to complete				2
Decision Reached on Prototype				4
Implement any engineering changes				
Contingency Budget for changes	2000	1	2000	
Estimated time to Complete				3
Engineering Costs to Implement LBNL Electronics				
Costs for non-contributed hardware	8000	1	8000	
Costs for testing ZDC module with LBNL FEE	3000	1	3000	
One time cost for pre-production			41352.8	
Final Production costs				
Cost/module for Quantity estimate	21017.52	5	105087.6	
Total Cost to Complete			146440.4	

Worksheet for fiber length	
Max fiber length in module(cms)	65
Module active width(cms)	9.2
fiber diameter(cms)	0.047
fiber pitch(cms)	0.05
number of layers	12
fiber purchase/module(meters)	1435.2

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Costs for testing ZDC module with LBNL FEE	3000	1	3000	
One time cost for pre-production			41352.8	

What we need to do next

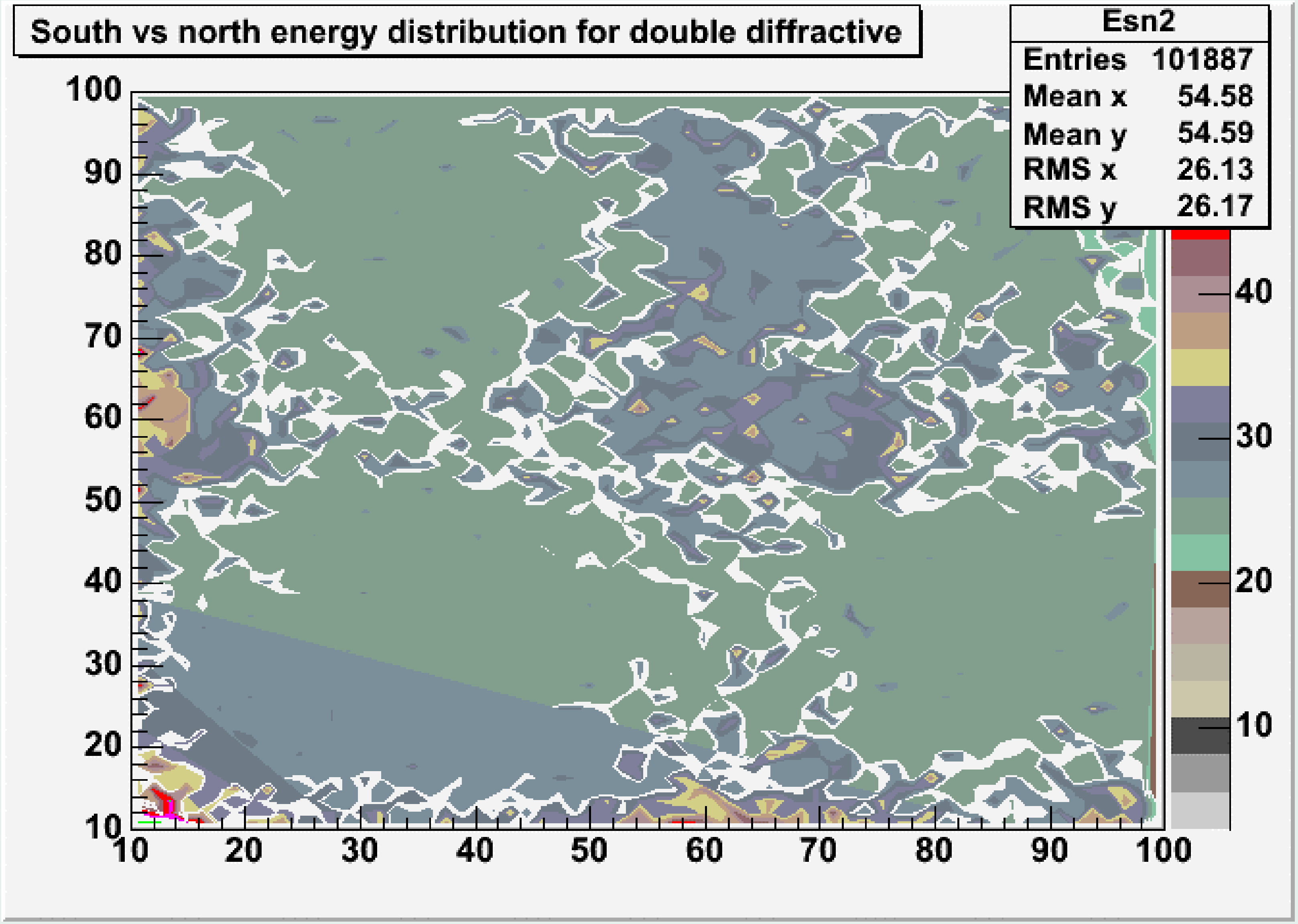
- ATLAS ZDC design complete since Nov. ‘04
- Reviewed by Turner, Schmickler
- Now proceed to prototype construction (BNL Physics funding)
- Need to understand interface to LHC DAQ
- We’d like to do a beam test (possibly together with TAN Ion Chamber)

What we need from LARP

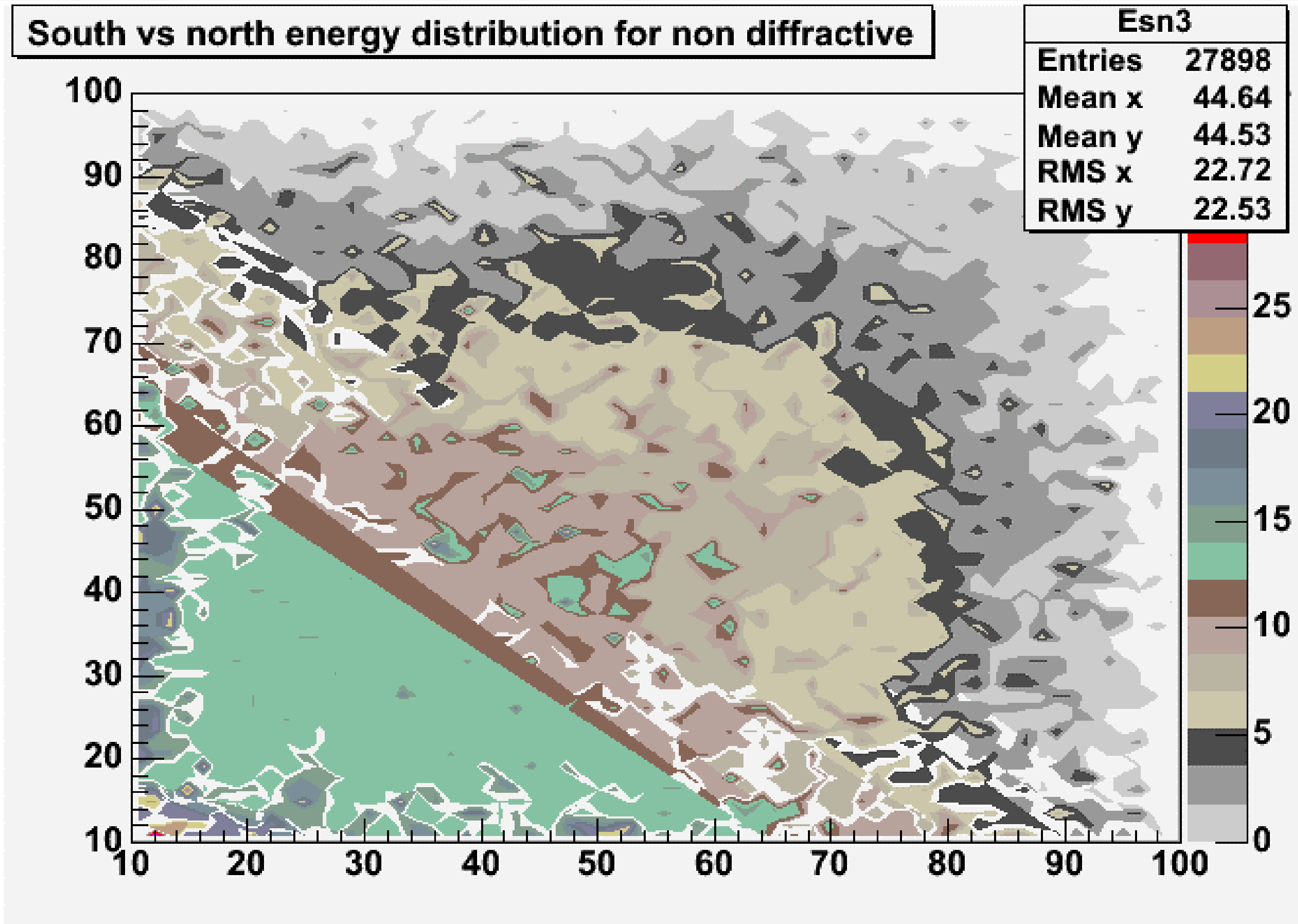
- Collaboration on readout issues, funding for necessary electronics
- Support for possible beam test
- Travel, as needed to complete integration with accelerator instrumentation

Extra slides

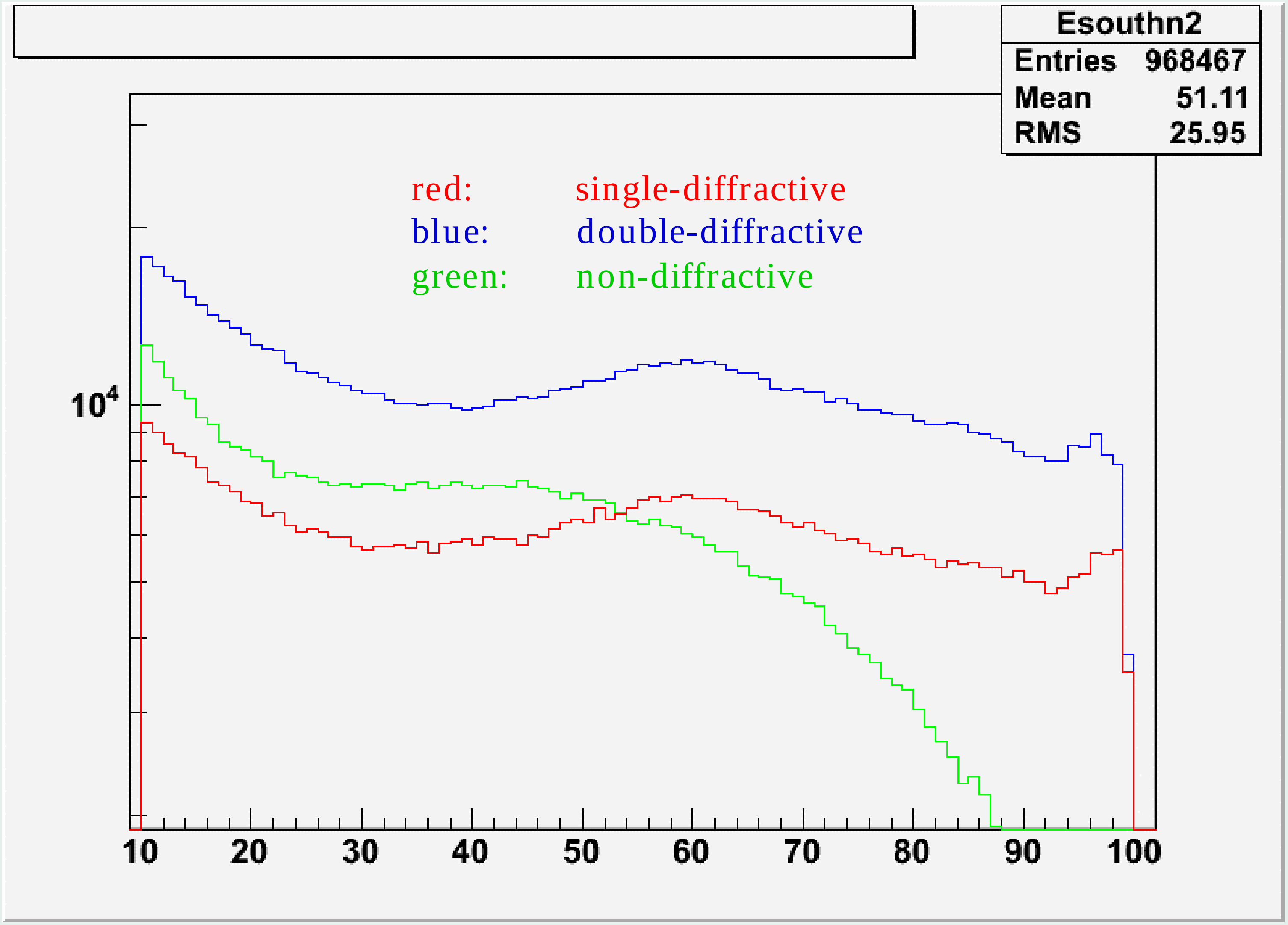
2D ZDCN vs ZDCS energy for ddiff



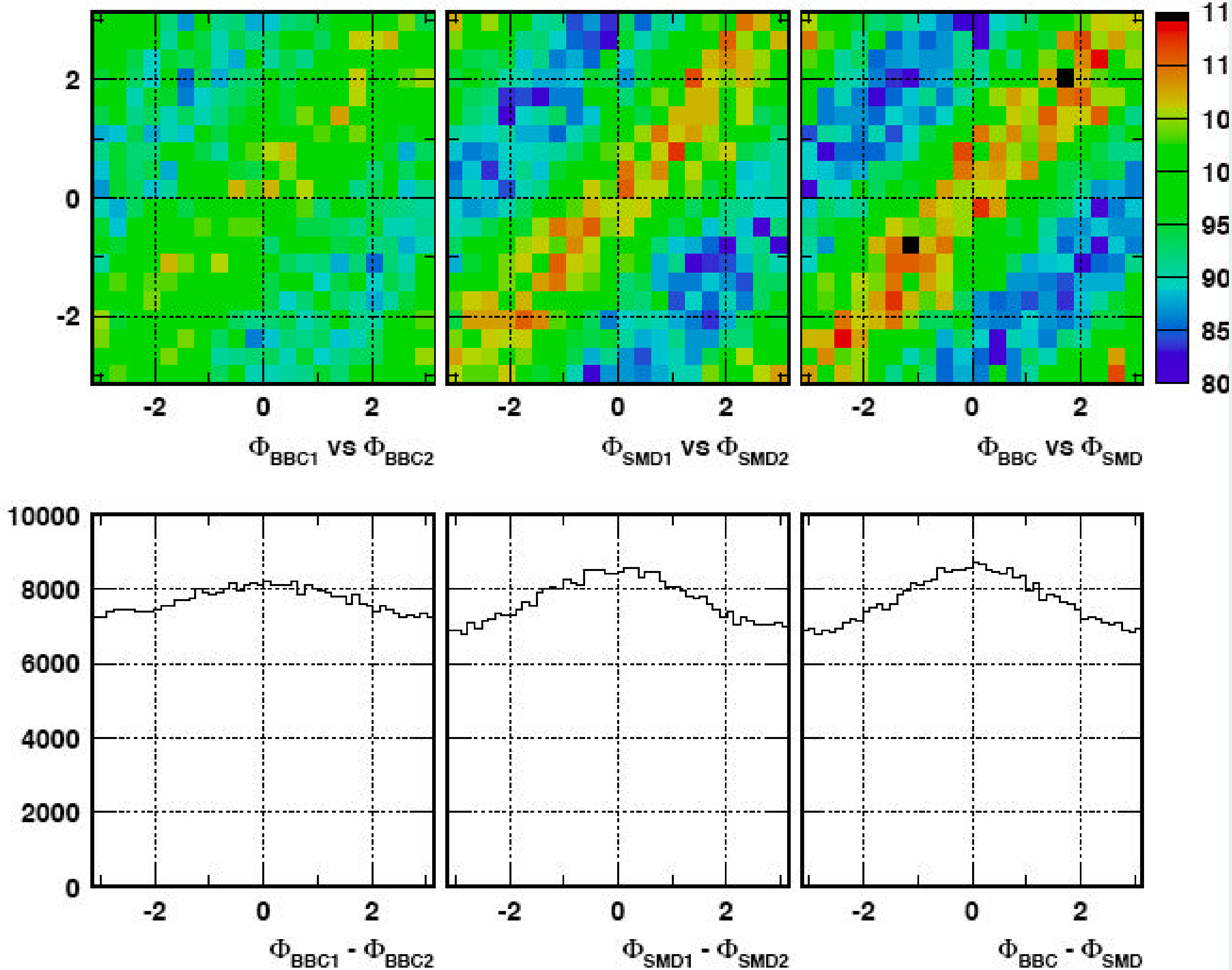
2D ZDCN vs ZDCS energy for ndiff



Neutral particle en. distr.



Directed flow, v_1, is largest at ZDC location



Physics Opportunities

The black disk limit: Diffractive scattering was observed in over 10% of all DIS events at HERA. ---- operation with nuclei should allow the observation of a far greater fraction of diffractive events, approaching the quantum mechanical limit of 50%. The detailed diffractive data will provide a stringent test on our understanding of the strong interactions.

Three Dimensional Mapping of Strong Matter: The study of exclusive reactions, such as the production of vector mesons or real photons, will allow the mapping of strongly interacting matter in nucleons and nuclei. These data are sure to bring a great leap forward in our understanding of how nuclear matter is formed, and will be critical in the search for the Color Glass Condensate.

Radiation Patterns in Strong Interactions: The study of the fundamental radiation patterns in strong interactions, which lead to the small-x structure of nucleons, will be studied by studying jet and particle production over a large rapidity range.

Hadronization in nucleons and nuclei: The evolution of colored quarks and gluons struck by the virtual photon in deep inelastic scattering into observed colorless hadrons is one of the clearest manifestations of confinement.