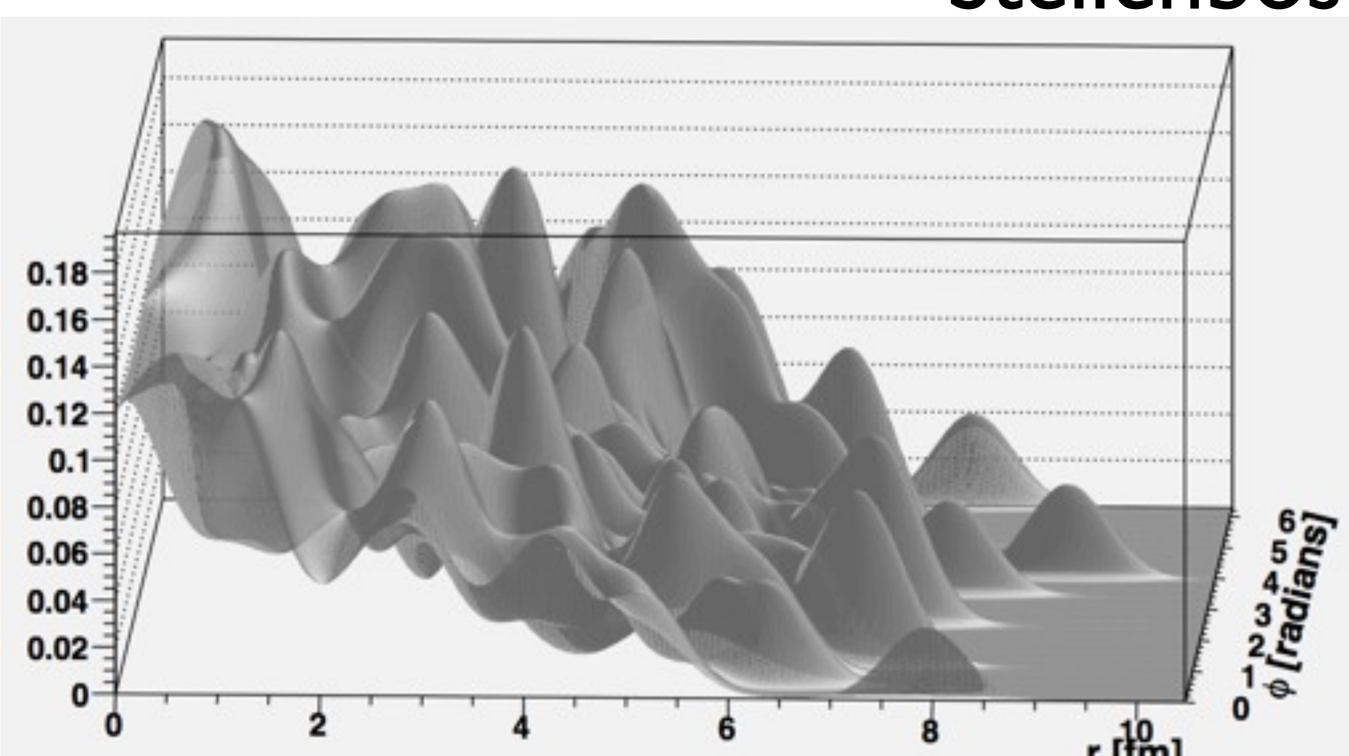
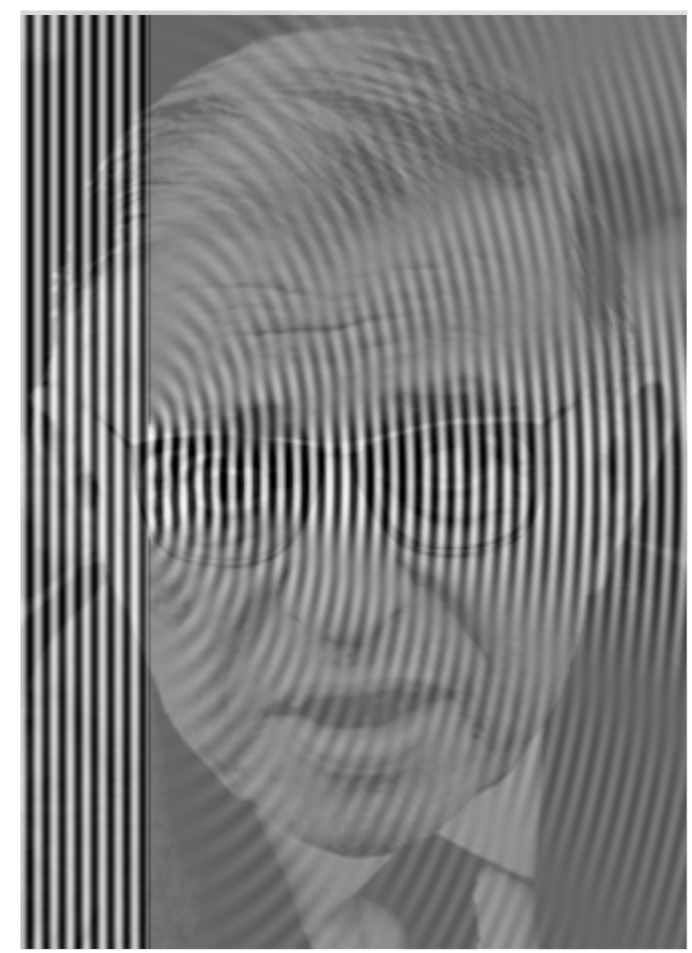
Diffraction in eA at an EIC and how to simulate it with Sartre

Tobias Toll
Stellenbosch 2/2/12





e+A Physics Program: Science Matrix

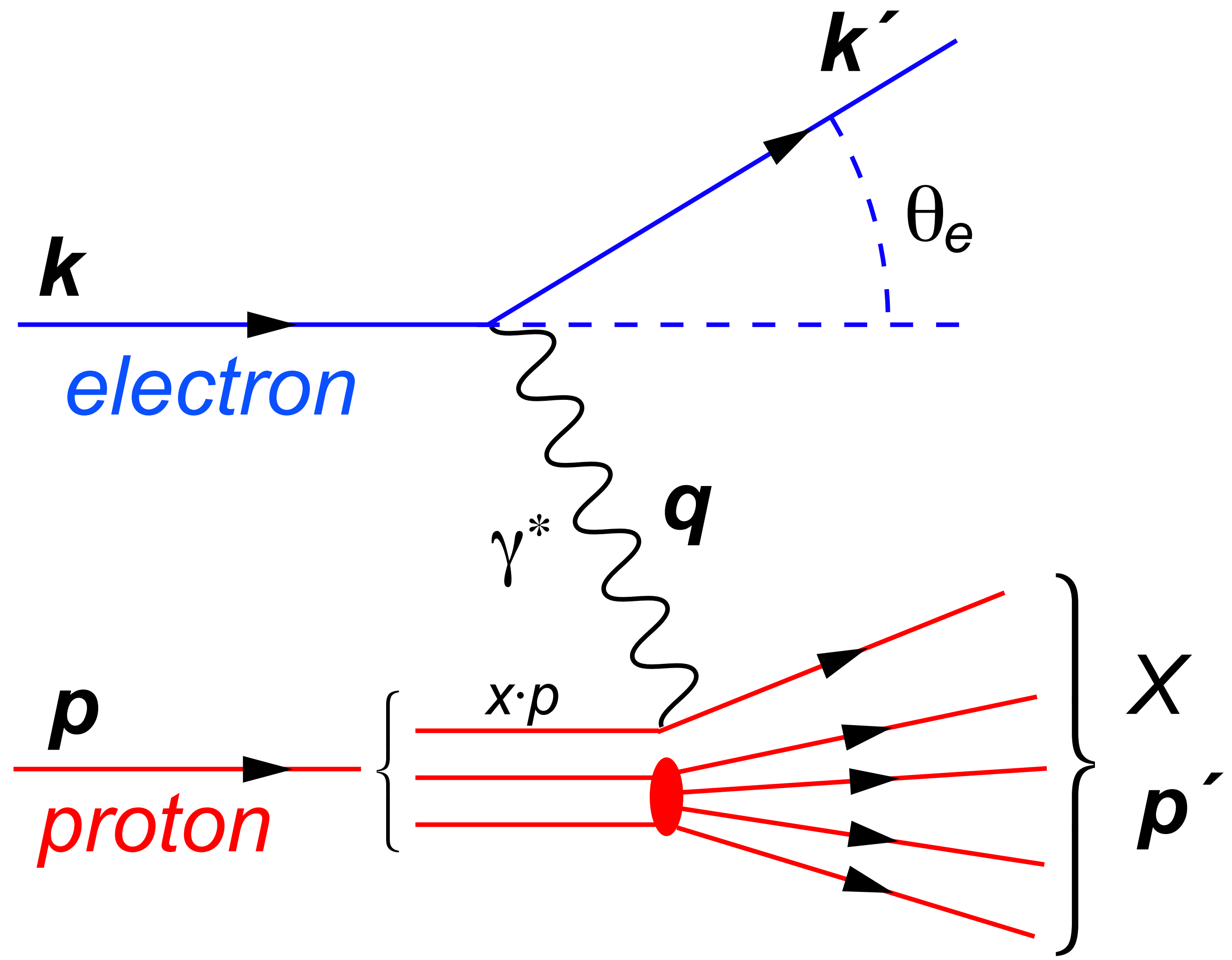
Result of INT workshop in Seattle in fall ’10 (arXiv: 1108.1713)

Deliverables	Observables	What we learn	Phase-I	Phase-II
integrated gluon distributions	$F_{2,L}$	nuclear wave function; saturation, Q_s	gluons at $10^{-3} < x < 1$	saturation regime
k_T dependent gluons; gluon correlations	di-hadron correlations	non-linear QCD evolution / universality	onset of saturation	measure Q_s
transport coefficients in cold matter	large-x SIDIS; jets	parton energy loss, shower evolution; energy loss mechanisms	light flavors and charm; jets	rare probes and bottom; large-x gluons
b dependence of gluon distribution and correlations	Diffractive VM production and DVCS, coherent and incoherent parts	Interplay between small-x evolution and confinement	Moderate x with light and heavy nuclei	Extend to low-x range (saturation region)

“Seeing” Diffraction

Slides from T. Ullrich

A DIS event (theoretical view)



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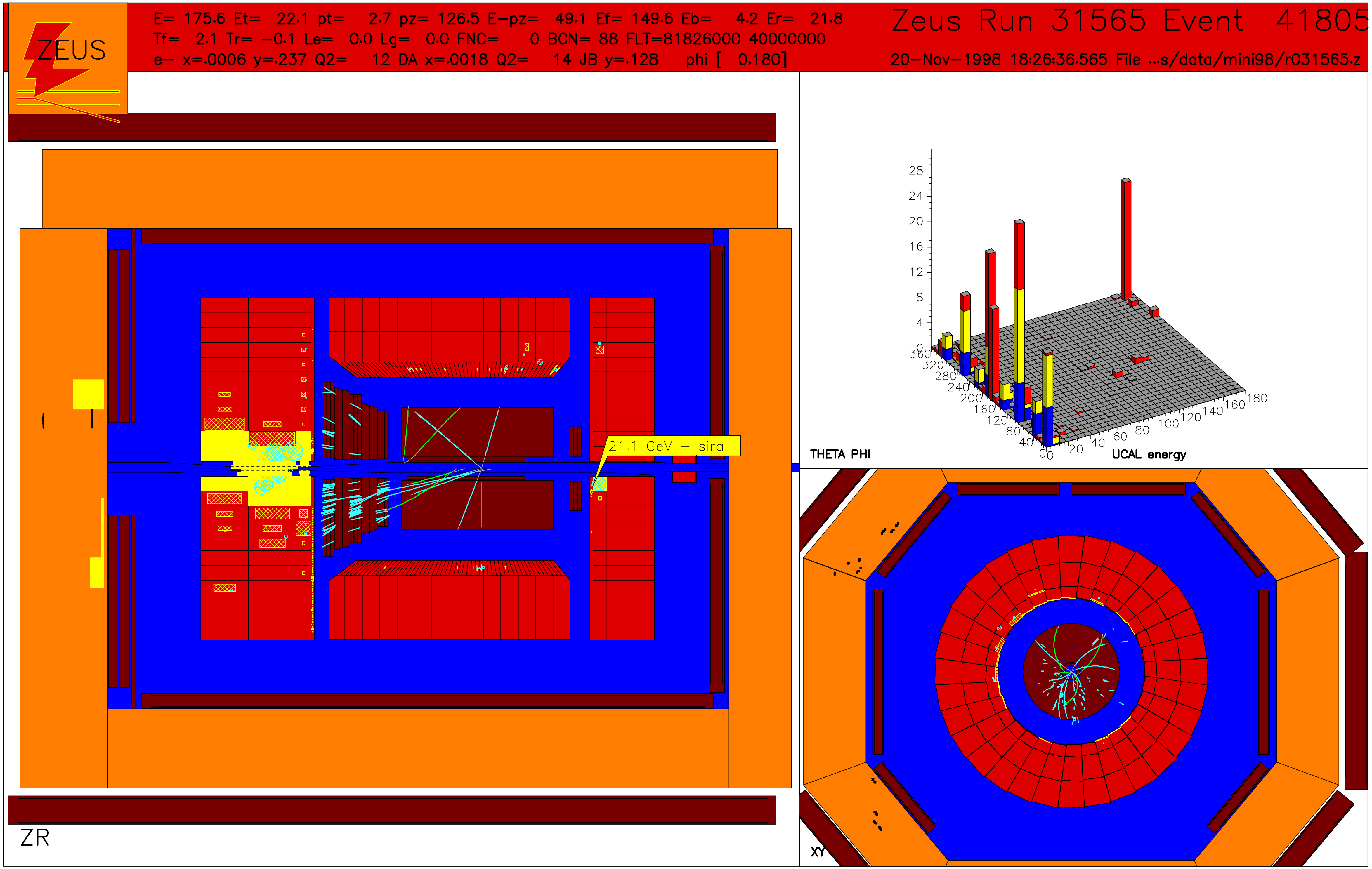
A DIS event (experimental view)



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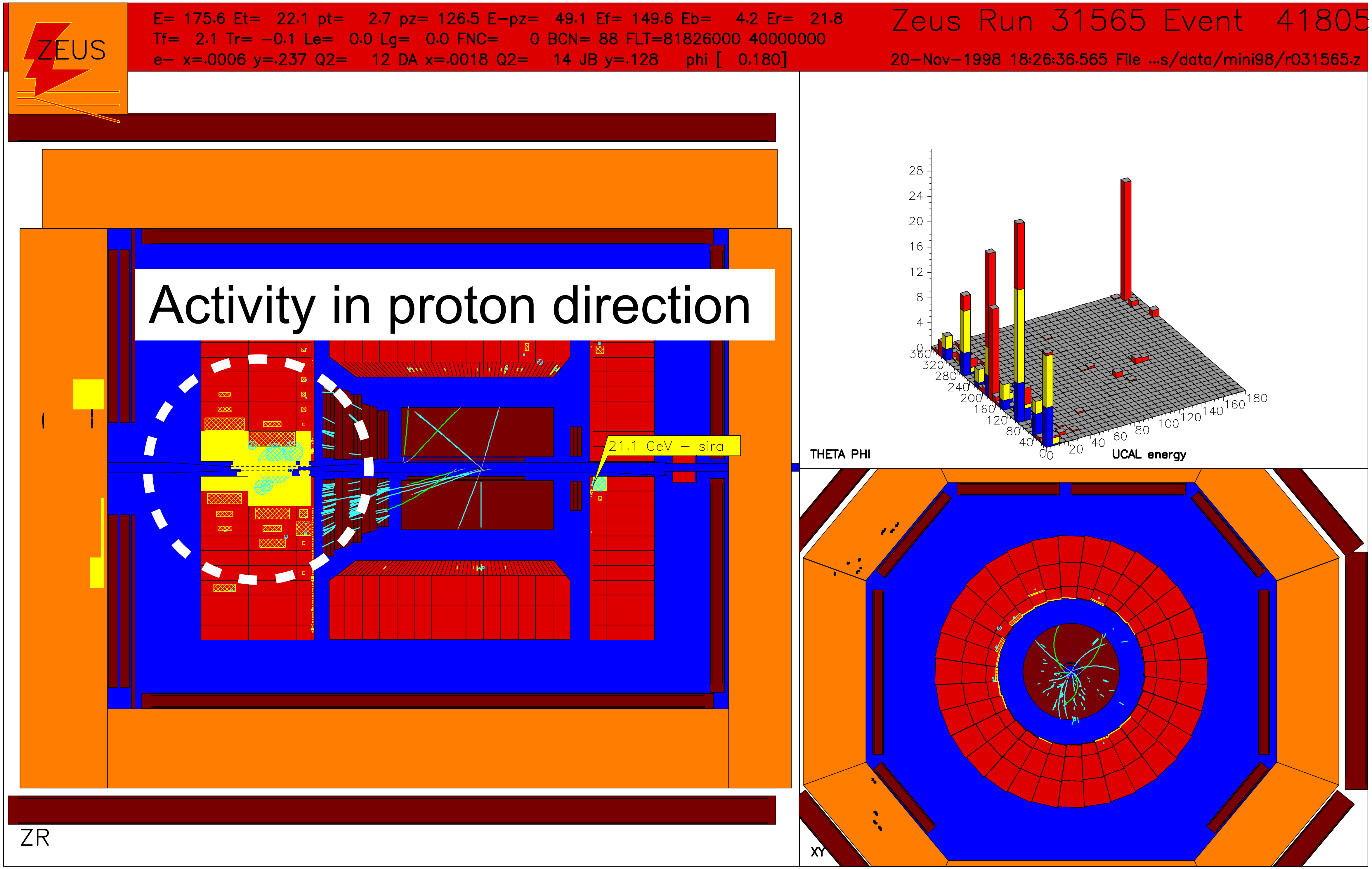

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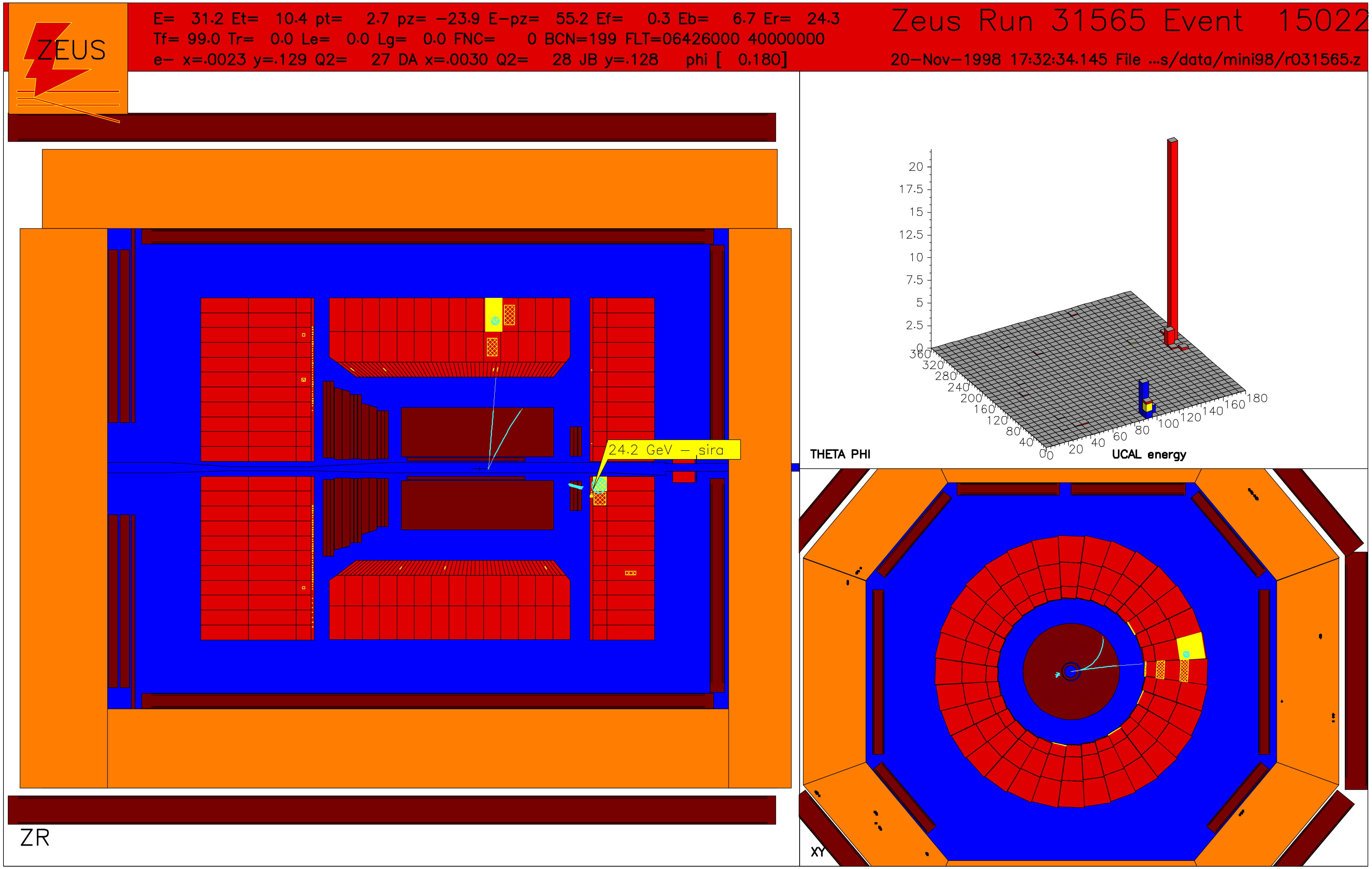
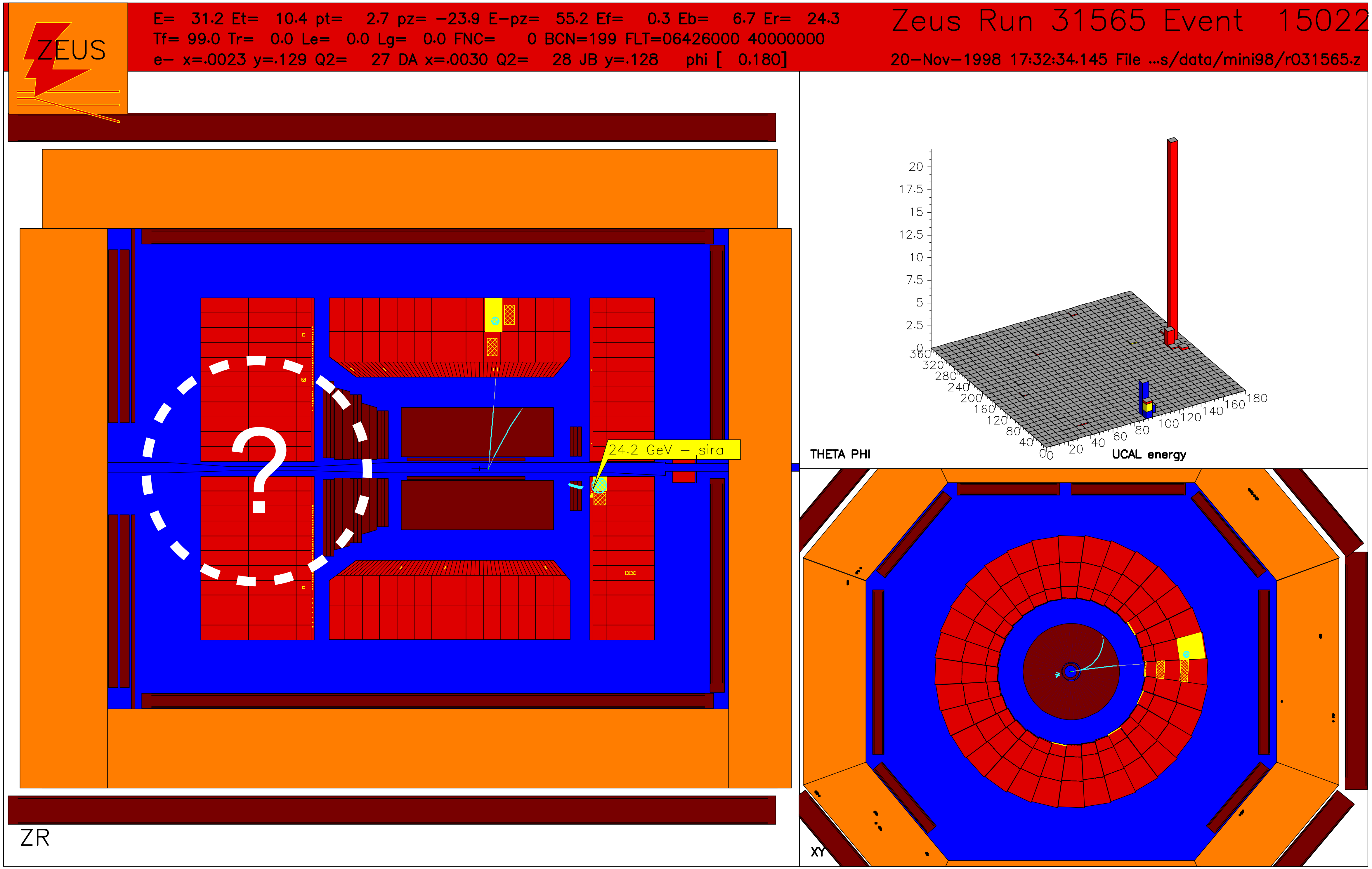


"Seeing" Diffraction

A diffractive event (experimental view)



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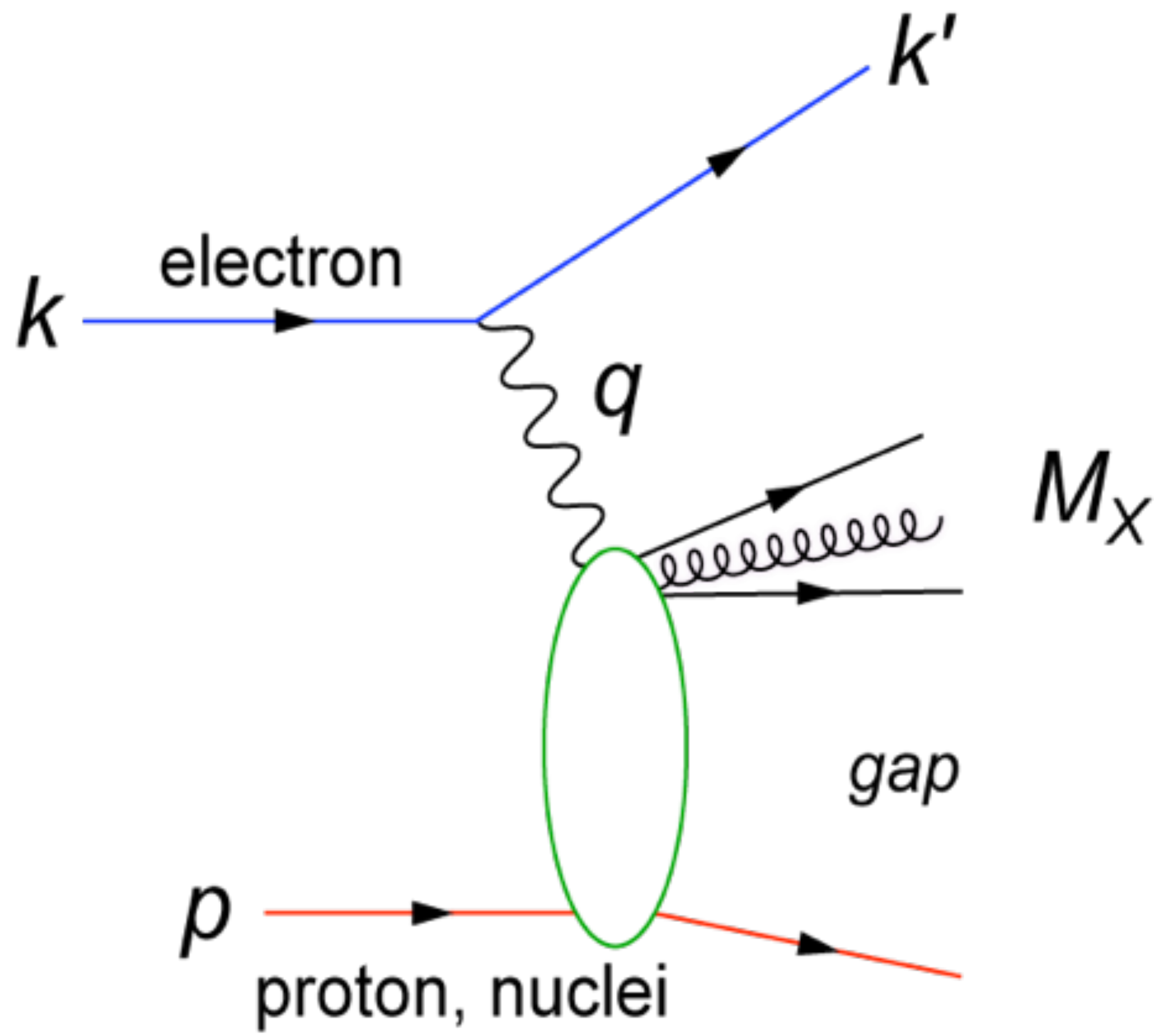
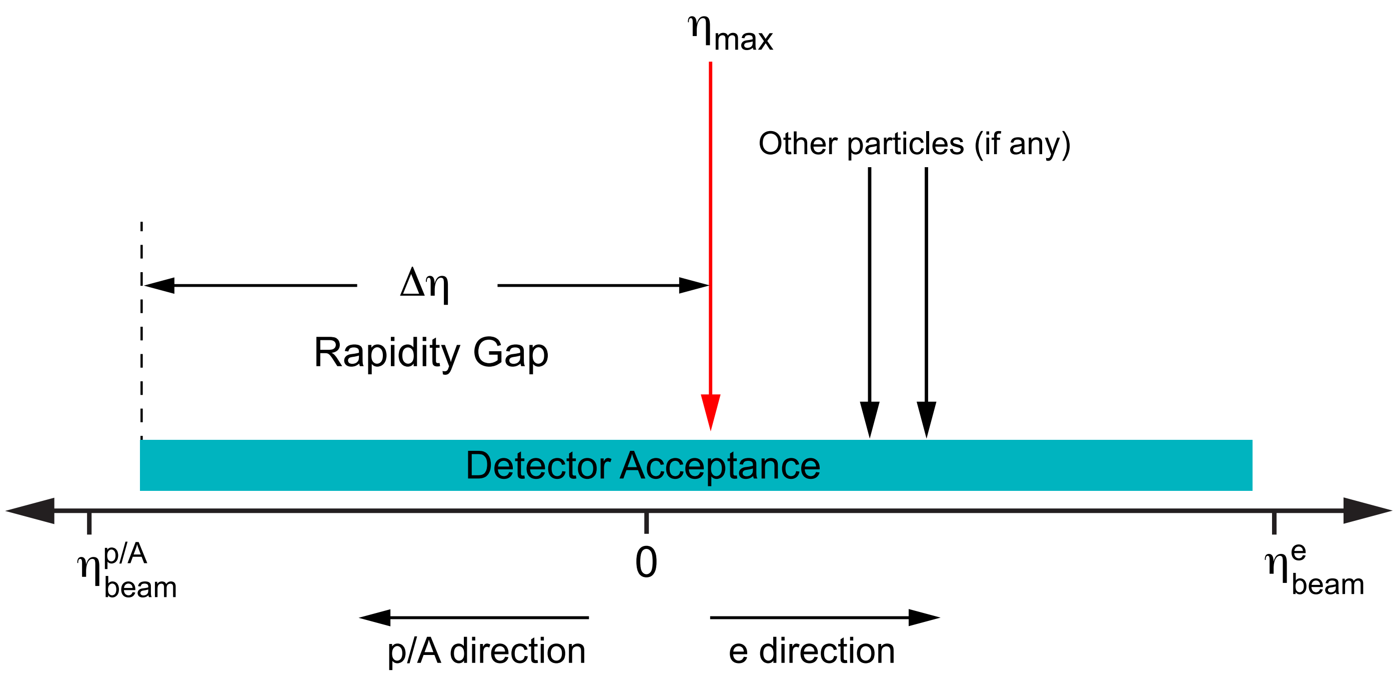
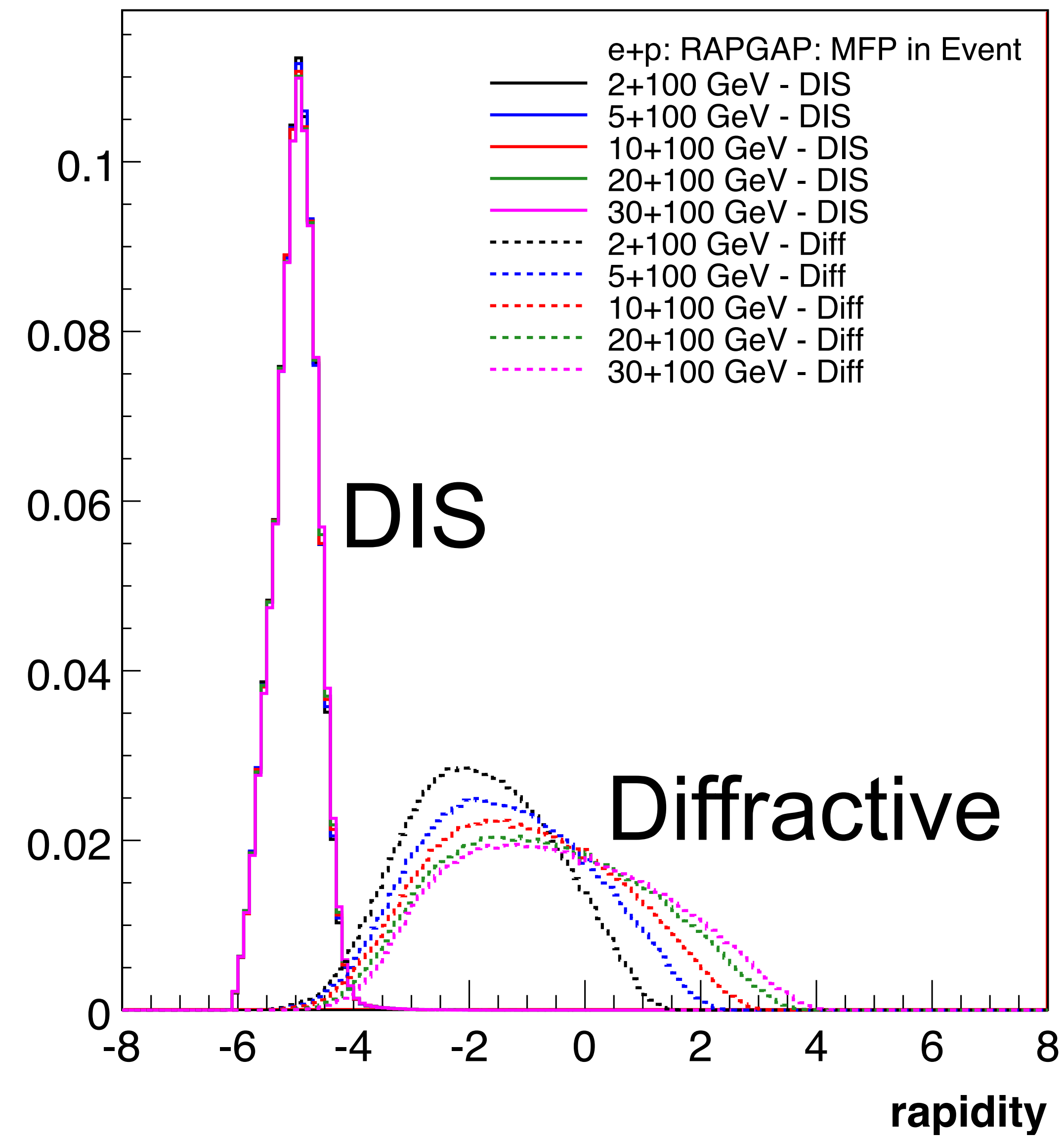


Large Rapidity Gap Method (LRG)

- Identify Most Forward Going Particle (MFP)
  - Works at HERA but at higher √s
  - EIC smaller beam rapidities



Diffractive ρ^0 production at EIC: η of MFP

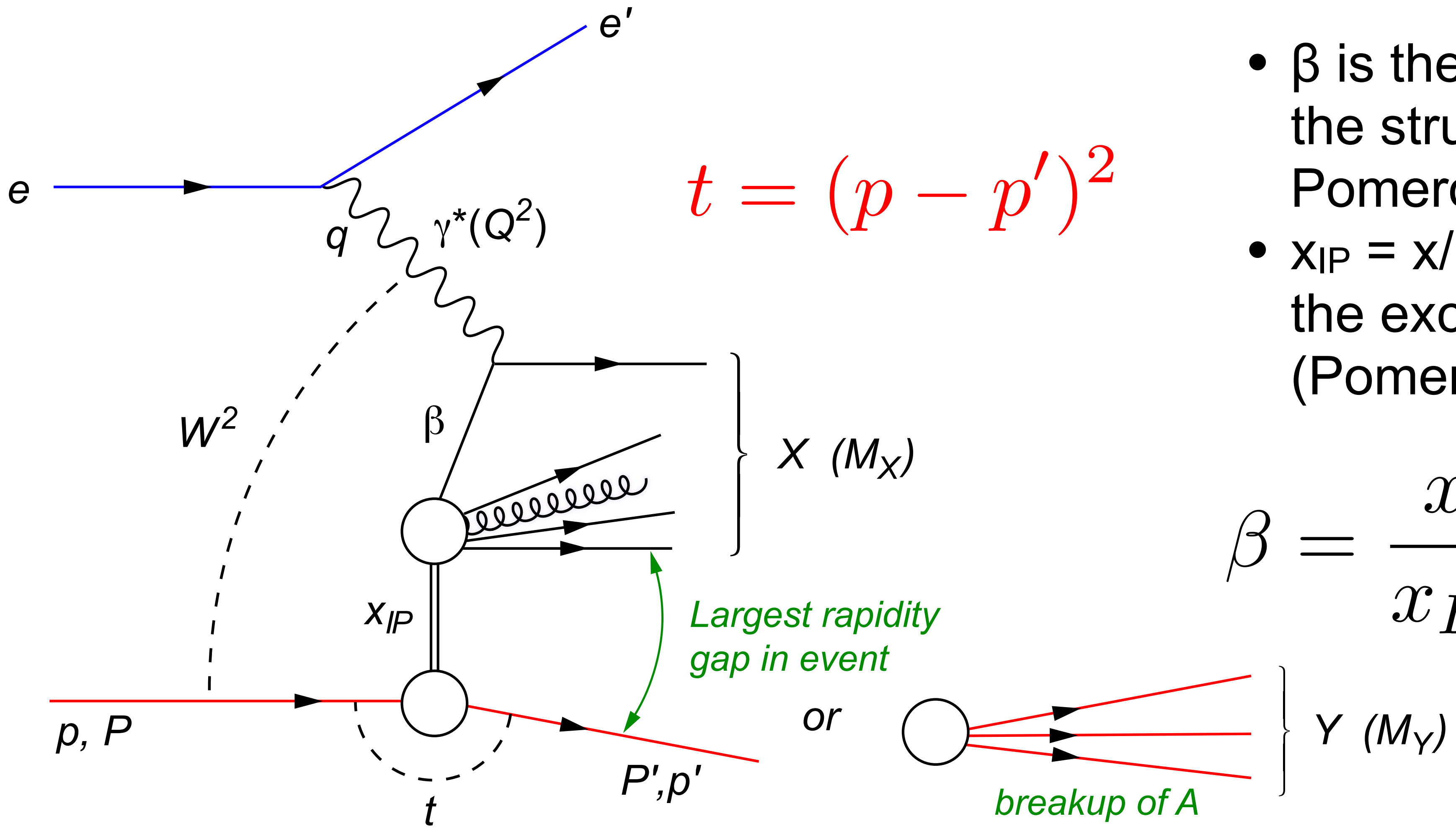


Hermeticity requirement:

- needs just to detect presence
- does not need momentum or PID
- studies done at BNL: √s not a show stopper for EIC (can achieve 1% contamination, 80% efficiency)

M. Lamont '10

Hard Diffraction in DIS at Small *x*



$$t = (p - p')^2$$

- β is the momentum fraction of the struck parton w.r.t. the Pomeron
- $x_{IP} = x/\beta$: momentum fraction of the exchanged object (Pomeron) w.r.t. the hadron

$$\beta = \frac{x}{x_{I\!P}} = \frac{Q^2}{Q^2 + M_X^2 - t}$$

$$\frac{d^4\sigma^{eh \to eXh}}{dx\,dQ^2\,d\beta\,dt} = \frac{4\pi\alpha_{em}^2}{\beta^2 Q^4}\left[\left(1 - y + \frac{y^2}{2}\right) F_2^{D,4}(x, Q^2, \beta, t) - \frac{y^2}{2} F_L^{D,4}(x, Q^2, \beta, t)\right]$$

- **Diffraction in e+p:**
  - coherent ⇔ p intact
  - incoherent ⇔ breakup of p
  - HERA: 15% of all events are diffractive
- **Diffraction in e+A:**
  - coherent diffraction (nuclei intact)
  - incoherent diffraction: breakup into nucleons (nucleons intact)
  - Predictions: $\sigma_{diff}/\sigma_{tot}$ in e+A ~25-40%

Hard Diffraction in DIS at Small *x*

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- Diffraction in e+A:
  - coherent diffraction (nuclei intact)
  - incoherent diffraction: breakup into nucleons (nucleons intact)
  - Predictions: $\sigma_{diff}/\sigma_{tot}$ in e+A ~25-40%

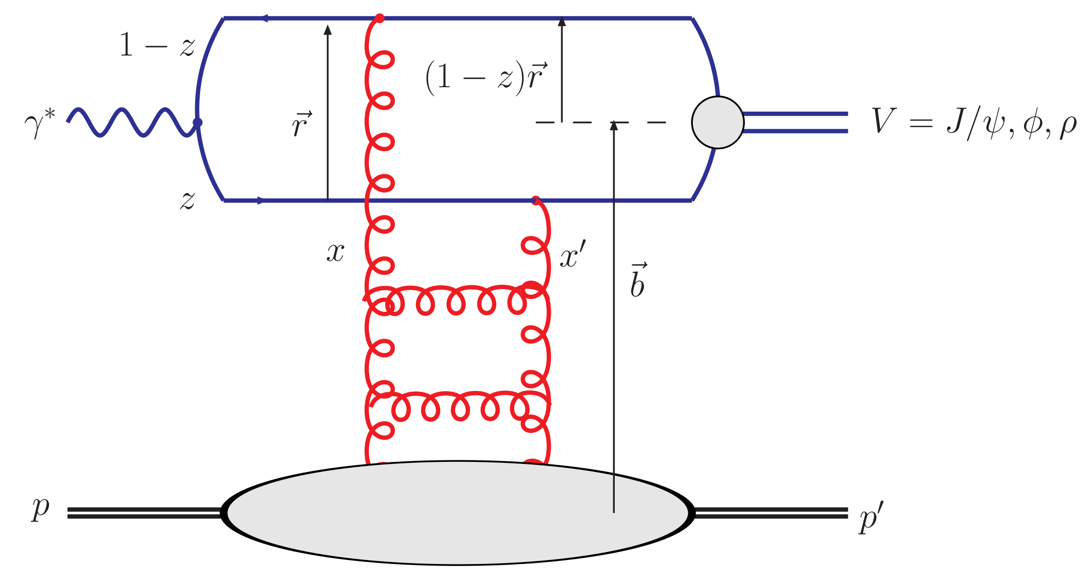
Why Is Diffraction So Kif?

- Sensitive to gluon momentum distribution

$$\frac{d\sigma^{\gamma^* p \to pV}}{dt} \sim \left| \int \Psi_V^* \frac{d\sigma_{q\bar{q}}}{d^2b} \Psi e^{-ib\Delta} \right|^2$$

$$\frac{d\sigma_{q\bar{q}}}{d^2\vec{b}} \sim r^2 \alpha_s x g(x, \mu^2) T(b)$$

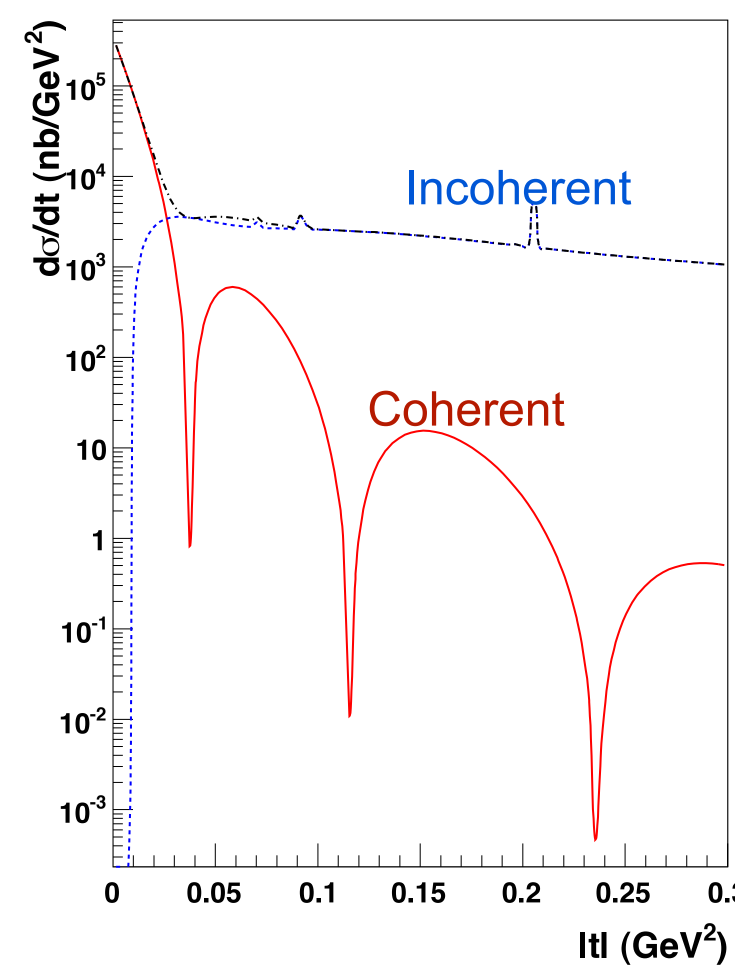
  - $\sigma \propto g(x,Q^2)^2$



- Sensitive to spatial gluon distribution

$$\frac{d\sigma}{dt} \equiv$$ Fourier Transformation of Source Density $\rho_g(b)$

  - Hot topic:
    - Gluonic spatial density
    - just Woods-Saxon + nucleon g(b)?
  - Incoherent Case: measure of fluctuation/ lumpiness in $\rho_g^A(\mathbf{b})$



Measuring t=(p-p')^2

$$\theta_{\min} = 0.08\mathrm{mrad}(10\sigma)$$
$$p = 100\ \mathrm{GeV}$$

species (A)	p_T^{min} (GeV/c)
d (2)	0.02
Si (28)	0.22
Cu (64)	0.51
In (115)	0.92
Au (197)	1.58
U (238)	1.90

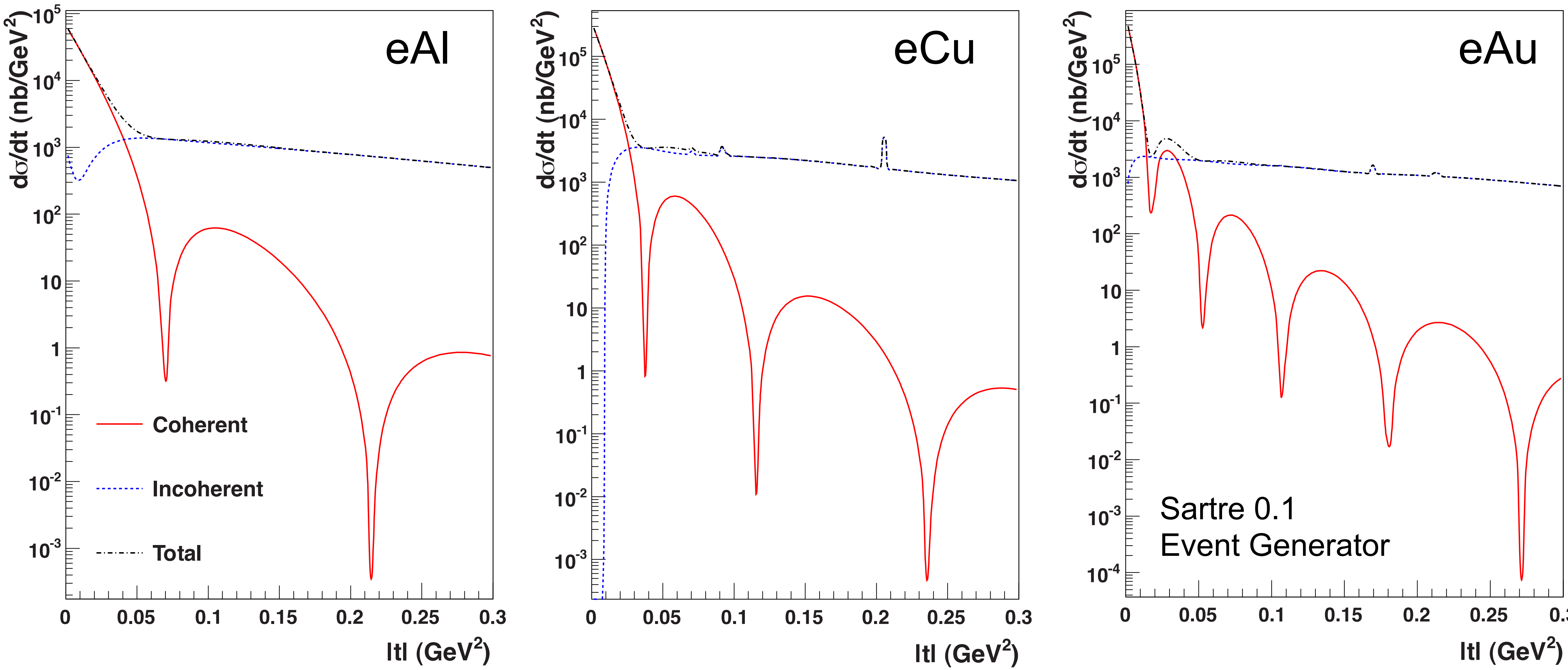
For coherent diffraction one needs to measure the scattered ion. Only possible if it is separated from the beamline detectors by an angle $\theta_{\min}$, which requires a momentum kick of at least:

$$p_t^{\min} \approx pA\theta_{\min}$$

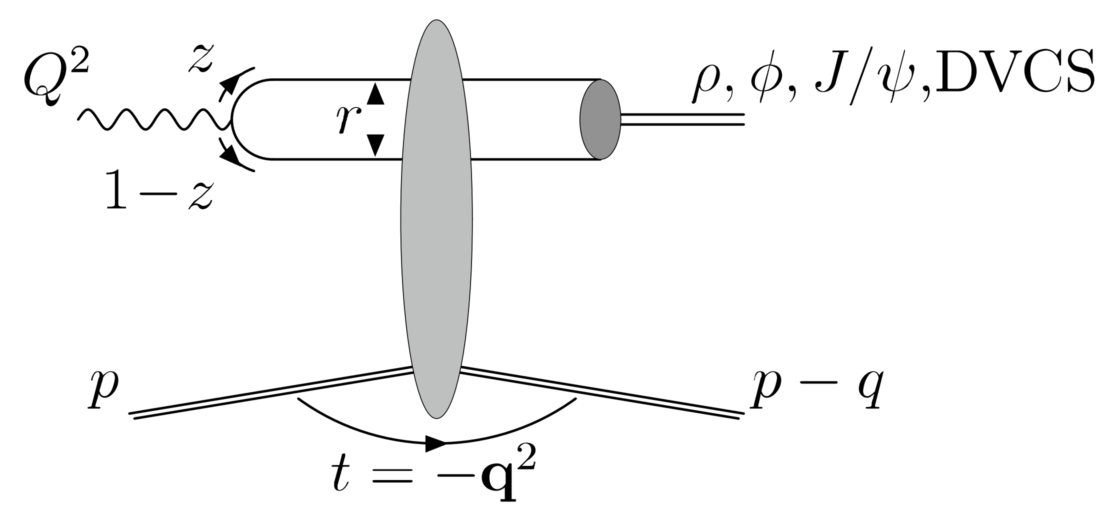
For incoherent diffraction all beam remnants have to be measured for t to be reconstructed.

Both cases impossible - Need exclusive diffraction!

Exclusive Vector Meson Production



- Golden channel: e + A → e' + VM + A'
  - $t = (P_A - P_{A'})^2 = (P_{VM} + P_{e'} - P_e)^2$
  - photoproduction ($Q^2 \approx 0$): $t \approx p^2_{T,VM}$
  - moderate Q^2: need p_T of e'
  - Issues:
    - transverse spread of the beam (distorts small t) ⇒ requires beam cooling
    - detect incoherent events ⇒ detect nuclear breakup



Detecting Nuclear Breakup

- Detecting **all** fragments $p_{A'} = \sum p_n + \sum p_p + \sum p_d + \sum p_\alpha$ ... not possible
- Focus on n emission
  - Zero-Degree Calorimeter
  - Requires careful design of IR
- Additional measurements:
  - Fragments via Roman Pots
  - γ via EMC

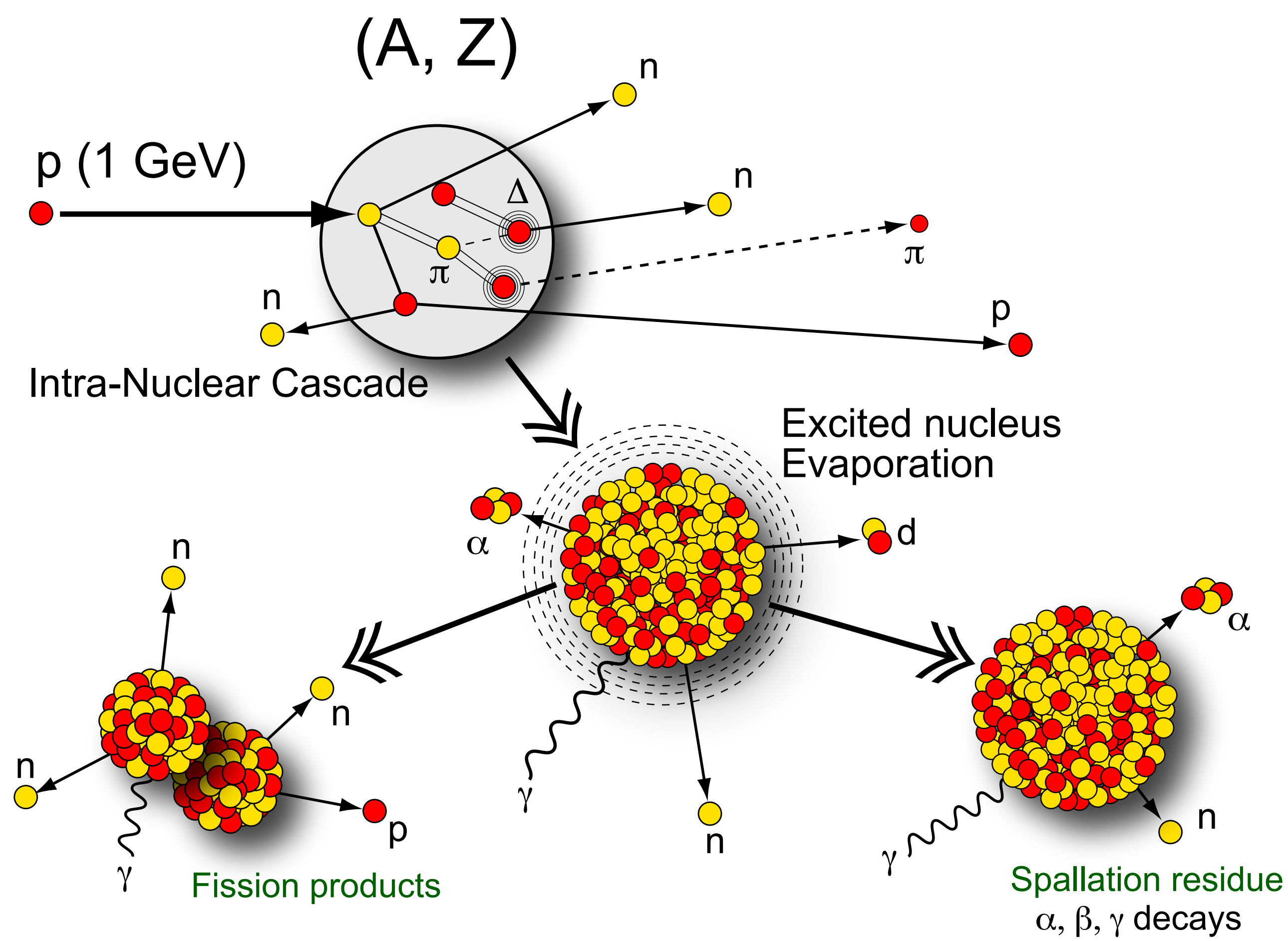
Traditional modeling done in pA:

Intra-Nuclear Cascade

- Particle production
- Remnant Nucleus (A, Z, E*, ...)
- ISABEL, INCL4

De-Excitation

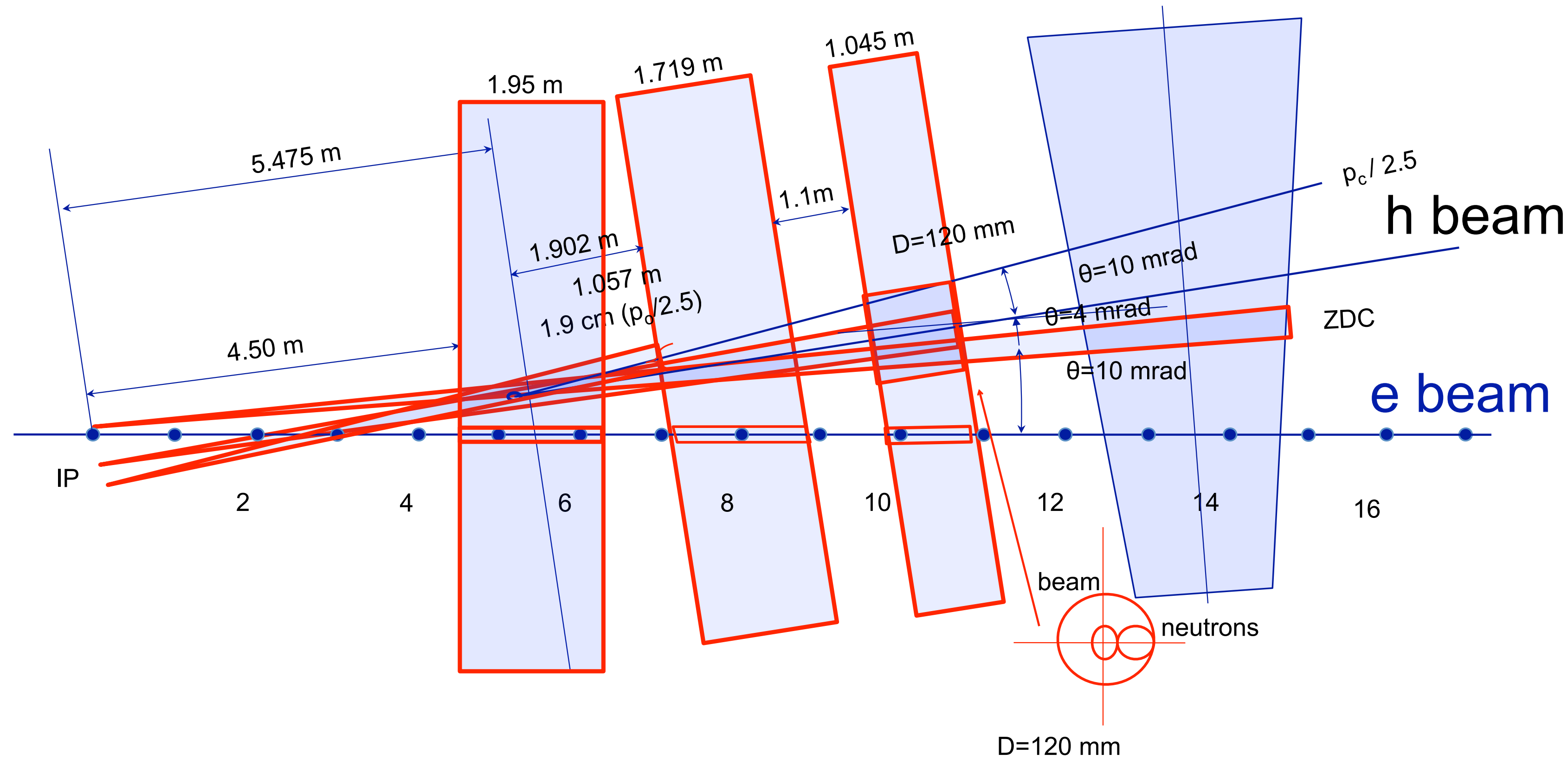
- Evaporation
- Fission
- Residual Nuclei
- Gemini++, SMM, ABLA (all no γ)



Experimental Reality

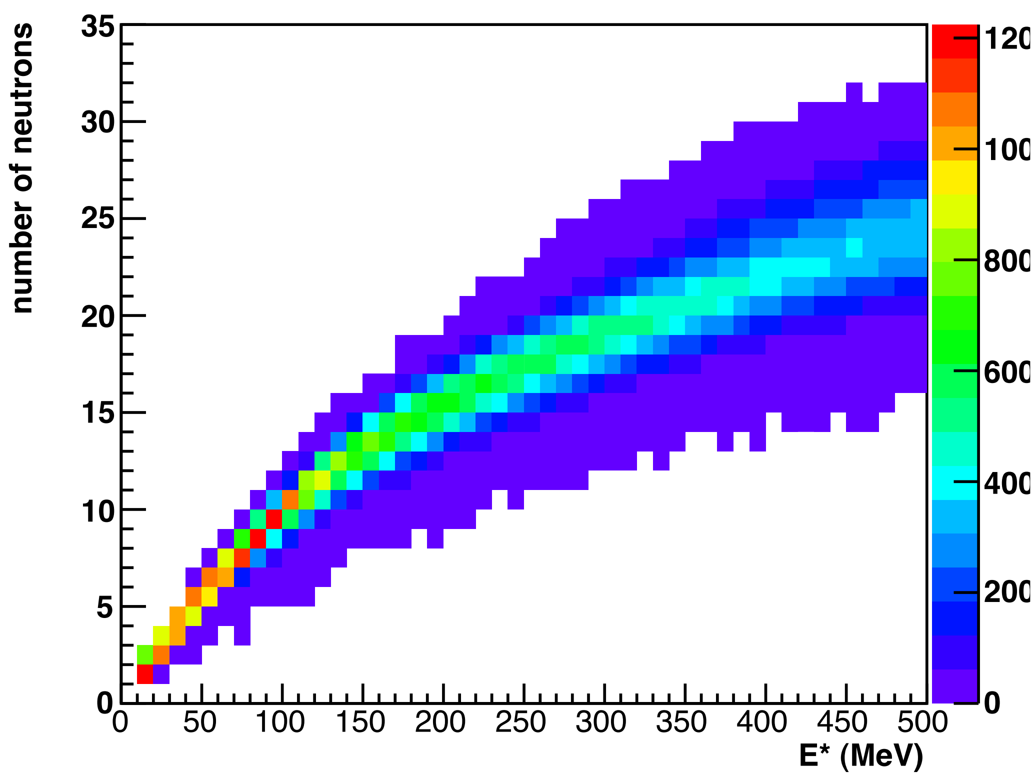
Here eRHIC IR layout:

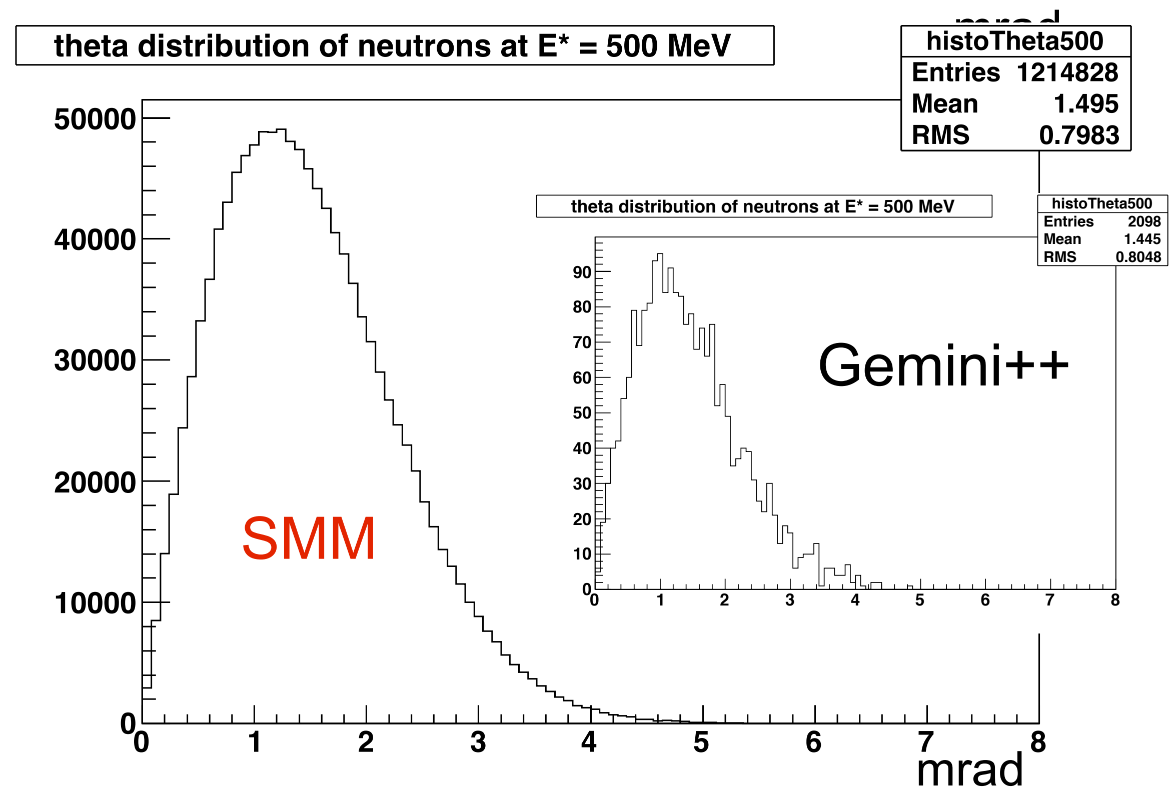
Need ±X mrad opening through triplet for *n* and room for ZDC



Big questions:

- Excitation energy E*?
- ep: $d\sigma/M_Y \sim 1/M_Y^2$
- eA? Assume ep and use $E^* = M_Y - m_p$ as lower limit





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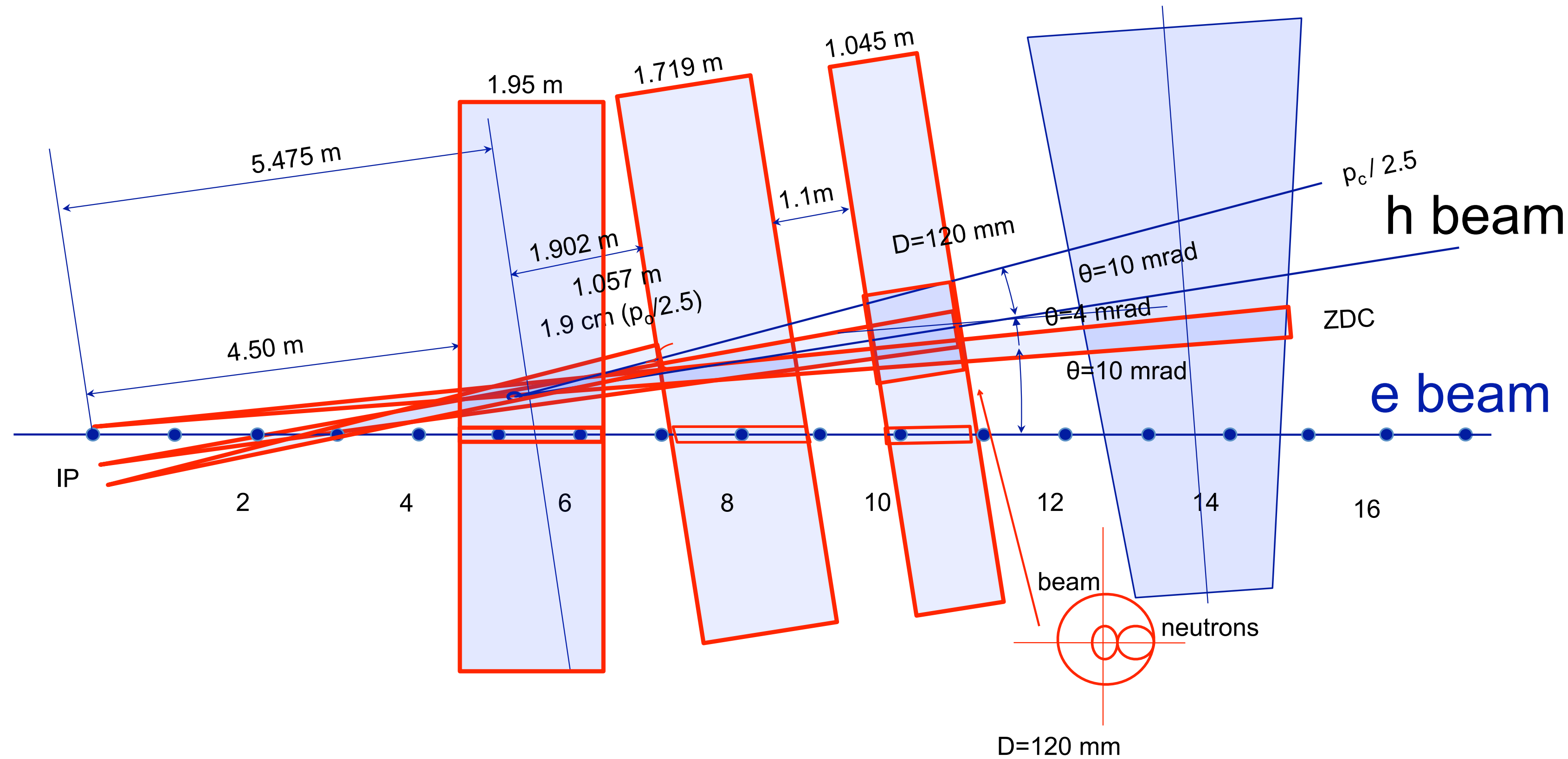

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Simulations using Gemini++ & SMM show it works:

- For $E^*_{tot} \geq 10$ MeV and 2.5 mrad *n* acceptance we have rejection power of at least 10^5.
- Separating incoherent from coherent diffractive events is possible at a collider with *n*-detection via ZDCs alone

Monte Carlos simulations

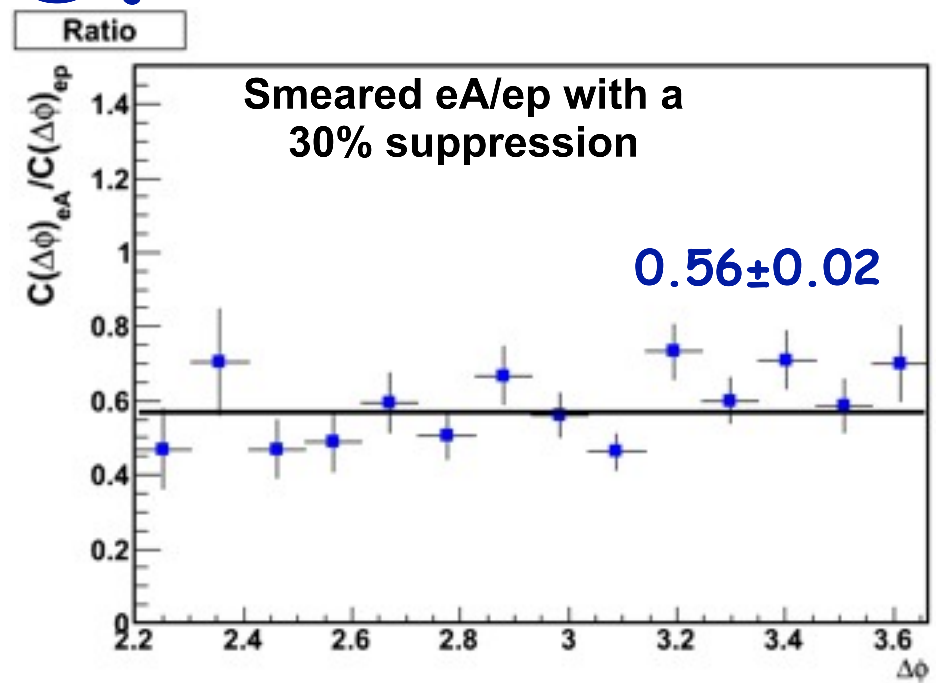
There are many Monte Carlo event generators for simulating DIS and diffraction in *ep*.

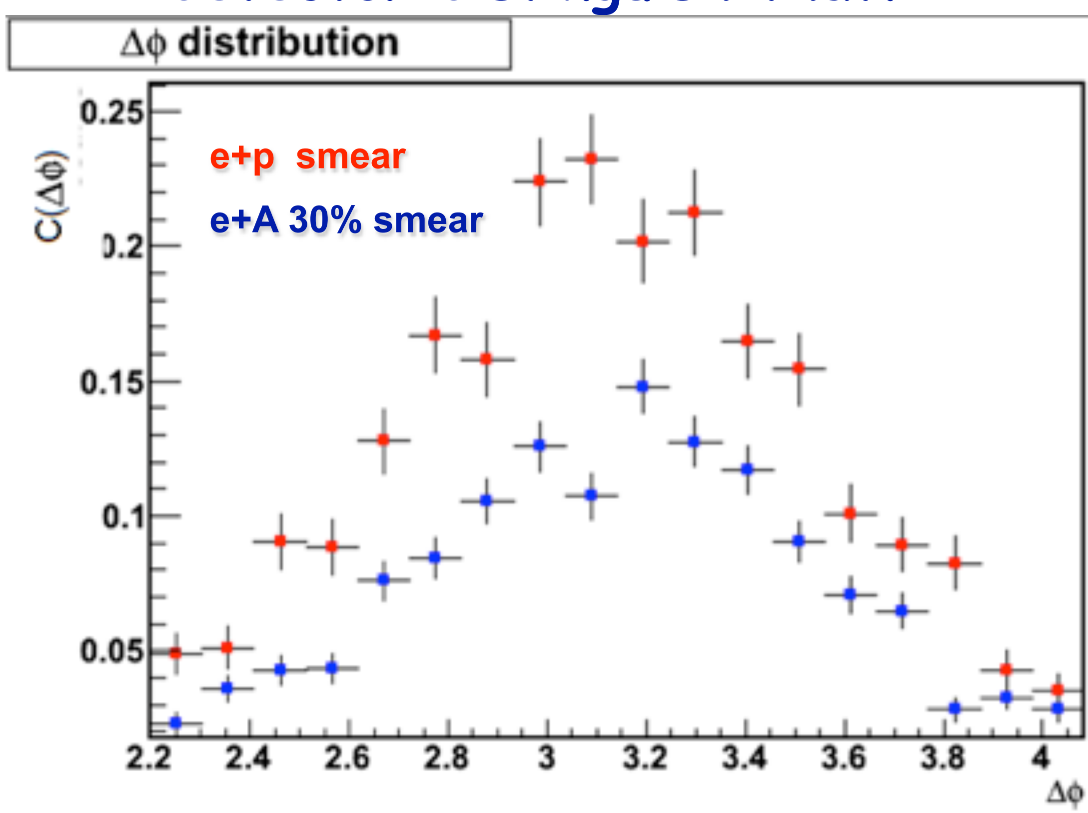
The only generator available for eA is DPMJet-III

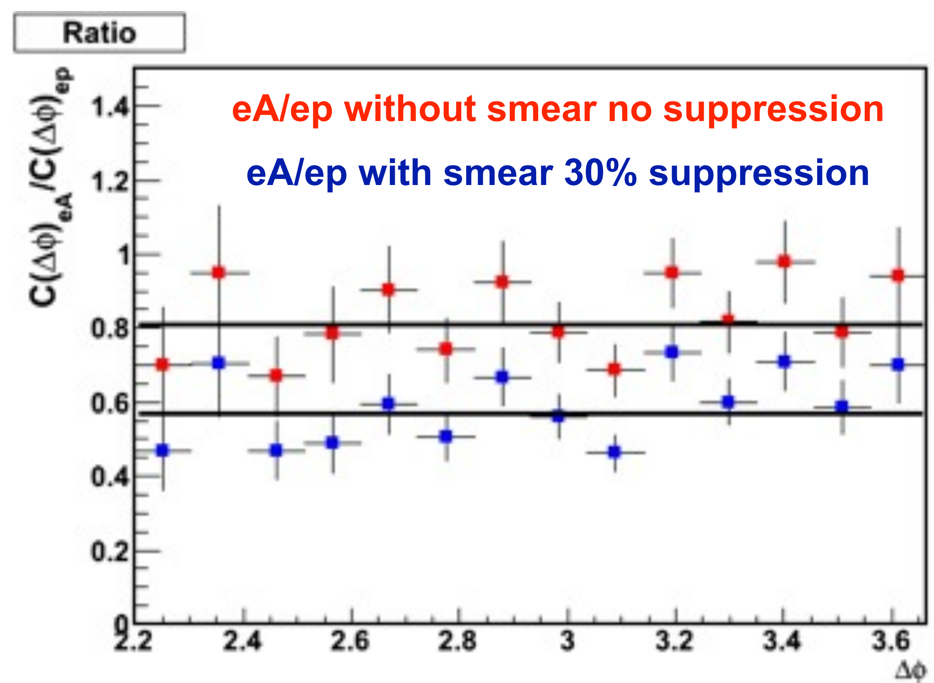
Dihadron correlation in eA using DPMJet

Detector smearing considered, to see the performance of certain detector resolution.

Suppose we have a 30% suppression, can our detector distinguish that?







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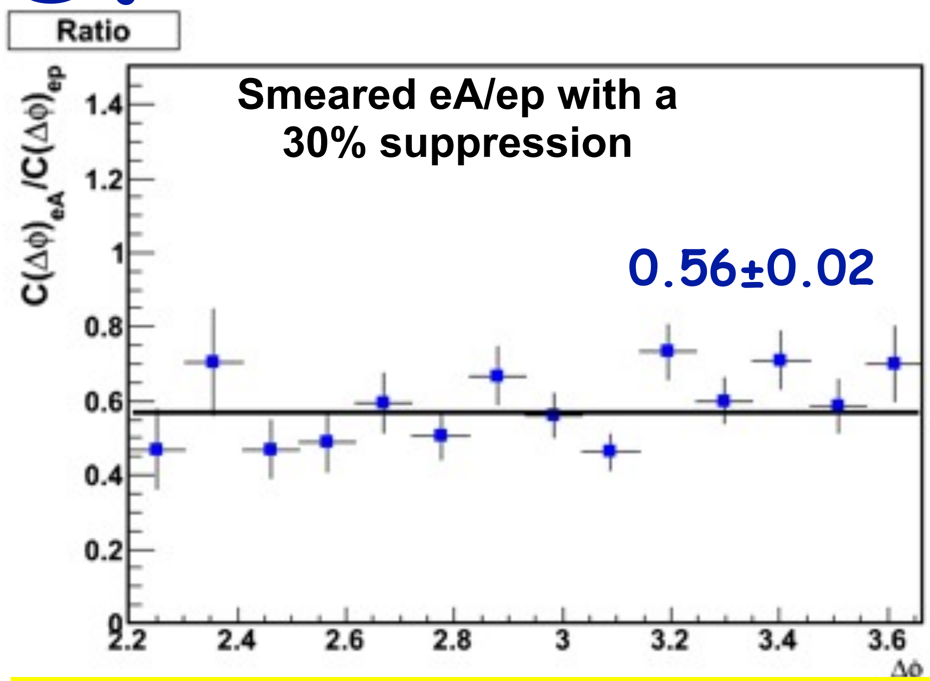
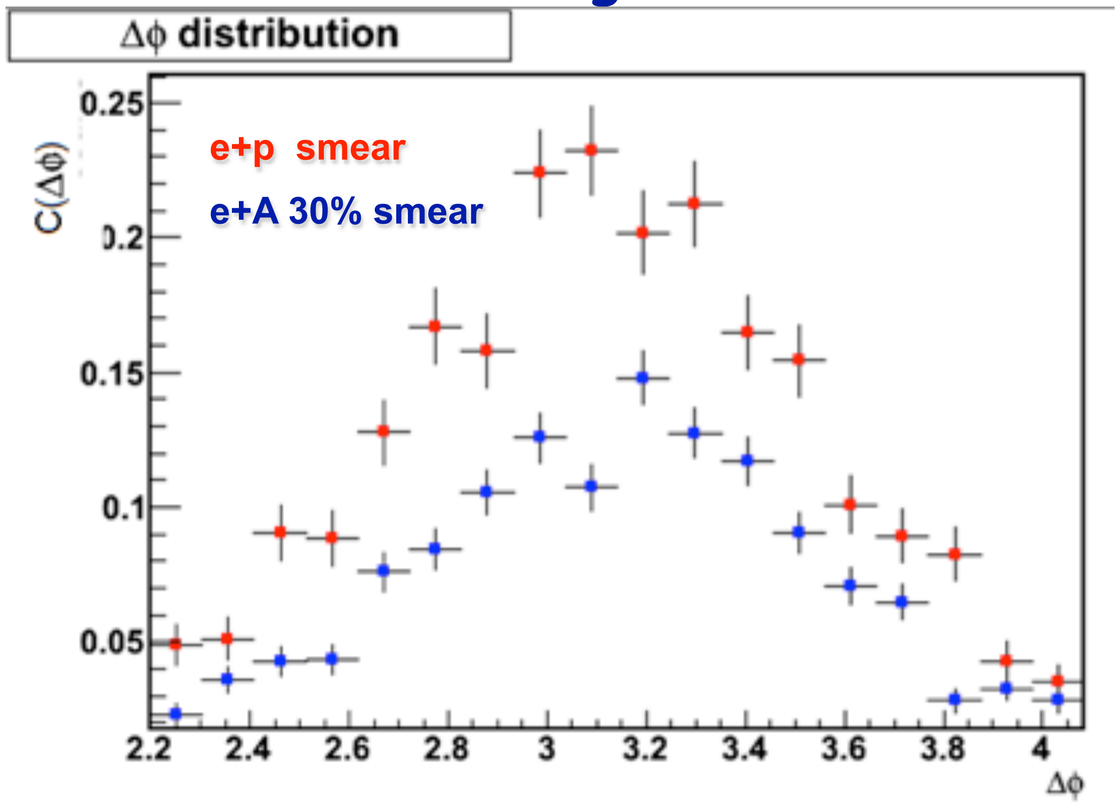
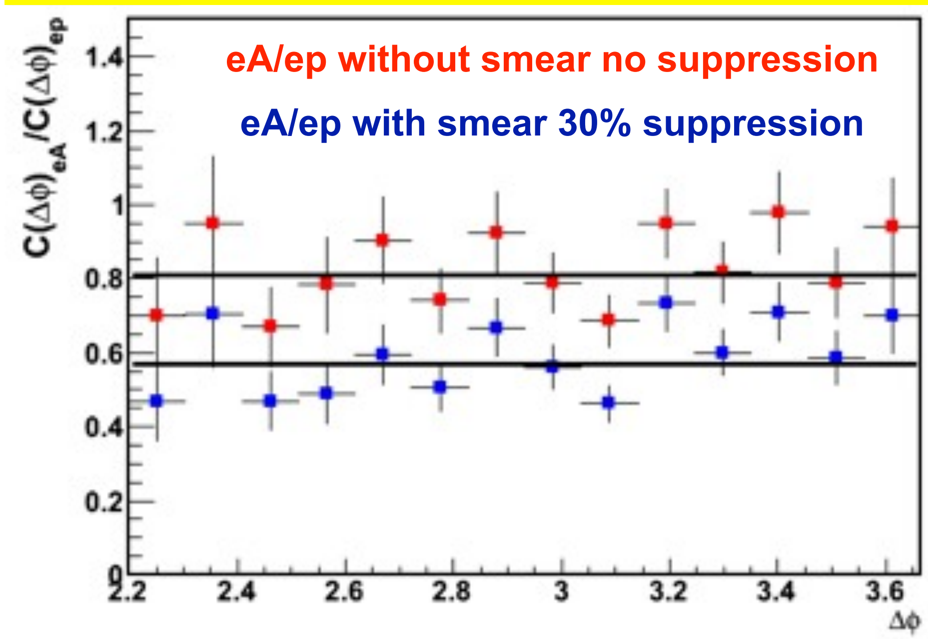


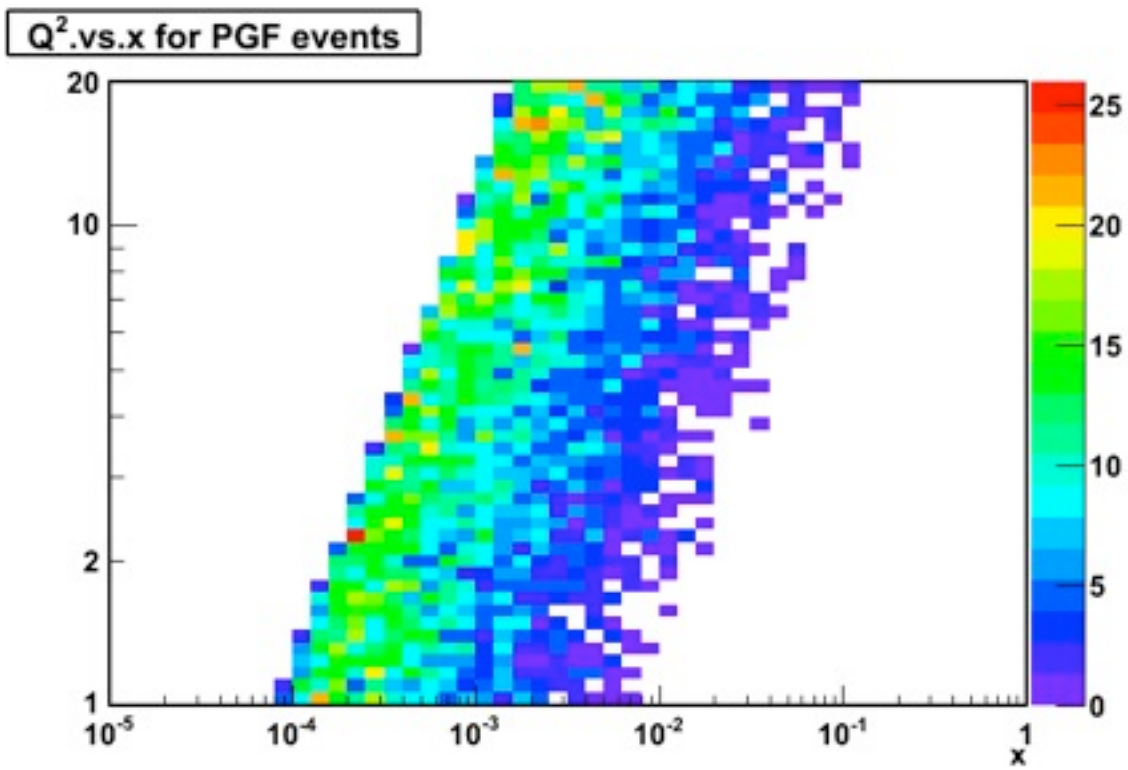


Smear effect doesn't make a big deal in this measurement!

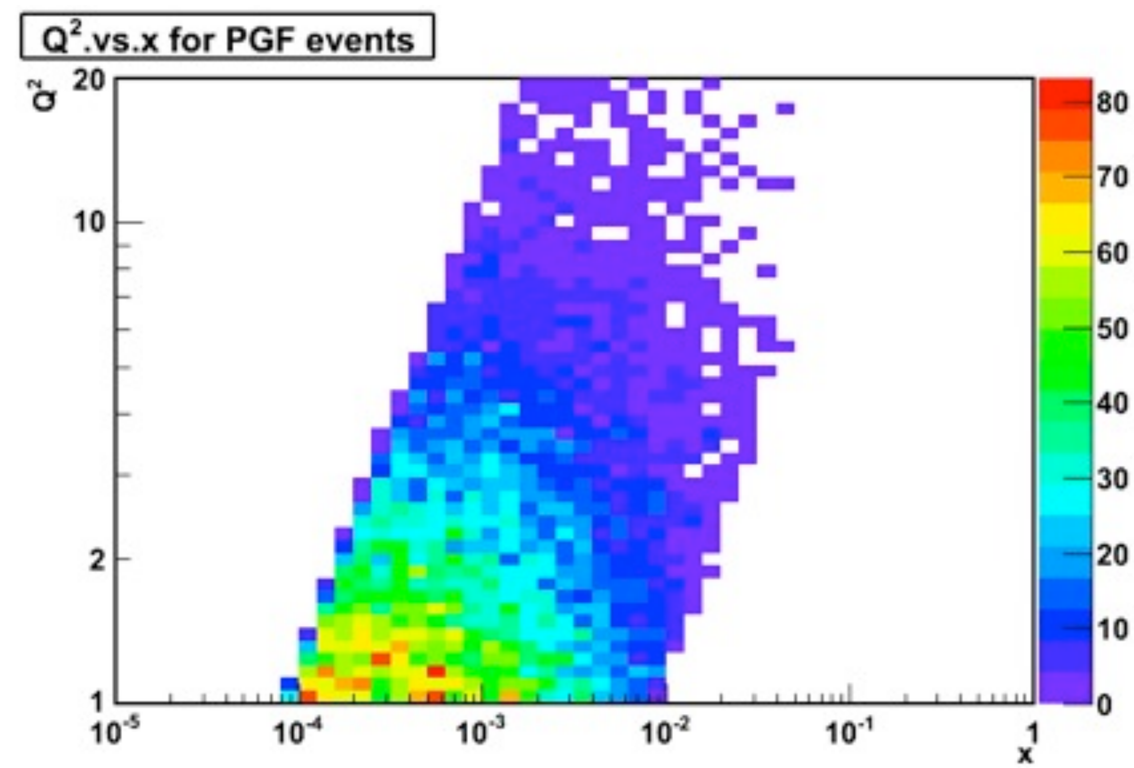


DPM-Jet

Photon Gluon Fusion events



DPMJet-III



Pythia

Work by Liang Zheng

Matrix element for direct process

Q2 involved in hard cross section

pythia

QCDC

$$\frac{d\hat{\sigma}_T}{d\hat{t}} = \frac{8}{3}\pi\alpha_s\alpha_{em}e_q^2 \frac{1}{(\hat{s}+Q_1^2)^2}\left\{\frac{\hat{s}^2+\hat{u}^2-2Q_1^2\hat{t}}{-\hat{s}\hat{u}} - \frac{2Q_1^2\hat{t}}{(\hat{s}+Q_1^2)^2}\right\}$$

$$\frac{d\hat{\sigma}_L}{d\hat{t}} = \frac{8}{3}\pi\alpha_s\alpha_{em}e_q^2 \frac{-4Q_1^2\hat{t}}{(\hat{s}+Q_1^2)^4} ,$$

PGF

$$\frac{d\hat{\sigma}_T}{d\hat{t}} = \pi\alpha_s\alpha_{em}e_q^2 \frac{1}{(\hat{s}+Q_1^2)^2}\frac{\hat{t}^2+\hat{u}^2}{\hat{t}\hat{u}}\left[1-\frac{2Q_1^2\hat{s}}{(\hat{s}+Q_1^2)^2}\right]$$

$$\frac{d\hat{\sigma}_L}{d\hat{t}} = \pi\alpha_s\alpha_{em}e_q^2 \frac{8Q_1^2\hat{s}}{(\hat{s}+Q_1^2)^4} .$$

dpmjet

QCDC

$$\sigma = \alpha_S\alpha_{\mathrm{em}}e_q^2\left[-\frac{8}{3}\frac{\hat{u}^2+\hat{s}^2}{\hat{s}\hat{u}}\right]$$

Only Photoproduction!

PGF

$$\sigma = \alpha_S\alpha_{\mathrm{em}}e_q^2\left[\frac{\hat{u}^2+\hat{t}^2}{\hat{t}\hat{u}}\right]$$

Discovered by Liang Zheng

DPM-Jet

Solution:
Redo study with Pythia 6
Use Nuclear PDFs as input
Add afterburners for:
- Hadronisation effects in the nucleus. Provided by R. Dupré and A. Accardi
- Nuclear break-up

Monte Carlos simulations

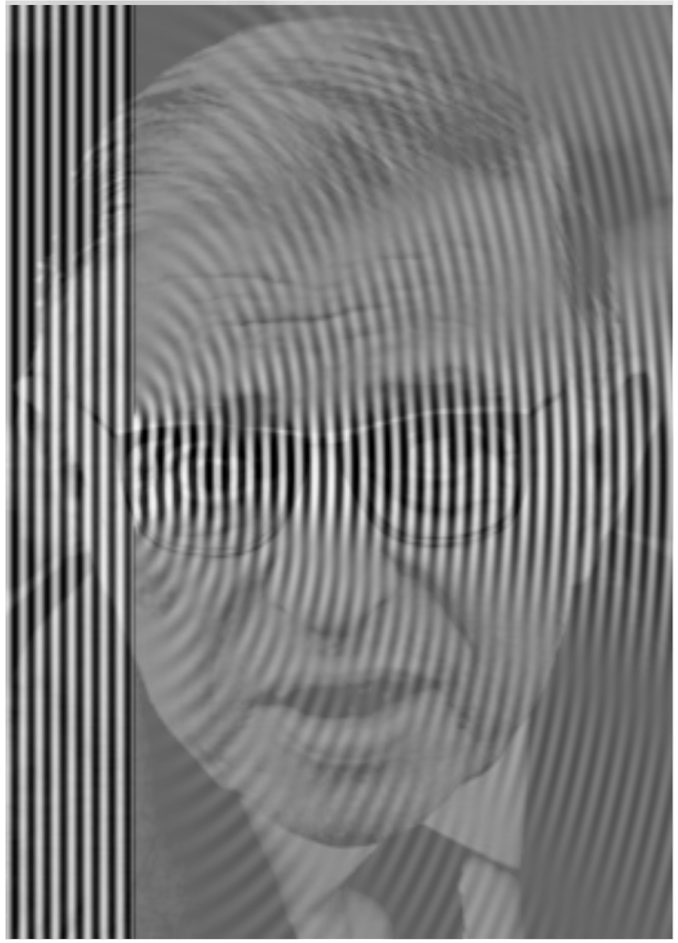
There are many Monte Carlo event generators for simulating DIS and diffraction in ep.

The only generator available for eA is DPMJet-III
- it only works for photo production
-it lacks many important processes, e.g. exclusive diffaction

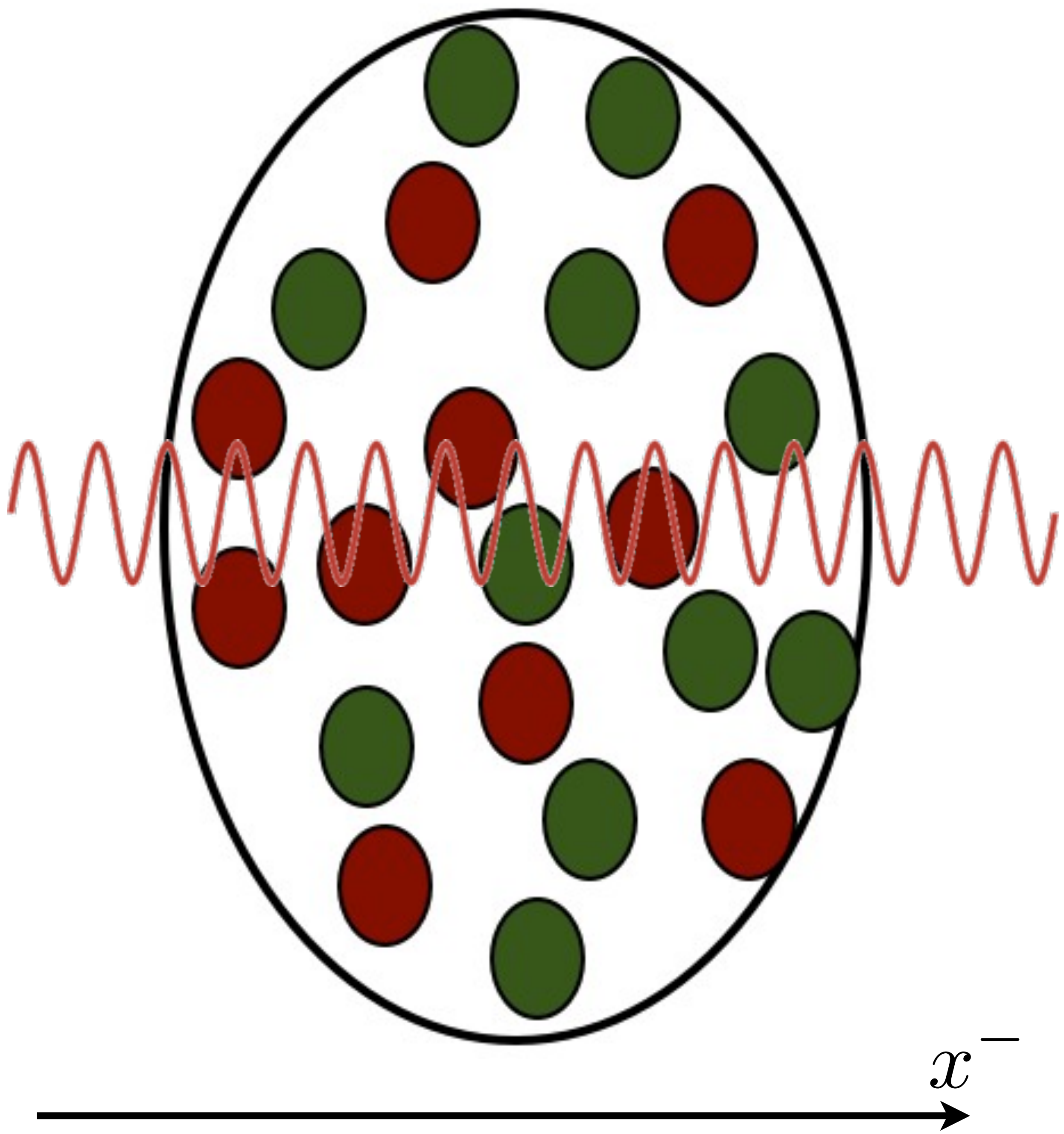
We have therefore written a new MC event generator:

Sartre

(papers in preparation)

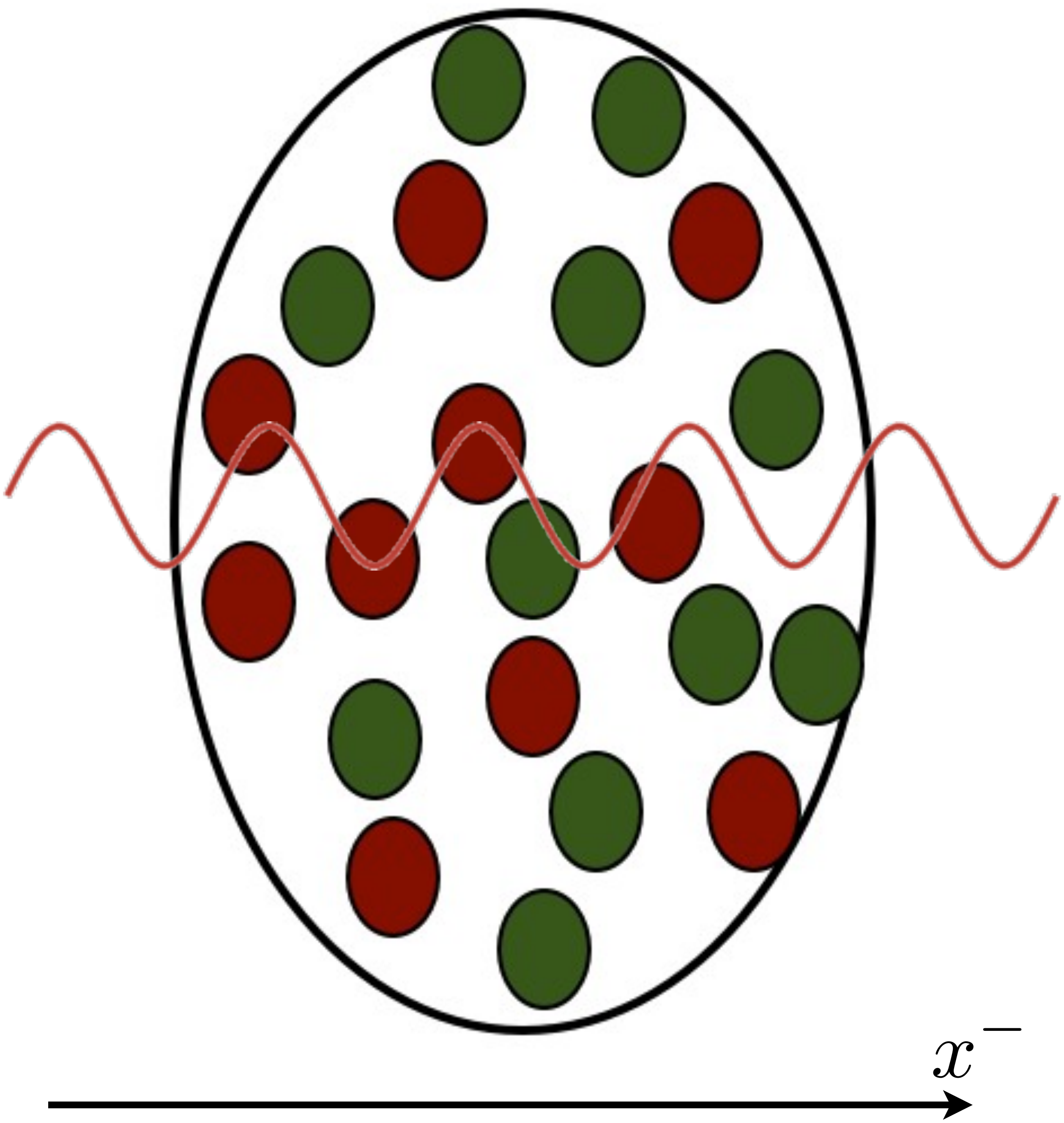


Probing the Nucleus at small *x*



At large x: large p^+, short wavelength in x^-, individual nucleons can be resolved.

Probing the Nucleus at small *x*



At large x: large p^+,
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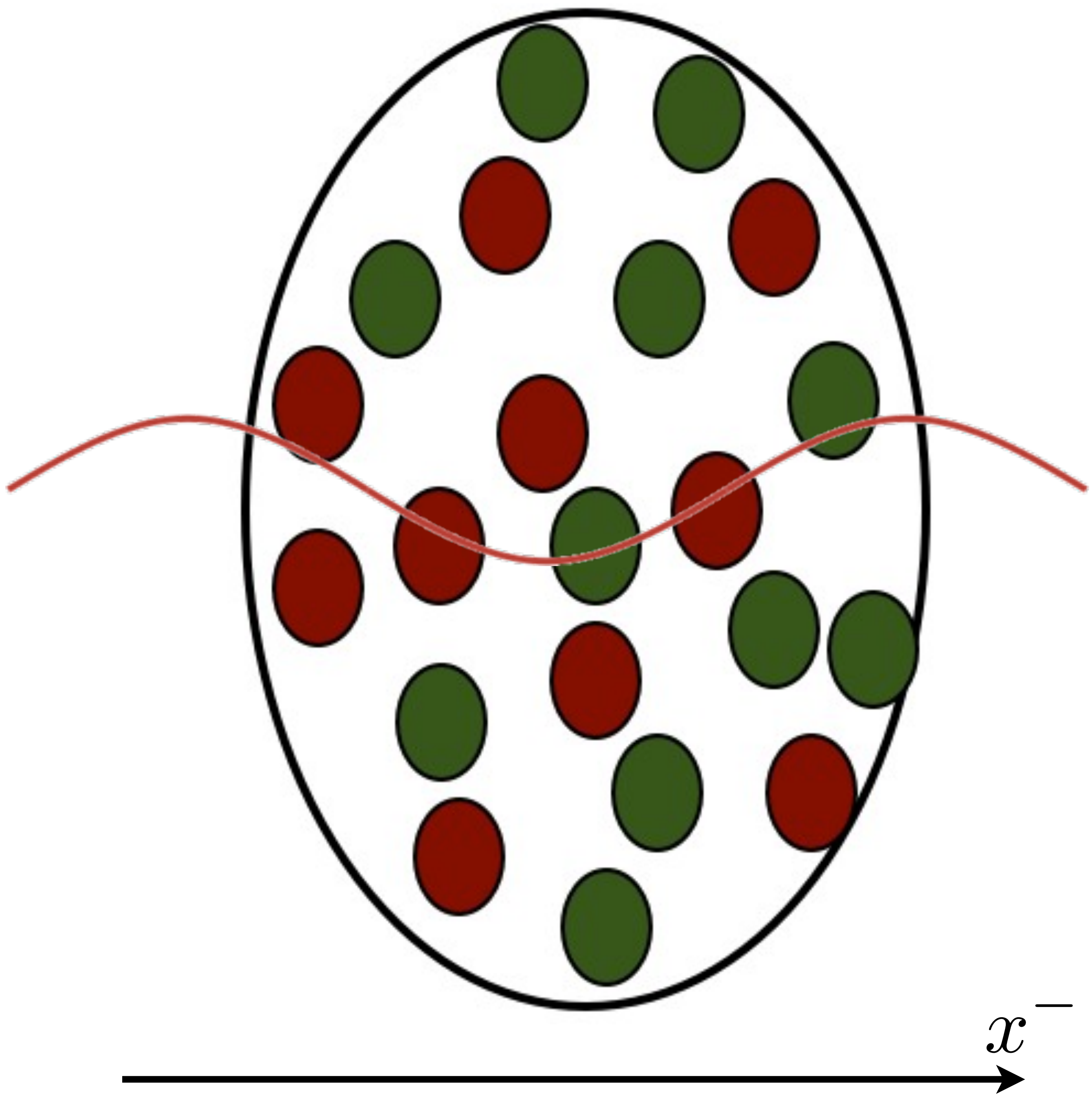
At smaller x,
coherently probe larger area.

Probing the Nucleus at small x



At large x: large p^+, short wavelength in x^-, individual nucleons can be resolved.

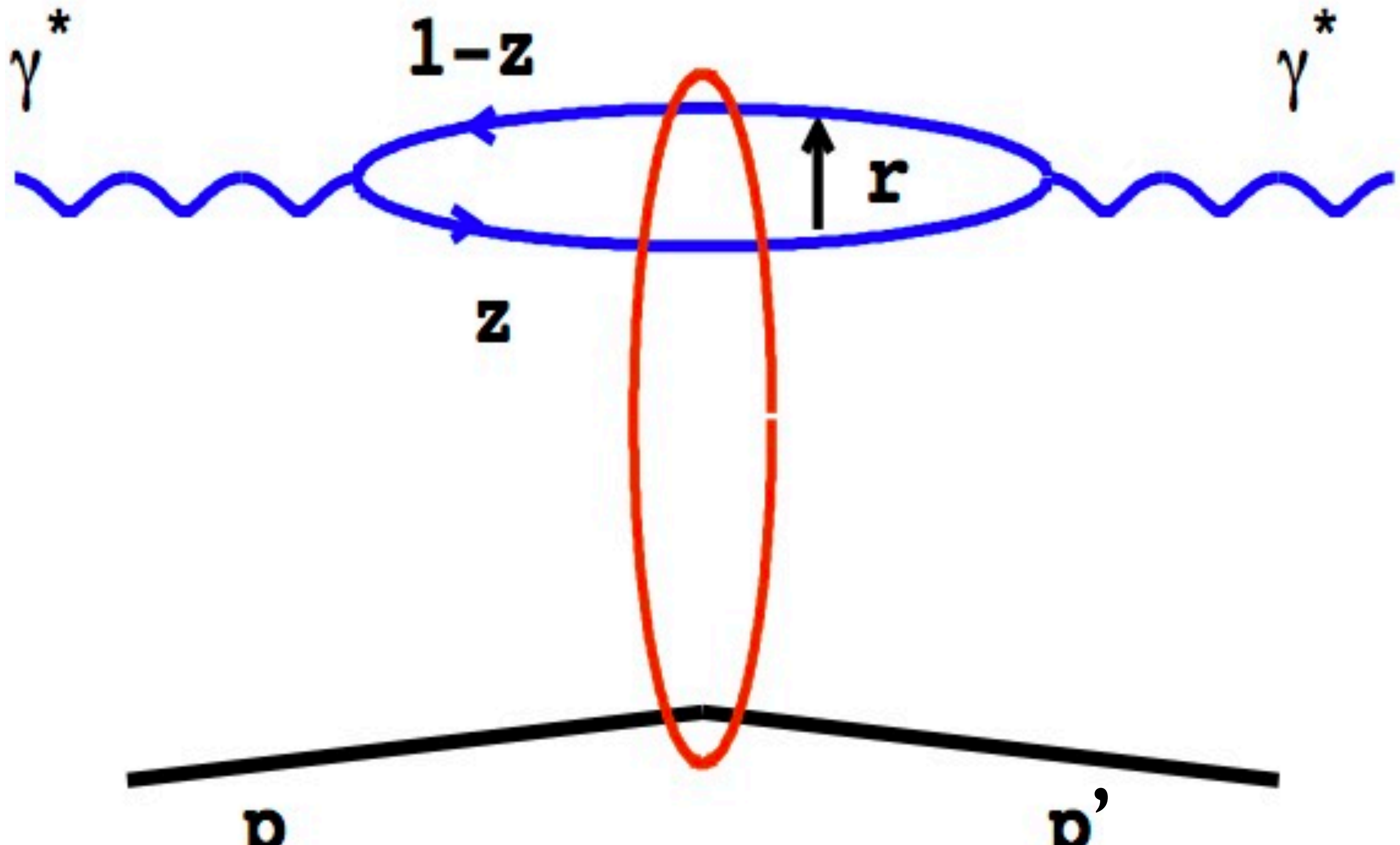
At smaller x, coherently probe larger area.

At $x \ll \frac{A^{-1/3}}{M_N R_p}$ coherently probing the whole nucleus.

Challenge for MC, can not just use "A x Pythia"!!

Start with *ep*

The Dipole Model



Elastic photon-proton scattering

$$\Delta \equiv (p'^{\mu} - p^{\mu})_{\perp}$$

$$\mathcal{A}^{\gamma^* p}(x, Q, \Delta) = \sum_f \sum_{h,\bar{h}} \int \mathrm{d}^2\mathbf{r} \int_0^1 \frac{\mathrm{d}z}{4\pi} \Psi^*_{h\bar{h}}(r, z, Q) \mathcal{A}_{q\bar{q}}(x, r, \Delta) \Psi_{h\bar{h}}(r, z, Q)$$

Exclusive diffractive processes at HERA within the dipole picture, H. Kowalski, L. Motyka, G. Watt, Phys. Rev. D74, 074016, arXiv:hep-ph/0606272v2

The Dipole Model

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Use:

Optical theorem:

$$\mathcal{A}_{q\bar{q}}(x,r,\Delta) = \int \mathrm{d}^2\boldsymbol{b}\, \mathrm{e}^{-\mathrm{i}\boldsymbol{b}\cdot\boldsymbol{\Delta}} \mathcal{A}_{q\bar{q}}(x,r,b) = \mathrm{i} \int \mathrm{d}^2\boldsymbol{b}\, \mathrm{e}^{-\mathrm{i}\boldsymbol{b}\cdot\boldsymbol{\Delta}}\, 2\,[1 - S(x,r,b)]\,.$$

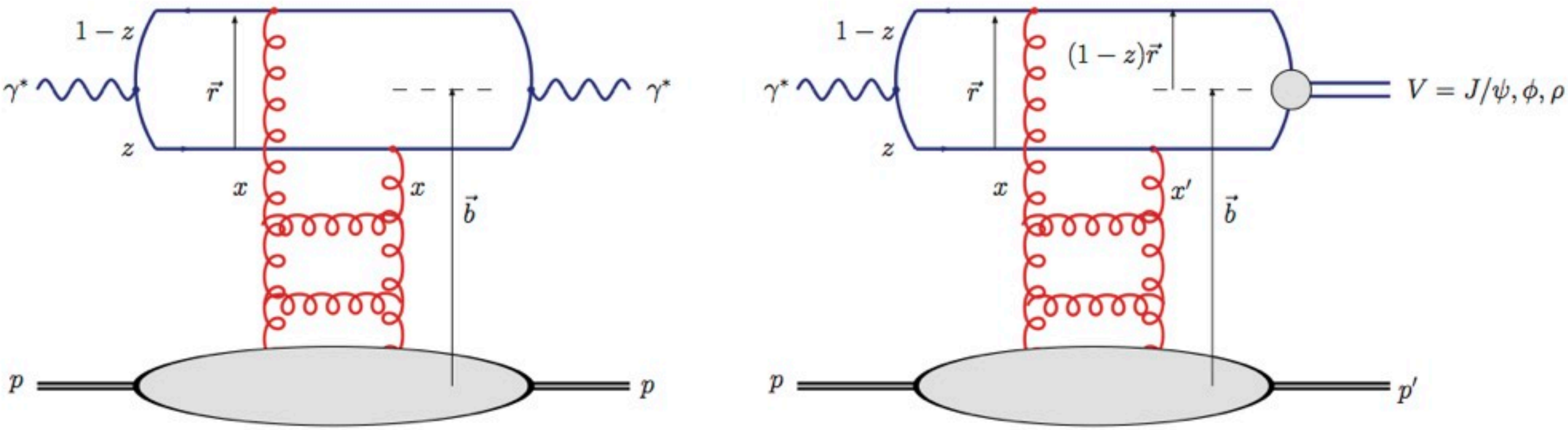
Real Part of S-matrix:

$$\sigma_{q\bar{q}}(x,r) = \mathrm{Im}\,\mathcal{A}_{q\bar{q}}(x,r,\Delta=0) = \int \mathrm{d}^2\boldsymbol{b}\, 2[\overbrace{1 - \mathrm{Re}\,S(x,r,b)}^{\mathcal{N}(x,r,b)}]$$

Define dipole cross-section:

$$\frac{\mathrm{d}\sigma_{q\bar{q}}}{\mathrm{d}^2\mathbf{b}} = 2\mathcal{N}(x,r,b)$$

Vector Meson Production



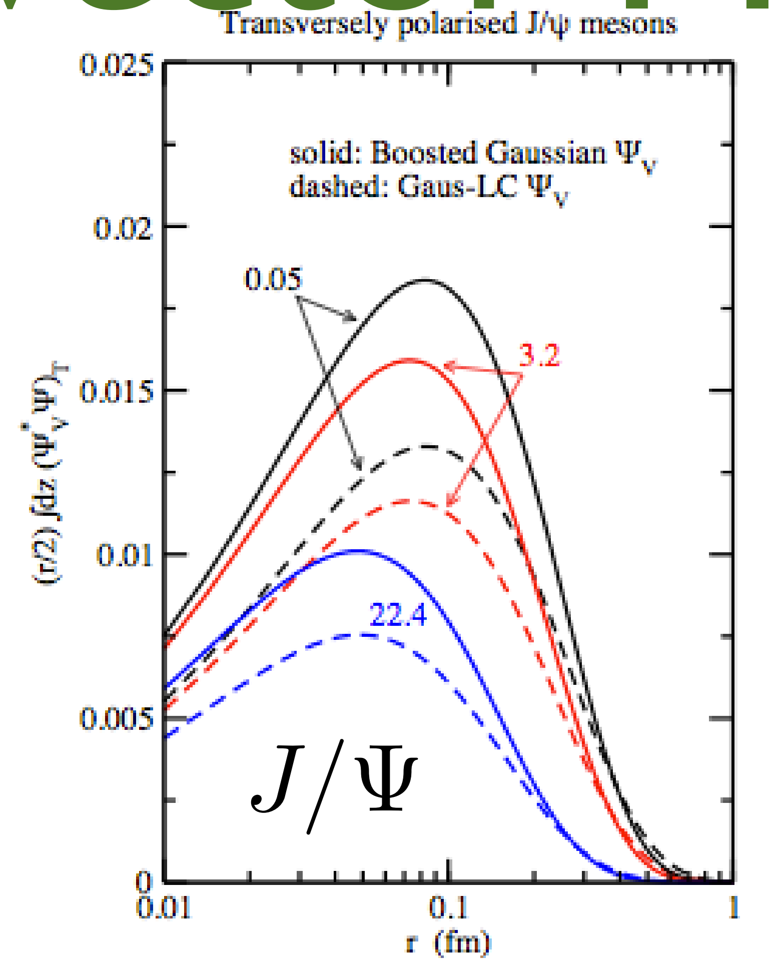
$$\Delta \equiv (p'^{\mu} - p^{\mu})_{\perp}$$

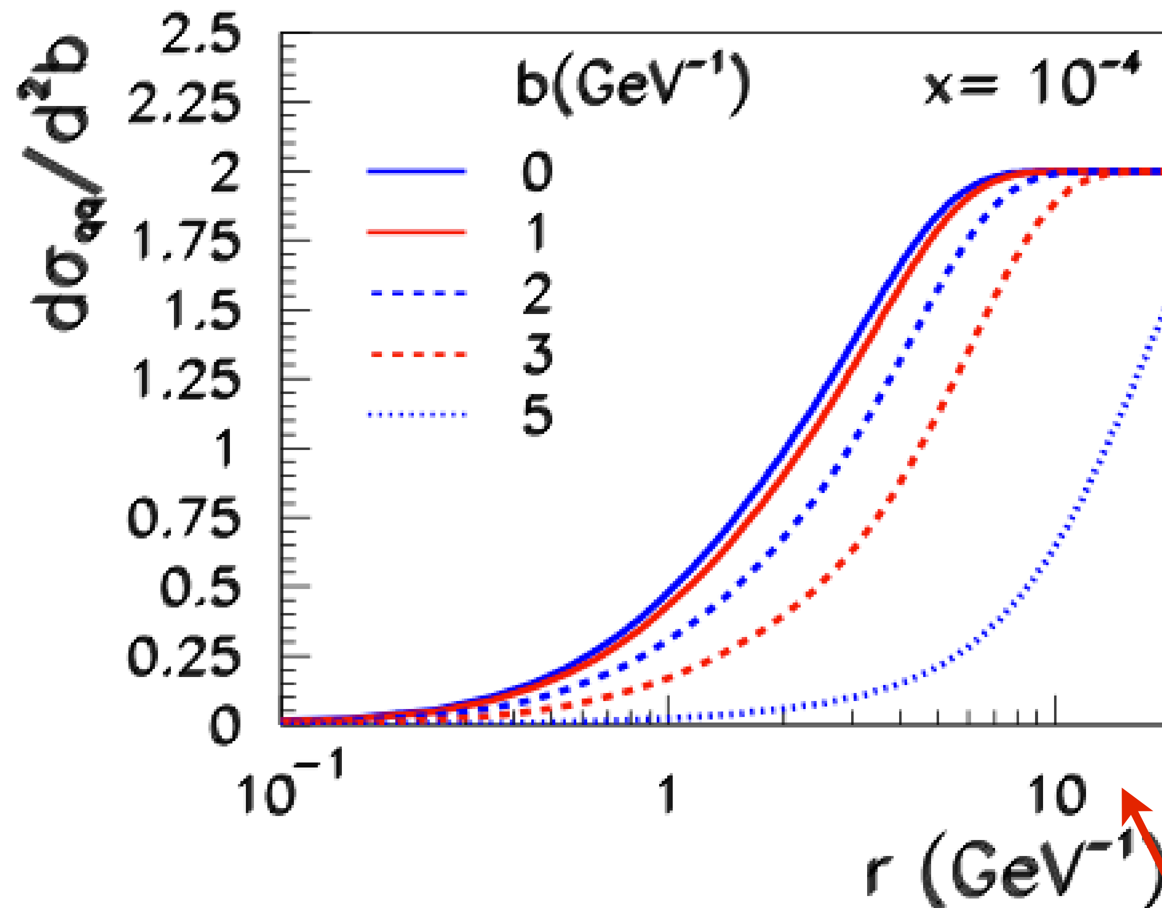
$$\mathcal{A}_{T,L}^{\gamma^* p \to V p}(x, Q, \Delta) = i \int \mathrm{d}^2\mathbf{r} \int_0^1 \frac{\mathrm{d}z}{4\pi} \int \mathrm{d}^2\mathbf{b} (\Psi_V^* \Psi)_{T,L} e^{-i([1-z]\mathbf{r}+\mathbf{b})\cdot\boldsymbol{\Delta}} \frac{\mathrm{d}\sigma_{q\bar{q}}}{\mathrm{d}^2\mathbf{b}}$$

"Known from QED"

Needs to be modeled

Vector Meson Production





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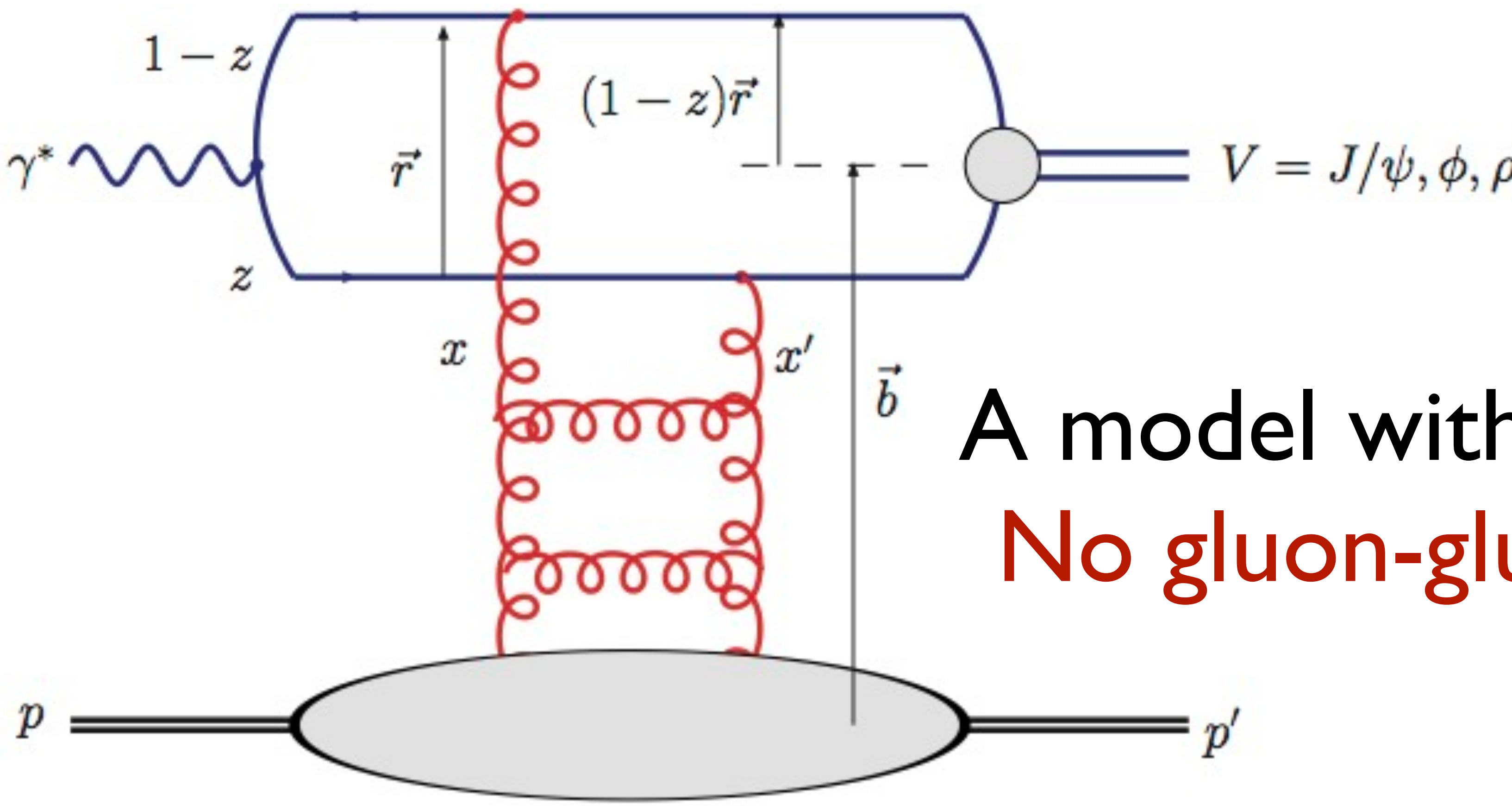
Needs to be modeled

The b-Sat Model

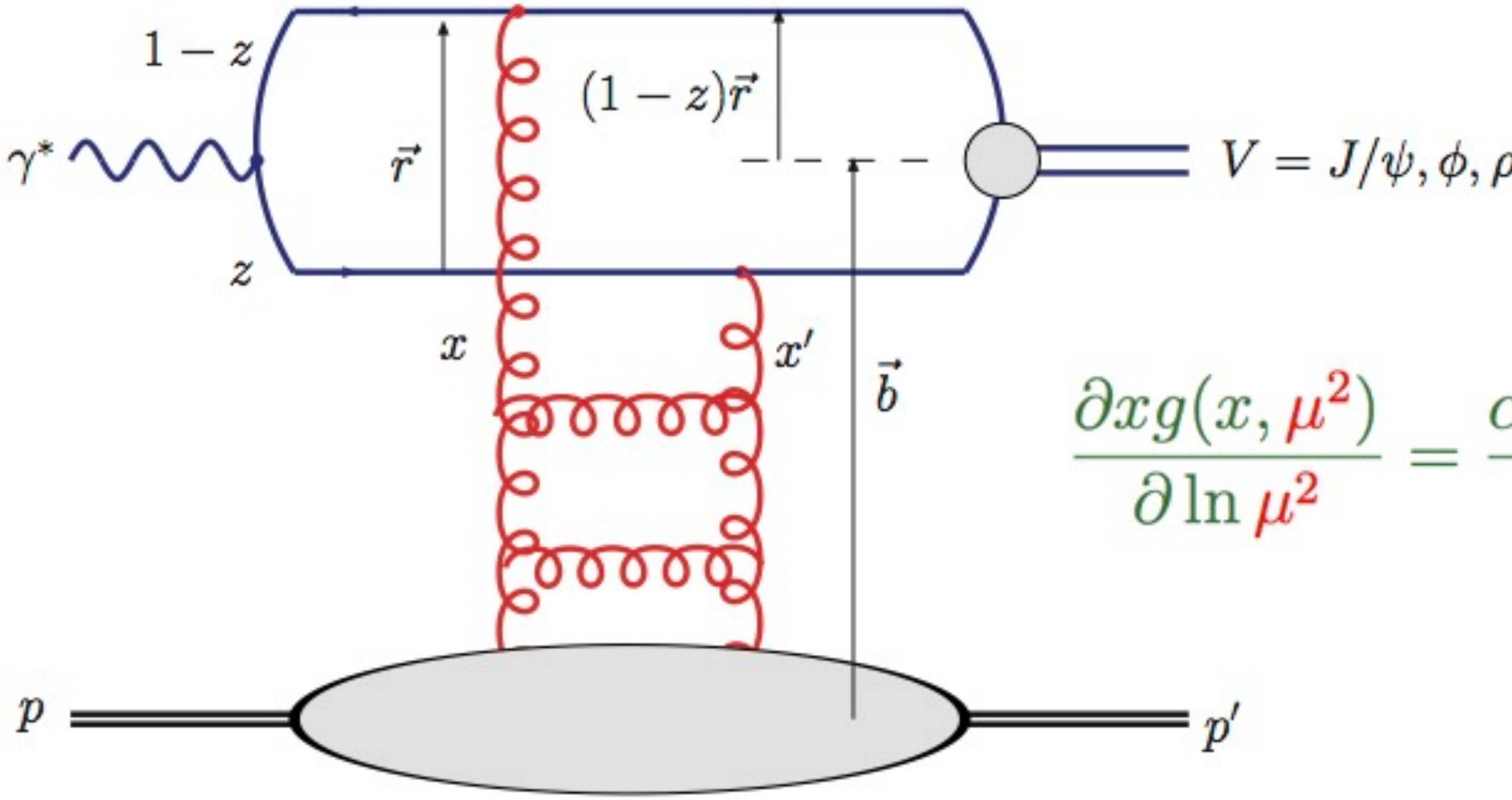


A model with multiple scatterings.

No gluon-gluon recombinations!

$$\frac{d\sigma_{q\bar{q}}}{d^2\mathbf{b}} = 2\left[1 - \exp\left(-\frac{\pi^2}{2N_c} r^2 \alpha_s(\mu^2) x g(x, \mu^2) T(b)\right)\right]$$

The b-Sat Model

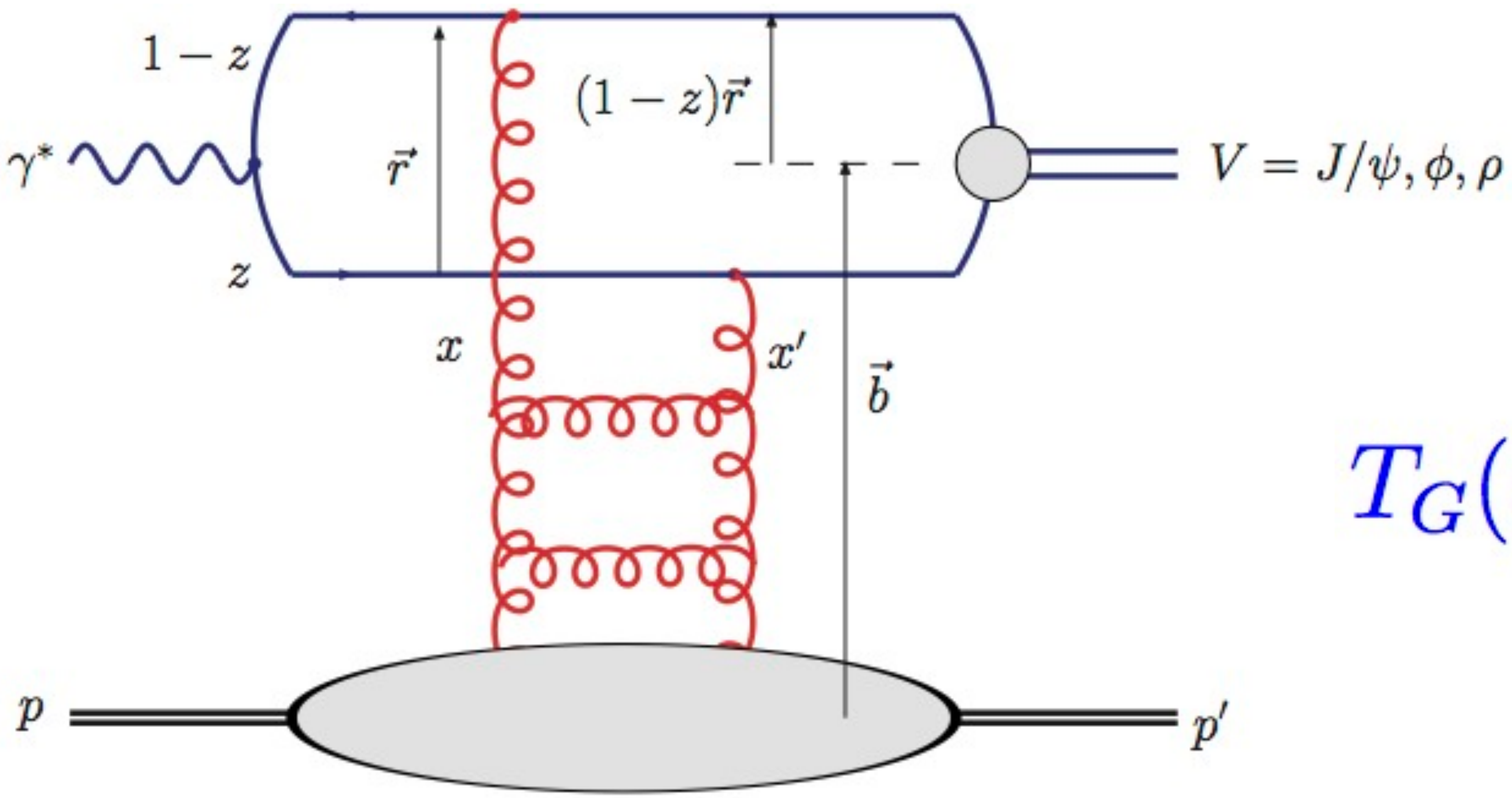


$$\frac{\partial xg(x,\mu^2)}{\partial \ln \mu^2} = \frac{\alpha_s(\mu^2)}{2\pi}\int_x^1 dz P_{gg}(z)\frac{x}{z}g\left(\frac{x}{z},\mu^2\right)$$

$$\frac{d\sigma_{q\bar{q}}}{d^2\mathbf{b}} = 2\left[1 - \exp\left(-\frac{\pi^2}{2N_c}r^2\alpha_s(\mu^2)xg(x,\mu^2)T(b)\right)\right]$$

$$\mu^2 = \frac{4}{r^2} + \mu_0^2$$

The b-Sat Model



$$T_G(b) = \frac{1}{2\pi B_G} e^{-\frac{b^2}{2B_G}}$$

$$\frac{\mathrm{d}\sigma_{q\bar{q}}}{\mathrm{d}^2\mathbf{b}} = 2\left[1 - \exp\left(-\frac{\pi^2}{2N_c} r^2 \alpha_s(\mu^2) xg(x,\mu^2) T(b)\right)\right]$$

Corrections to the cross-section

One can take the real part of the amplitude into account by multiplying the cross-sec. by a factor $(1+\beta^2)$

$$\beta = \tan\left(\lambda\frac{\pi}{2}\right) \qquad \lambda \equiv \frac{\partial \ln\left(\mathcal{A}_{T,L}^{\gamma^* p\to Ep}\right)}{\partial \ln(1/x)}$$

The two gluons carry different momentum fractions

This is the Skewedness effect

In leading ln(1/x) this effect disappears

It can be accounted for by a factor R_g

$$R_g(\lambda) = \frac{2^{2\lambda+3}}{\sqrt{\pi}}\frac{\Gamma(\lambda+5/2)}{\Gamma(\lambda+4)}$$

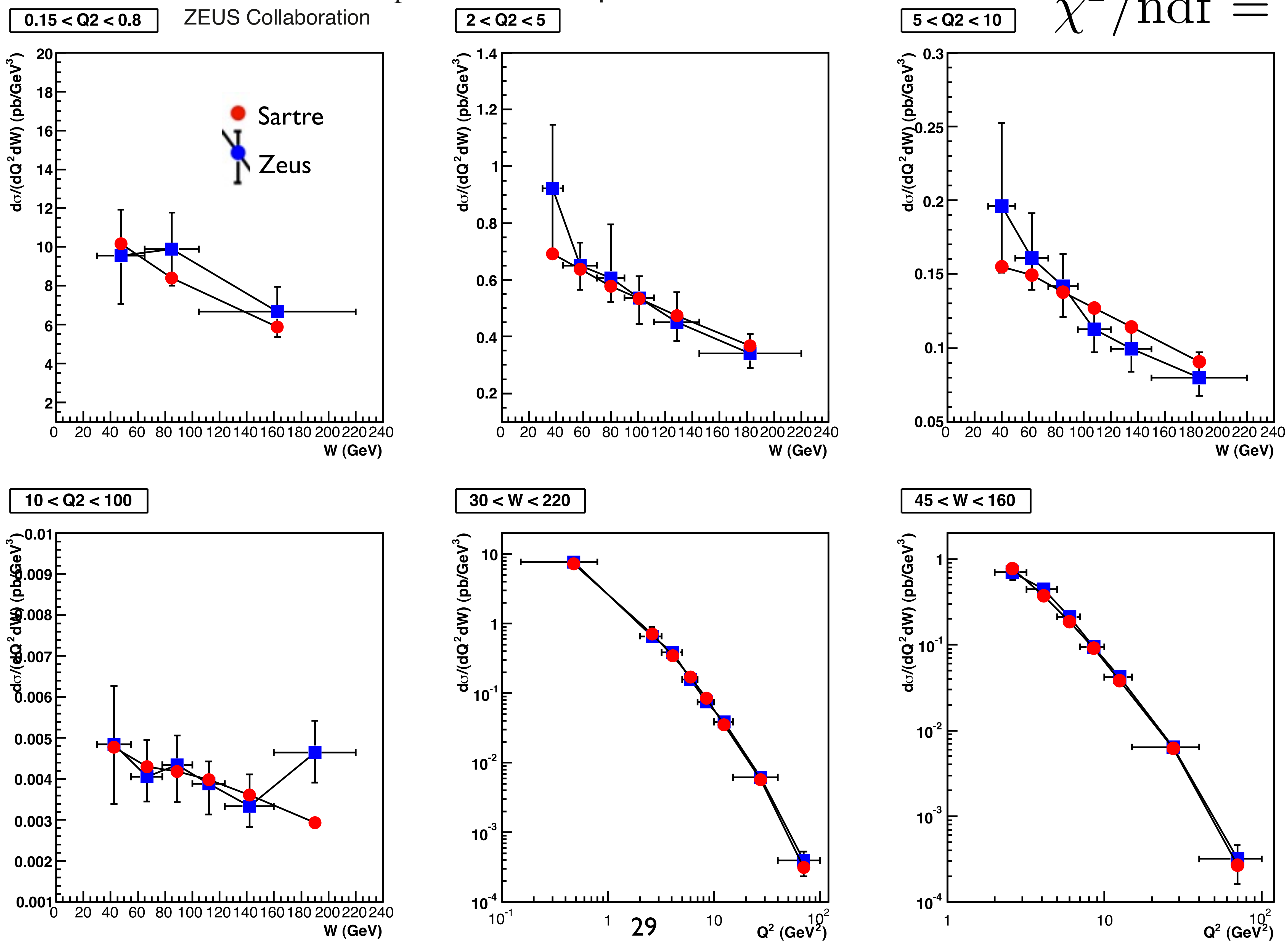
These goes bad for large $x \sim 10^{-2}$!

Implemented with exponential damping to control this.

Some *ep* results using tables

Exclusive electroproduction of J/ψ mesons at HERA
ZEUS Collaboration

$$\chi^2/\mathrm{ndf} = 0.51$$



Going from $e\rlap{/}p$ to eA

(the new stuff)

Going from *ep* to eA

ep:

$$\mathrm{Re}(S) = 1 - \mathcal{N}^{(p)}(x, r, \mathbf{b}) = 1 - \frac{1}{2}\frac{\mathrm{d}\sigma_{q\bar{q}}^{(p)}(x, r, \mathbf{b})}{\mathrm{d}^2\mathbf{b}}$$

eA: Independent scattering approximation

$$1 - \mathcal{N}^{(A)} = \prod_{i=1}^{A}\left(1 - \mathcal{N}^{(p)}(x, r, |\mathbf{b} - \mathbf{b}_i|)\right)$$

Assume the Woods-Saxon distribution

bSat:

$$\frac{\mathrm{d}\sigma_{q\bar{q}}^{A}}{\mathrm{d}^2\mathbf{b}} = 2\left[1 - \exp\left(-\frac{\pi^2}{2N_c} r^2 \alpha_s(\mu^2) x g(x, \mu^2) \sum_{i=1}^{A} T_p(\mathbf{b} - \mathbf{b}_i)\right)\right]$$

Going from *ep* to eA

Another difference in eA:
The Nucleus can break up
into colour neutral fragments!

When the nucleus breaks up, the scattering is called
incoherent

When the nucleus stays intact, the scattering is called
coherent

Total cross-section = incoherent + coherent

Incoherent Scattering

Nucleus dissociates ($f \neq i$):

Good, Walker

$$\sigma_{\text{incoherent}} \propto \sum_{f \neq i} \langle i|\mathcal{A}|f\rangle^{\dagger} \langle f|\mathcal{A}|i\rangle$$

complete set

$$= \sum_{f} \langle i|\mathcal{A}\overbrace{|f\rangle^{\dagger} \langle f|}\mathcal{A}|i\rangle - \langle i|\mathcal{A}|i\rangle^{\dagger} \langle i|\mathcal{A}|i\rangle$$

$$= \langle i \left| |\mathcal{A}|^2 \right| i\rangle - |\langle i|\mathcal{A}|i\rangle|^2 = \left\langle |\mathcal{A}|^2 \right\rangle - |\langle \mathcal{A}\rangle|^2$$

The incoherent CS is the variance of the amplitude!!

$$\frac{d\sigma_{\text{total}}}{dt} = \frac{1}{16\pi} \left\langle |\mathcal{A}|^2 \right\rangle$$

$$\frac{d\sigma_{\text{coherent}}}{dt} = \frac{1}{16\pi} |\langle \mathcal{A}\rangle|^2$$

Defining the average

$$\frac{\mathrm{d}\sigma_{\mathrm{total}}}{\mathrm{d}t} = \frac{1}{16\pi}\left\langle |\mathcal{A}|^2 \right\rangle_\Omega \qquad \frac{\mathrm{d}\sigma_{\mathrm{coherent}}}{\mathrm{d}t} = \frac{1}{16\pi}\left|\langle \mathcal{A}\rangle_\Omega\right|^2$$

Define average: $$\langle \mathcal{O}\rangle_\Omega \approx \frac{1}{C_{\mathrm{max}}}\sum_{j=1}^{C_{\mathrm{max}}} \mathcal{O}(\Omega_j)$$

$$\mathcal{A}(\Omega_j) = \int \mathrm{d}r \frac{\mathrm{d}z}{4\pi} \mathrm{d}^2\mathbf{b} (\Psi_V^*\Psi)(r,z) 2\pi r b J_0([1-z]r\Delta) e^{-i\mathbf{b}\cdot\boldsymbol{\Delta}} \frac{\mathrm{d}\sigma_{q\bar{q}}}{\mathrm{d}^2\mathbf{b}}(x,r,\mathbf{b},\Omega_j)$$

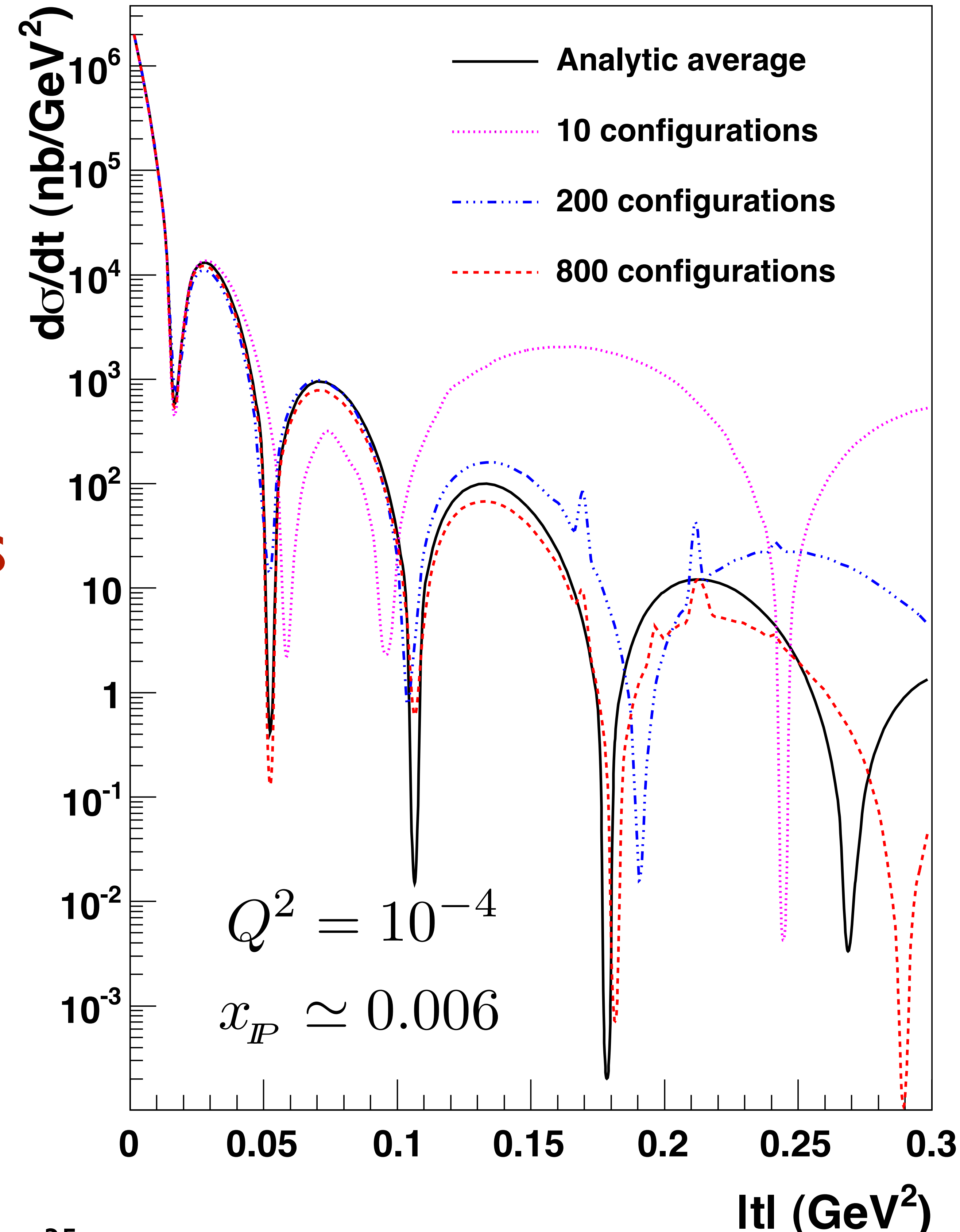
4 four-dimensional integrations for each phase-space point and configuration

Re, Im, L, T

How many configurations???

Convergence of sum:

Need ~1000 configurations to describe 5th minimum!!



Convergence of sum:

Problem with convergence of distribution at large |t|:

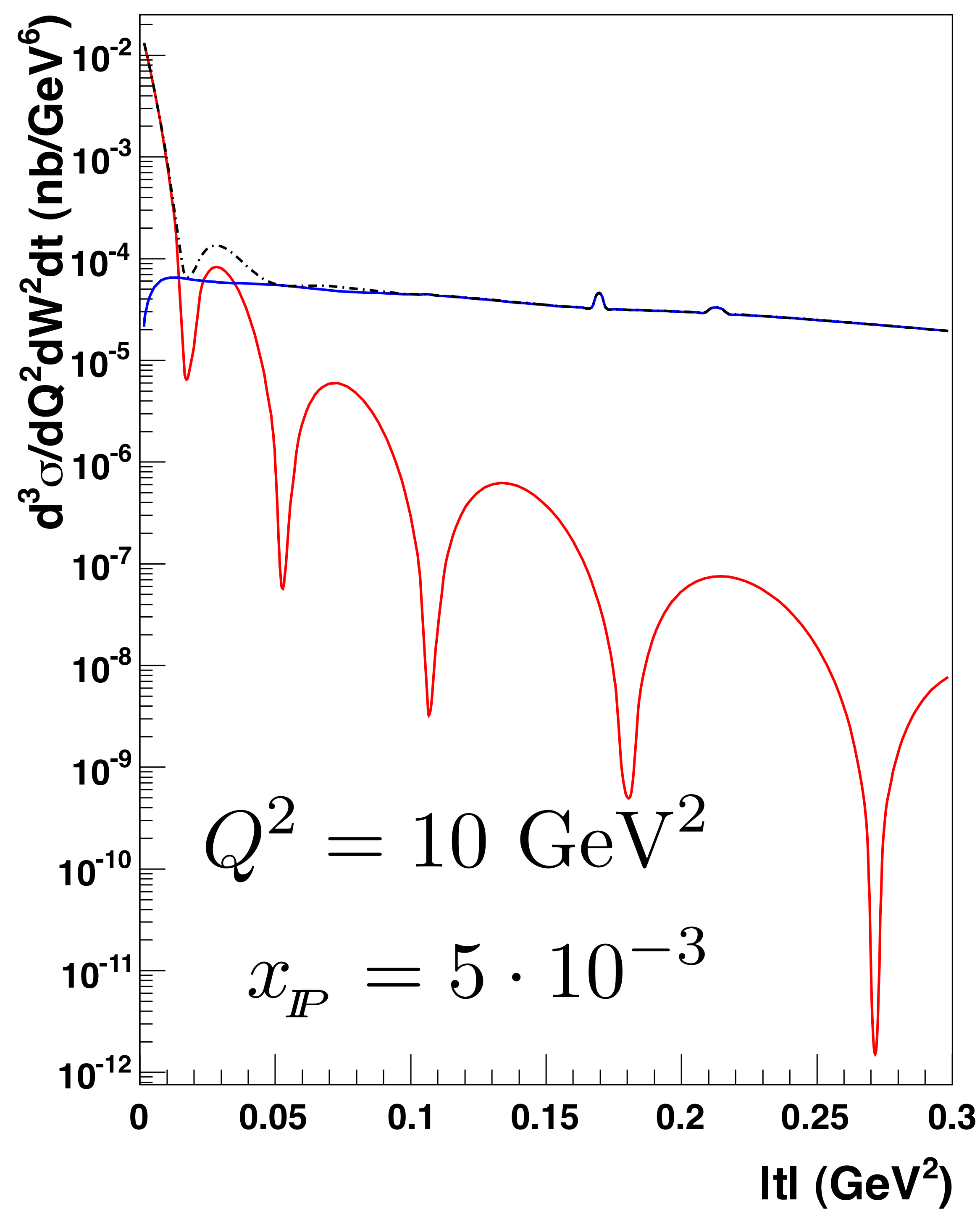
Average (coherent)

<<<<<

Variance (incoherent)

Or: At large |t| the nucleus is probed at a smaller scale.

$\Delta = \sqrt{-t}$ is the Fourier conjugate of *b*.



Convergence of sum:

Problem with convergence of distribution at large |t|:

Average (coherent)

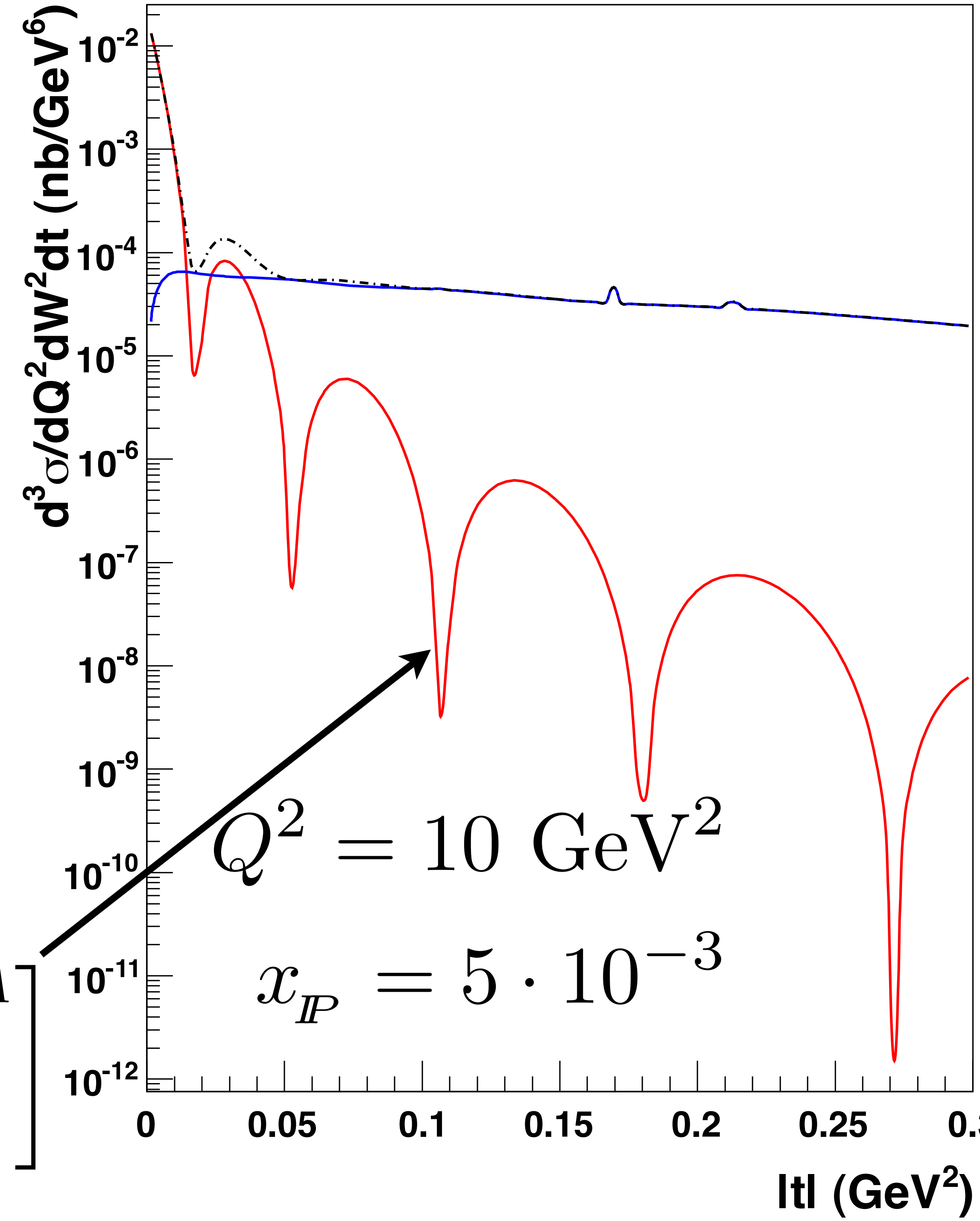
<<<<<

Variance (incoherent)

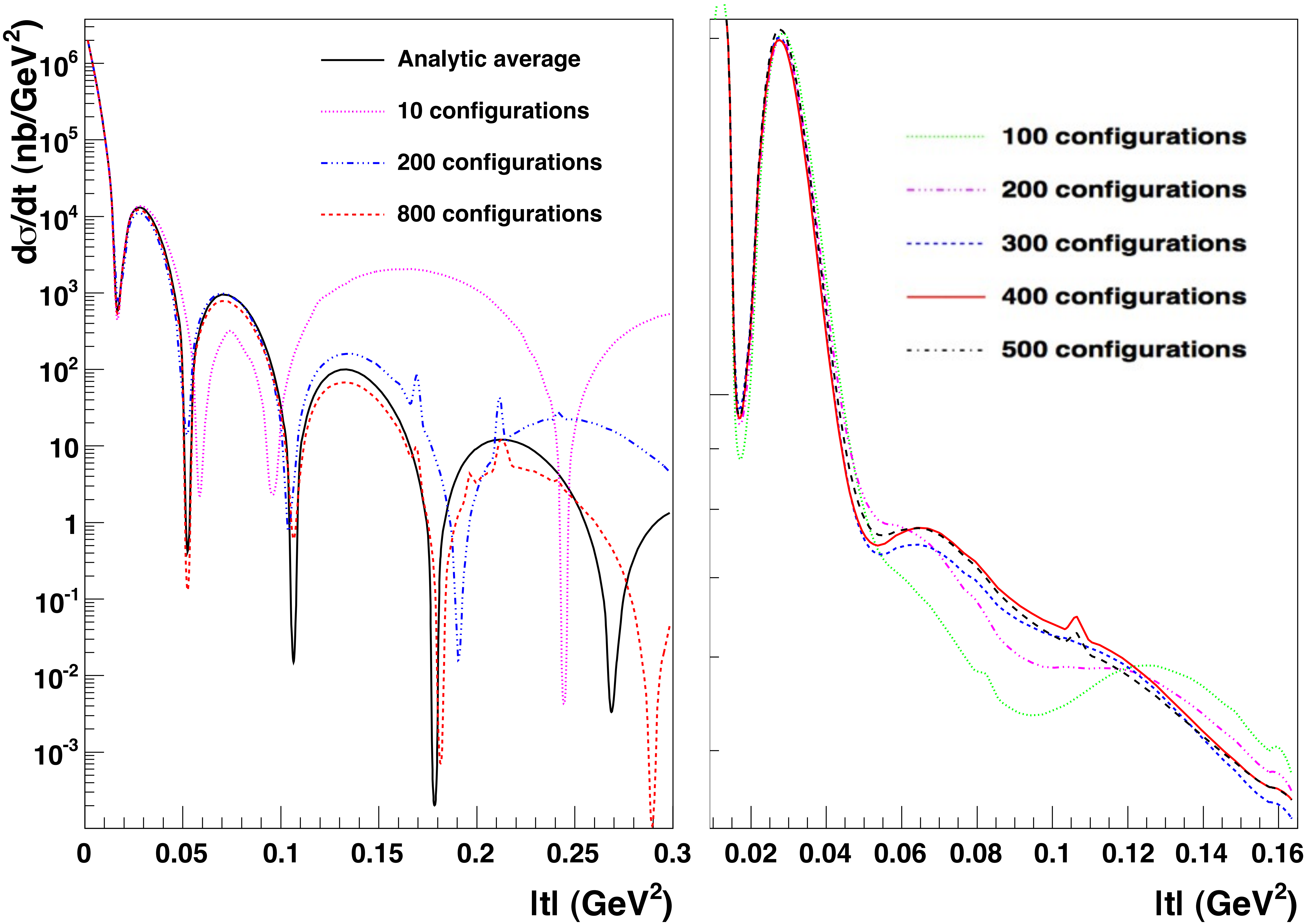
Solution

Calculate the average from:

$$\left\langle \frac{d\sigma_{q\bar{q}}}{d^2\mathbf{b}} \right\rangle_\Omega = 2\left[1 - \left(1 - \frac{T_A(\mathbf{b})}{2}\sigma_{q\bar{q}}^{(p)}\right)^A\right]$$



[An Impact parameter dipole saturation model](#) - [Kowalski, Henri & Derek Teaney](#) Phys.Rev. D68 (2003) 114005 . hep-ph/0304189



dσ/dt (nb/GeV²)
Analytic average
10 configurations
200 configurations
800 configurations
100 configurations
200 configurations
300 configurations
400 configurations
500 configurations
|t| (GeV²)
|t| (GeV²)

bNonSat

Linearize the dipole cross-section, use the first term in the expansion

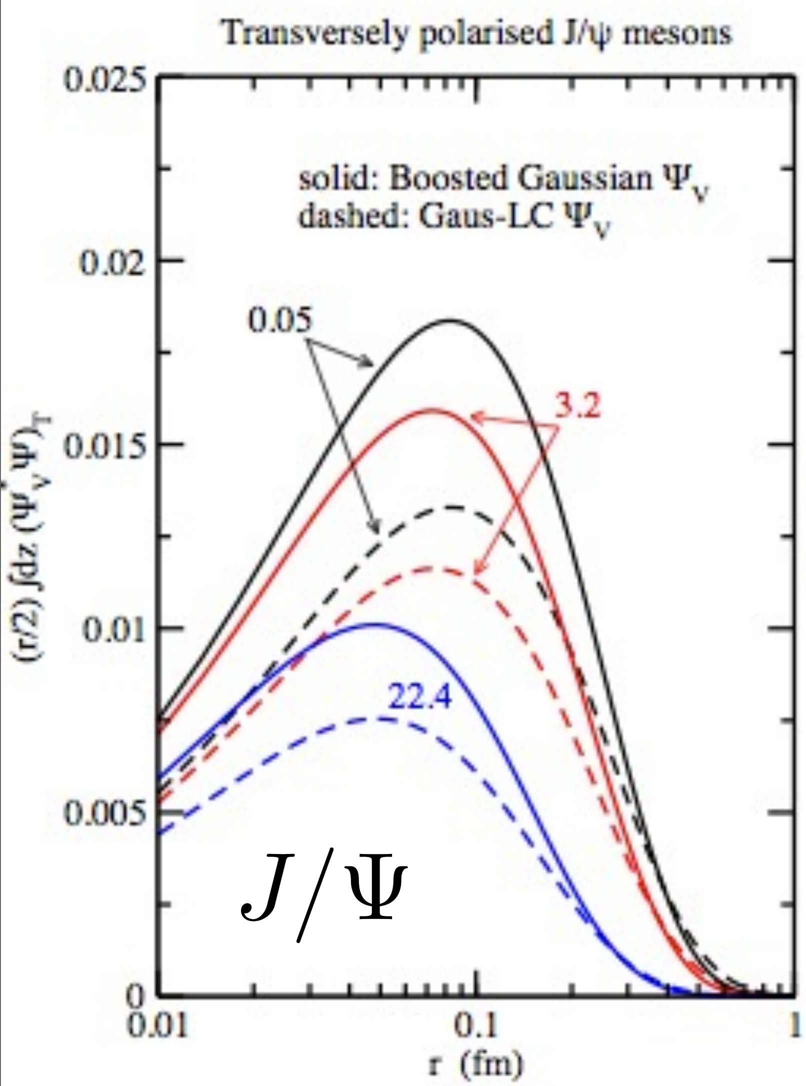
$$\frac{\mathrm{d}\sigma_{q\bar{q}}^{(p)}}{\mathrm{d}^2 b} = \frac{\pi^2}{N_C} r^2 \alpha_s(\mu^2) x g(x, \mu^2) T(b)$$

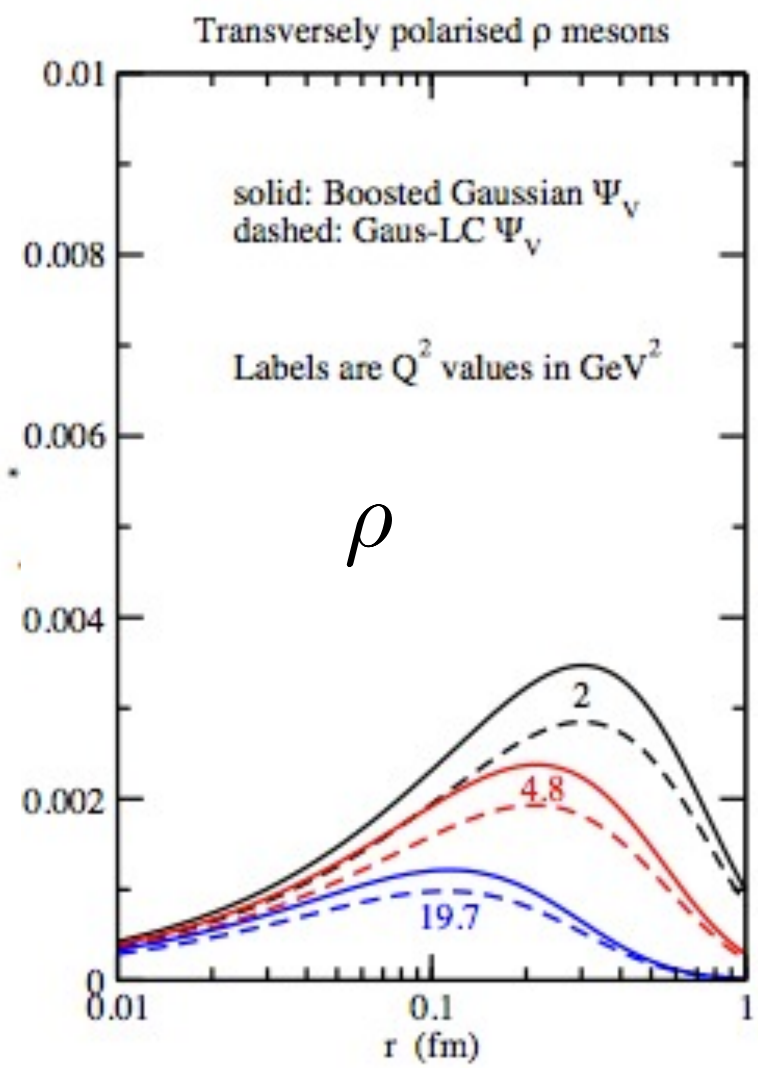
$$\frac{\mathrm{d}\sigma_{q\bar{q}}^{(A)}}{\mathrm{d}^2 b} = \frac{\pi^2}{N_C} r^2 \alpha_s(\mu^2) x g(x, \mu^2) \sum_{i=1}^{A} T(|\mathbf{b} - \mathbf{b}_i|)$$

$$\left\langle \frac{\mathrm{d}\sigma_{q\bar{q}}^{(A)}}{\mathrm{d}^2 b} \right\rangle_{\Omega} = \frac{\pi^2}{N_C} r^2 \alpha_s(\mu^2) x g(x, \mu^2) A T_A(b)$$

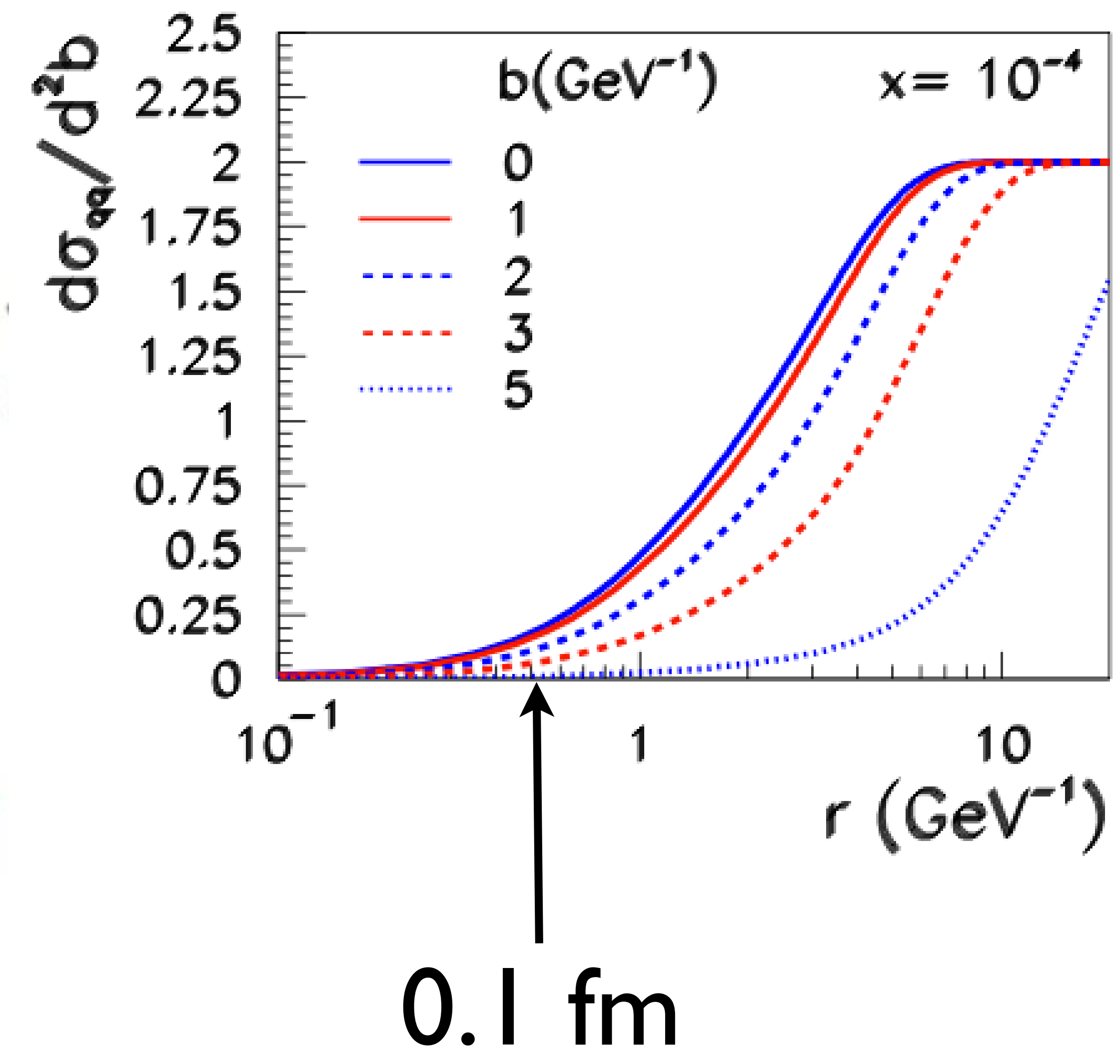
bNonSat

Vector meson wave overlaps





Dipole cross-section



Generating events

How Sartre works

4 four-dimensional integrations for each phase-space point **and** configuration

~1600 4D integrals/point

Use 3D lookup tables in Q^2, W^2, t independent of s and use the Open Science Grid to produce the tables.

Four tables to create a cross-section point:

$$\langle\, |\mathcal{A}_T|^2 \,\rangle, |\langle \mathcal{A}_T \rangle|\,, \langle\, |\mathcal{A}_L|^2 \,\rangle, |\langle \mathcal{A}_L \rangle|$$

$$\frac{\mathrm{d}^3\sigma}{\mathrm{d}Q^2\mathrm{d}W^2\mathrm{d}t} = f_T^\gamma \langle\, |A_T|^2 \,\rangle + f_L^\gamma \langle\, |A_L|^2 \,\rangle$$

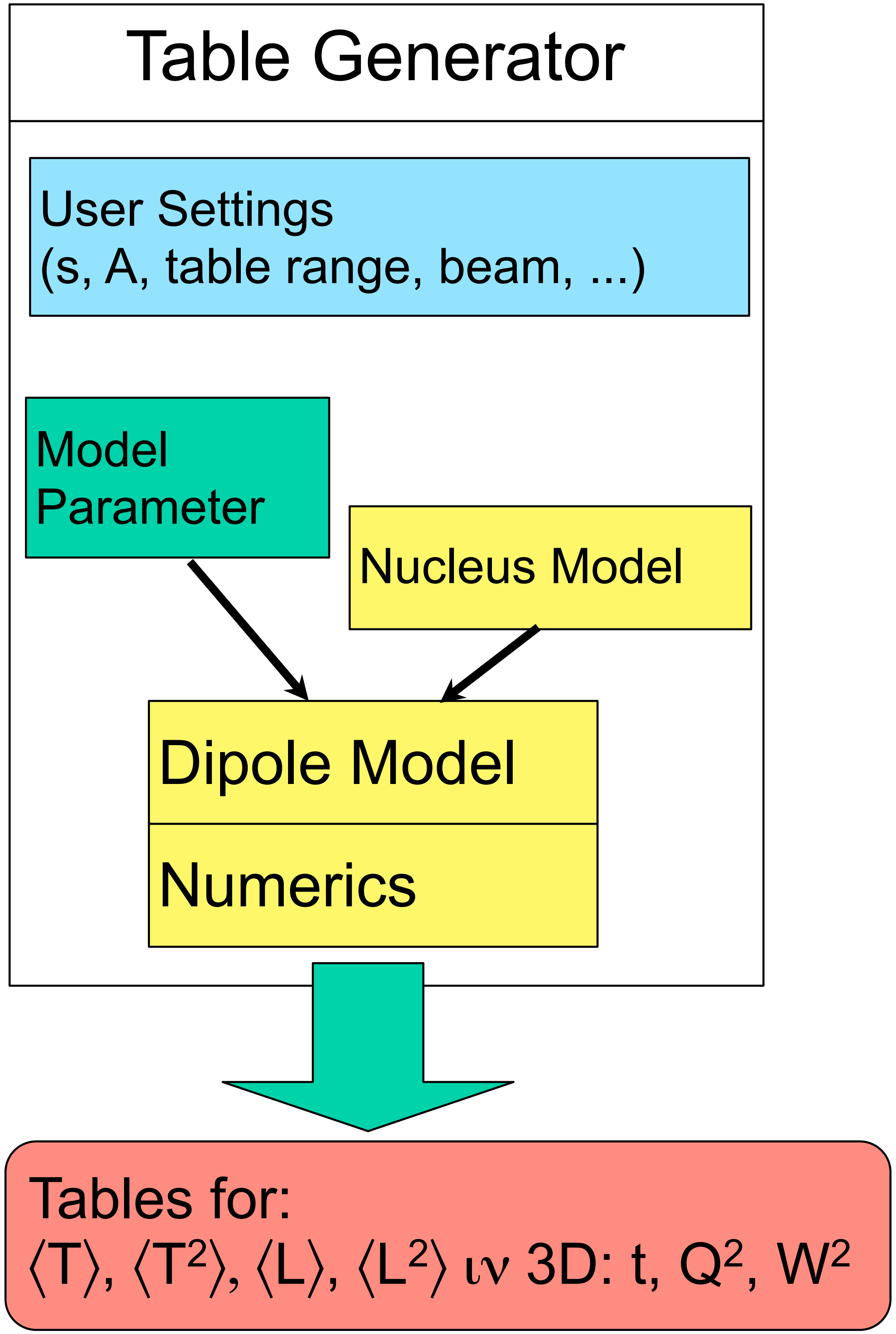
Transverse if:

$$\frac{f_T^\gamma \langle\, |\mathcal{A}_T| \,\rangle}{f_T^\gamma \langle\, |\mathcal{A}_T| \,\rangle + f_L^\gamma \langle\, |\mathcal{A}_L| \,\rangle} > R$$

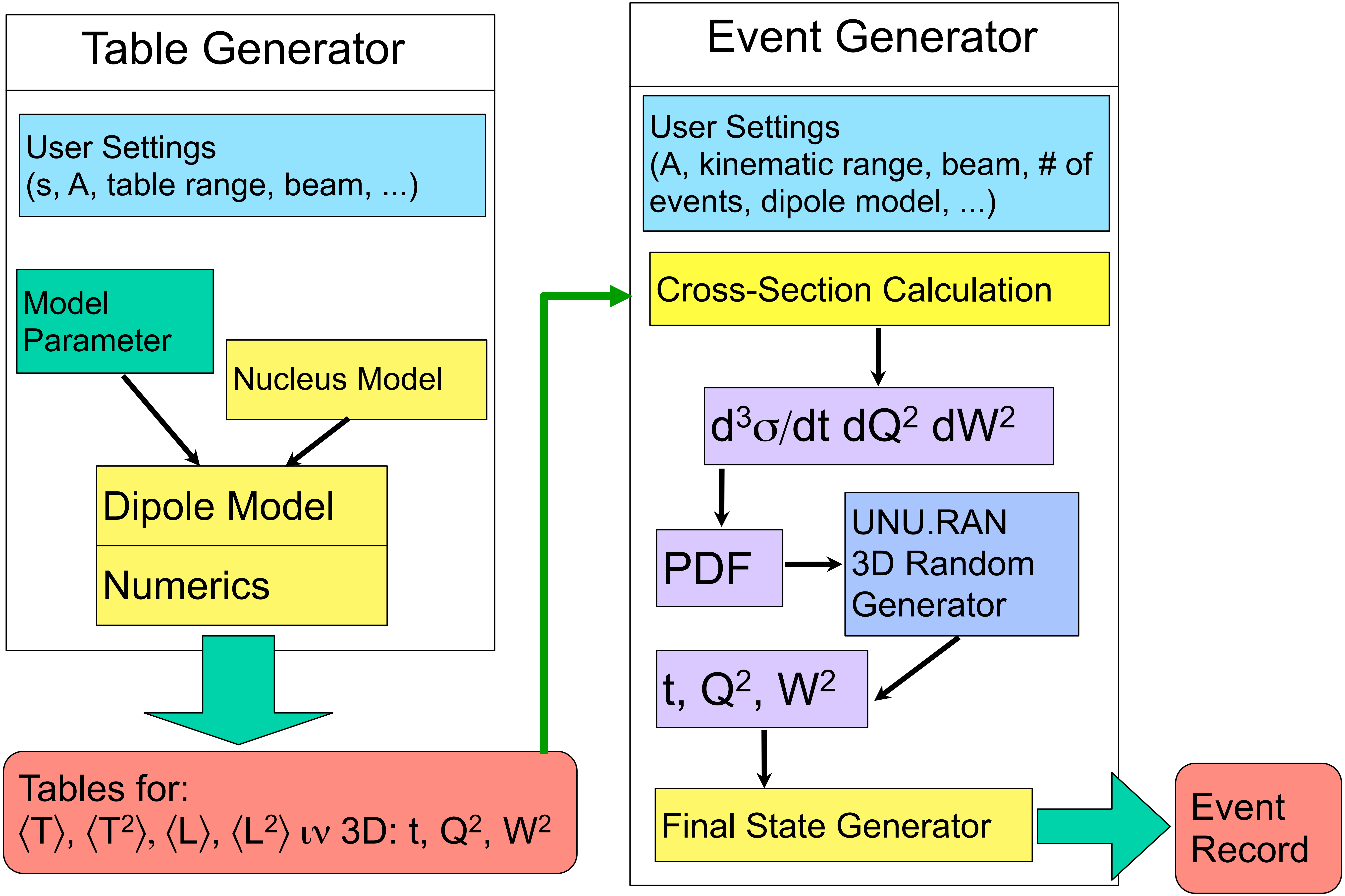
Breakup if:

$$\frac{|\langle A_T \rangle|^2 - \langle\, |A_T|^2 \,\rangle}{|\langle A_T \rangle|^2} > R$$

How Sartre works

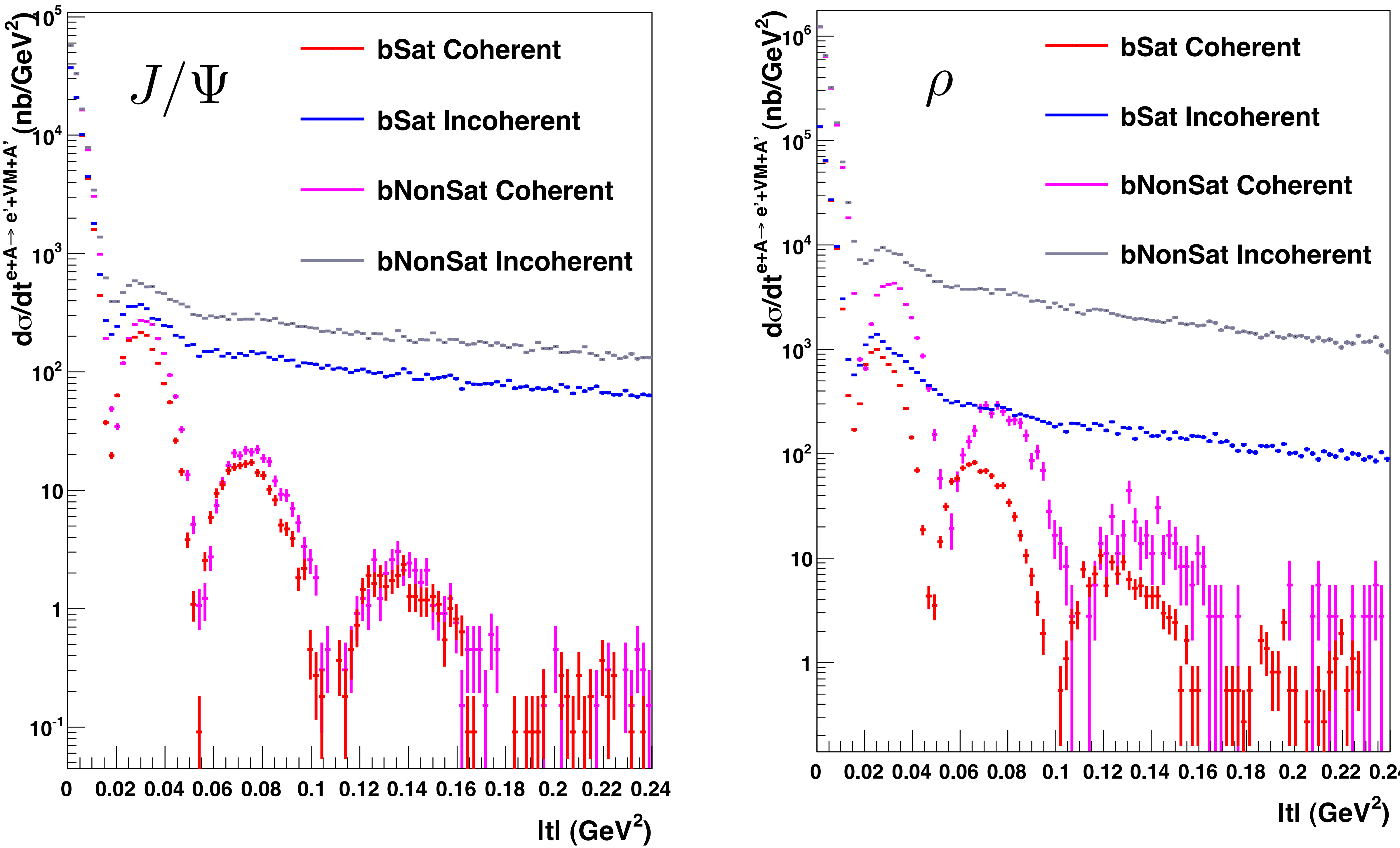


How Sartre works

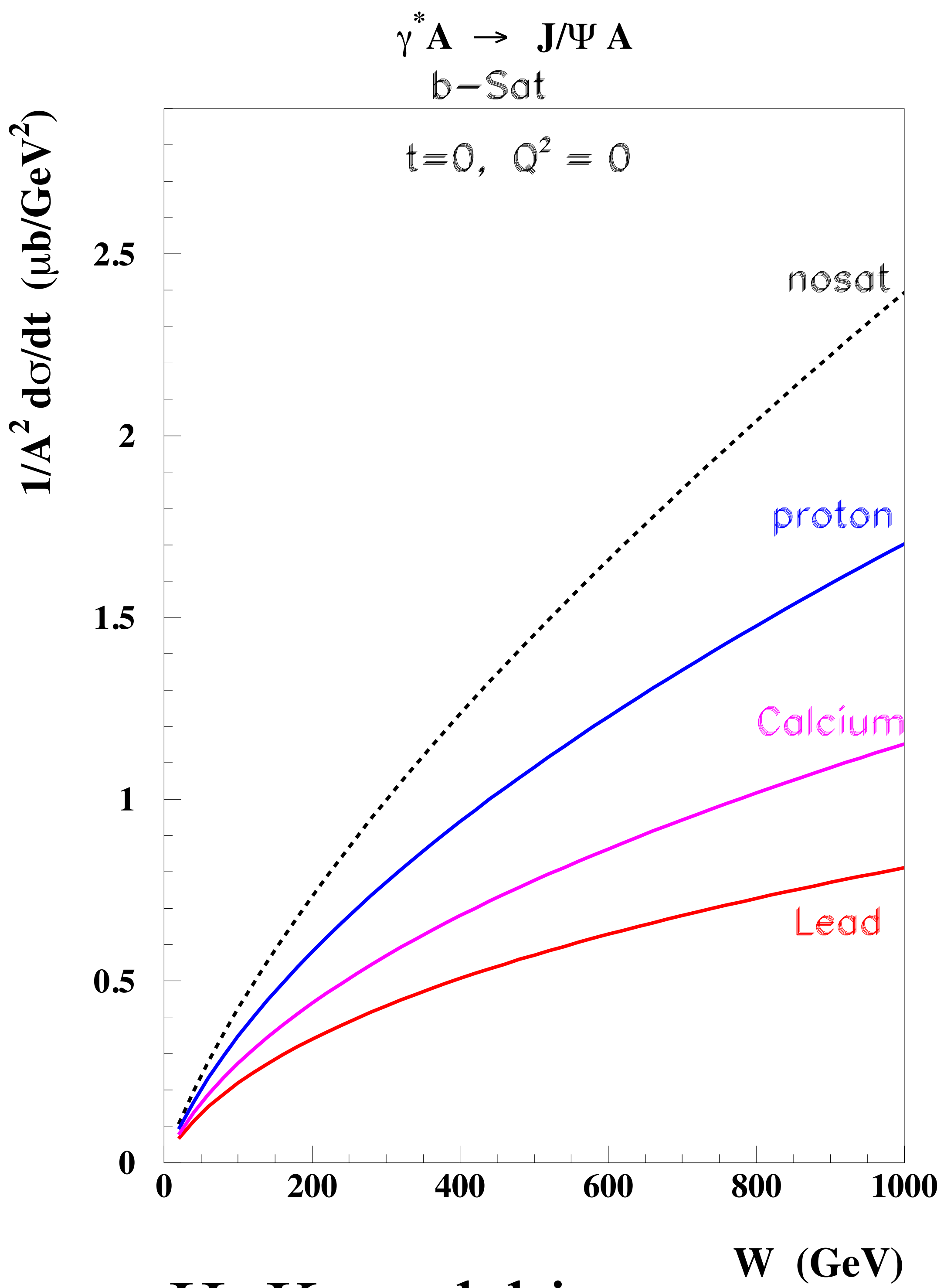


Some eA generated results

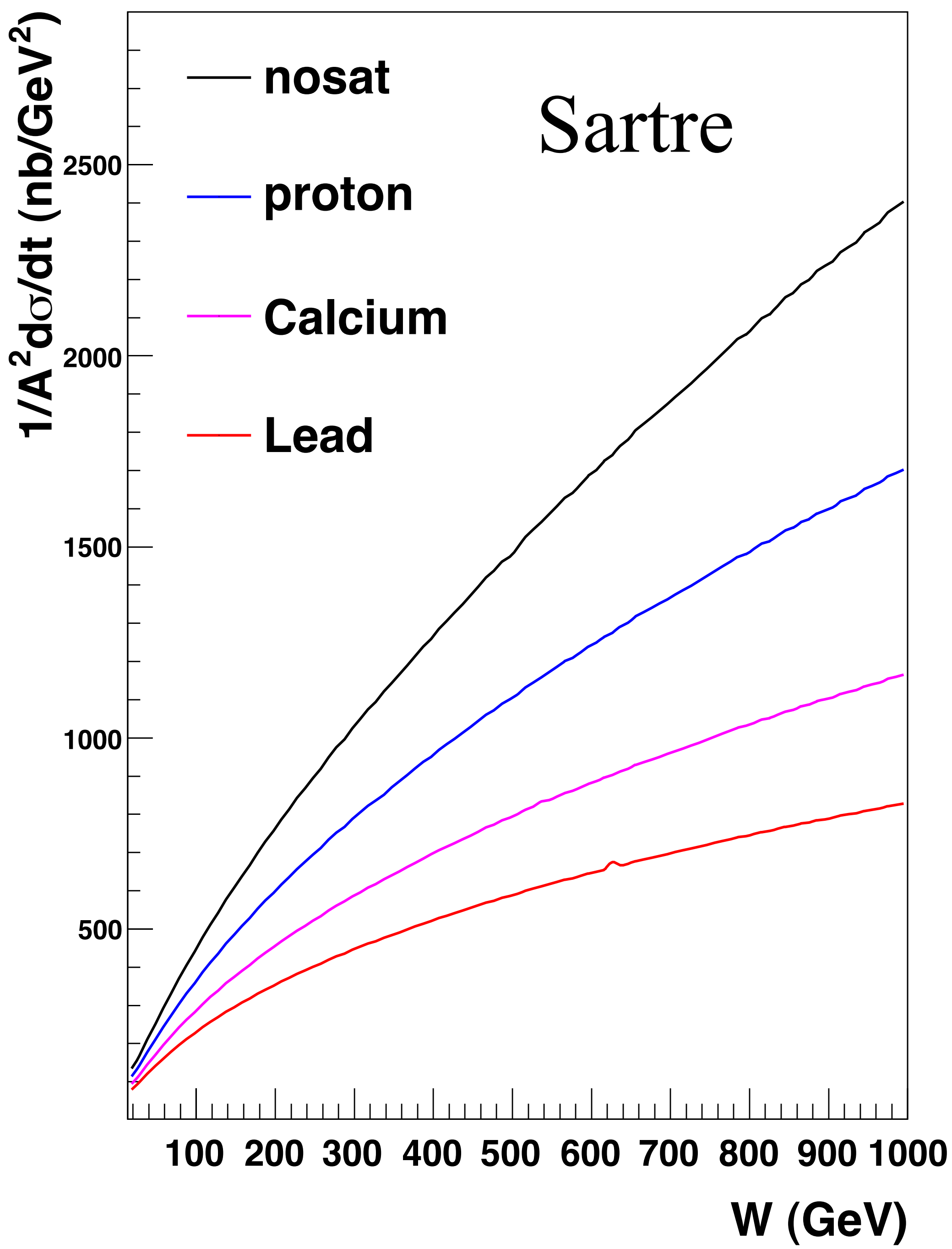
1M events, 5 GeV x 100 GeV



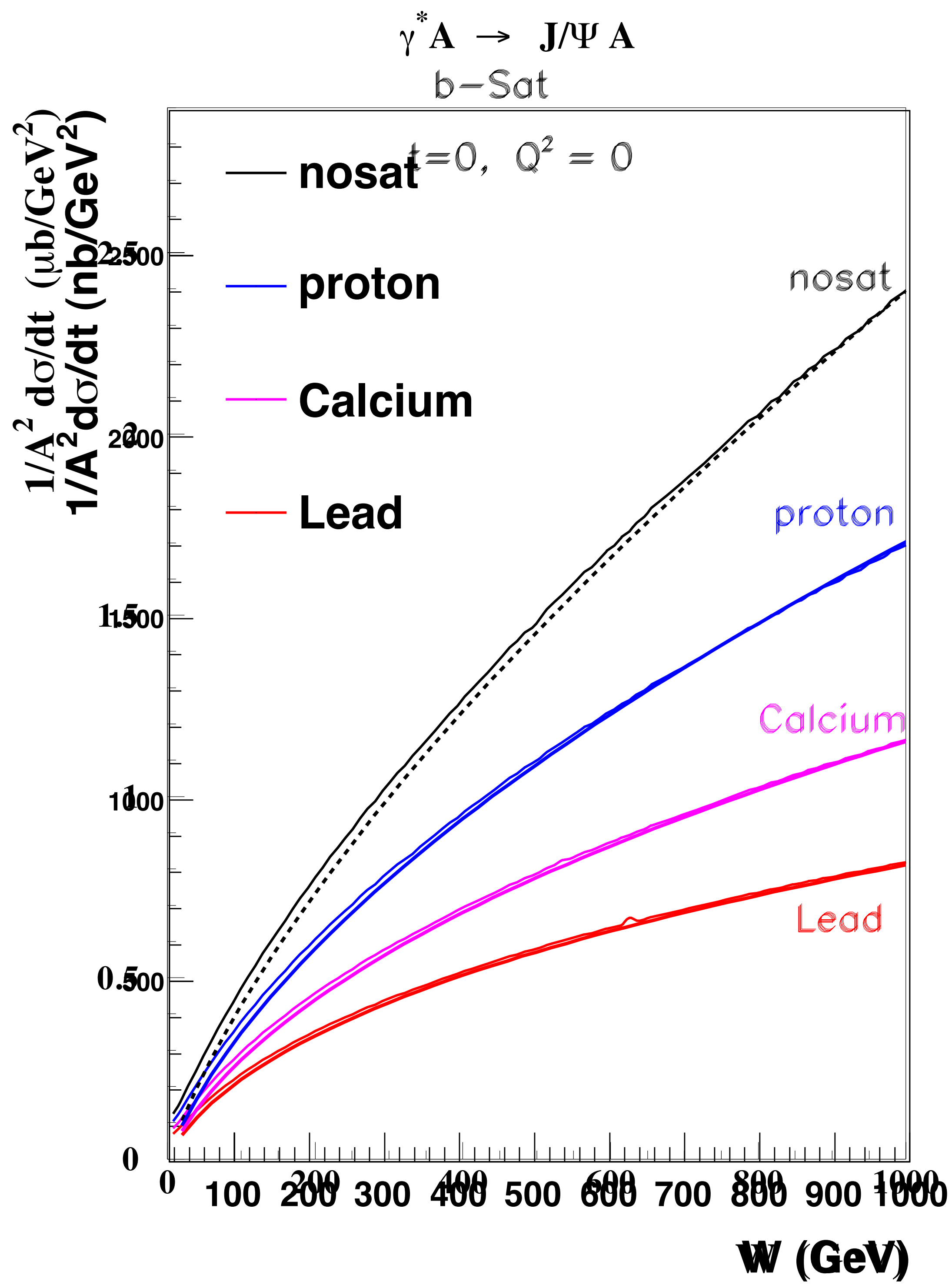
LHeC modelling



H. Kowalski

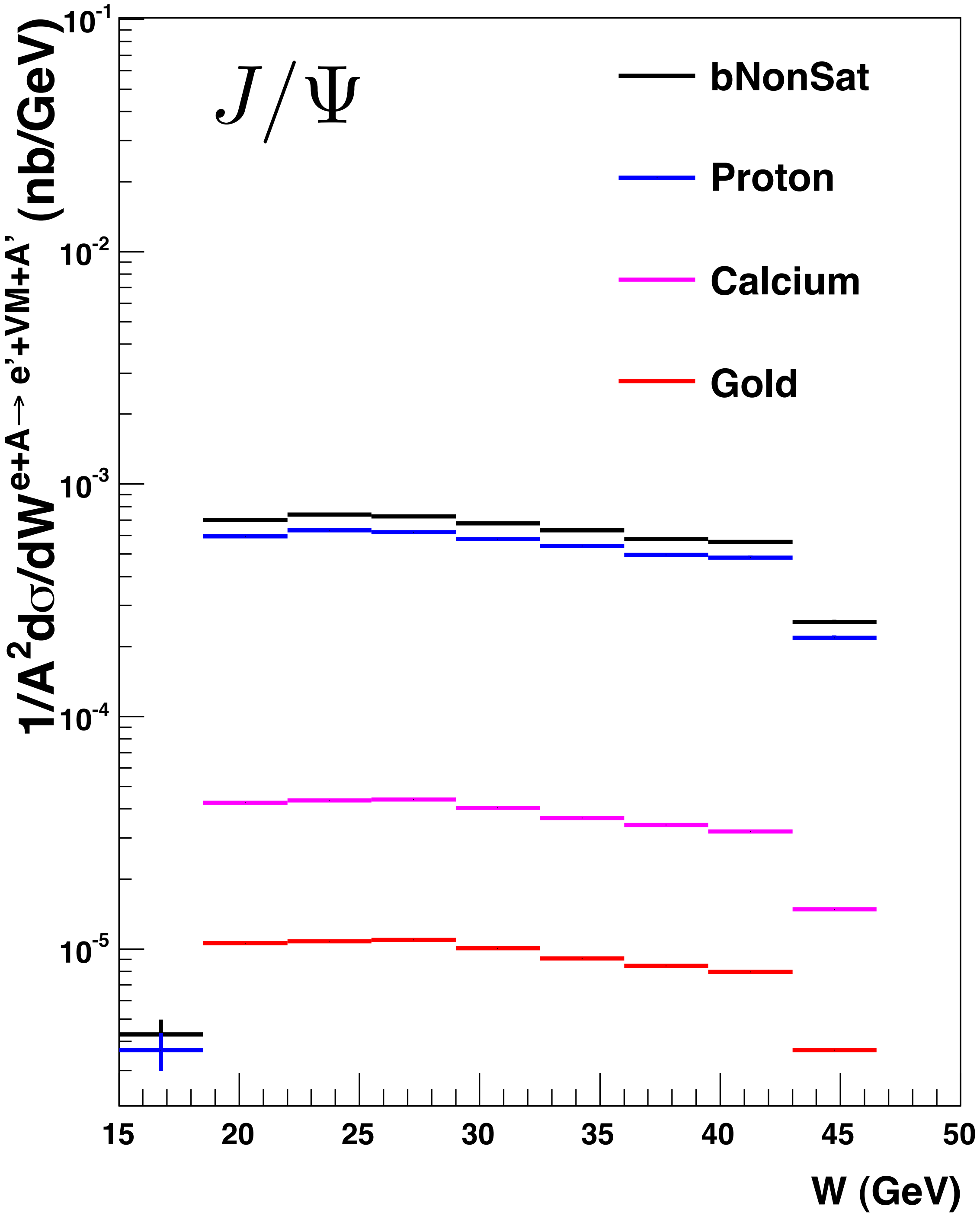


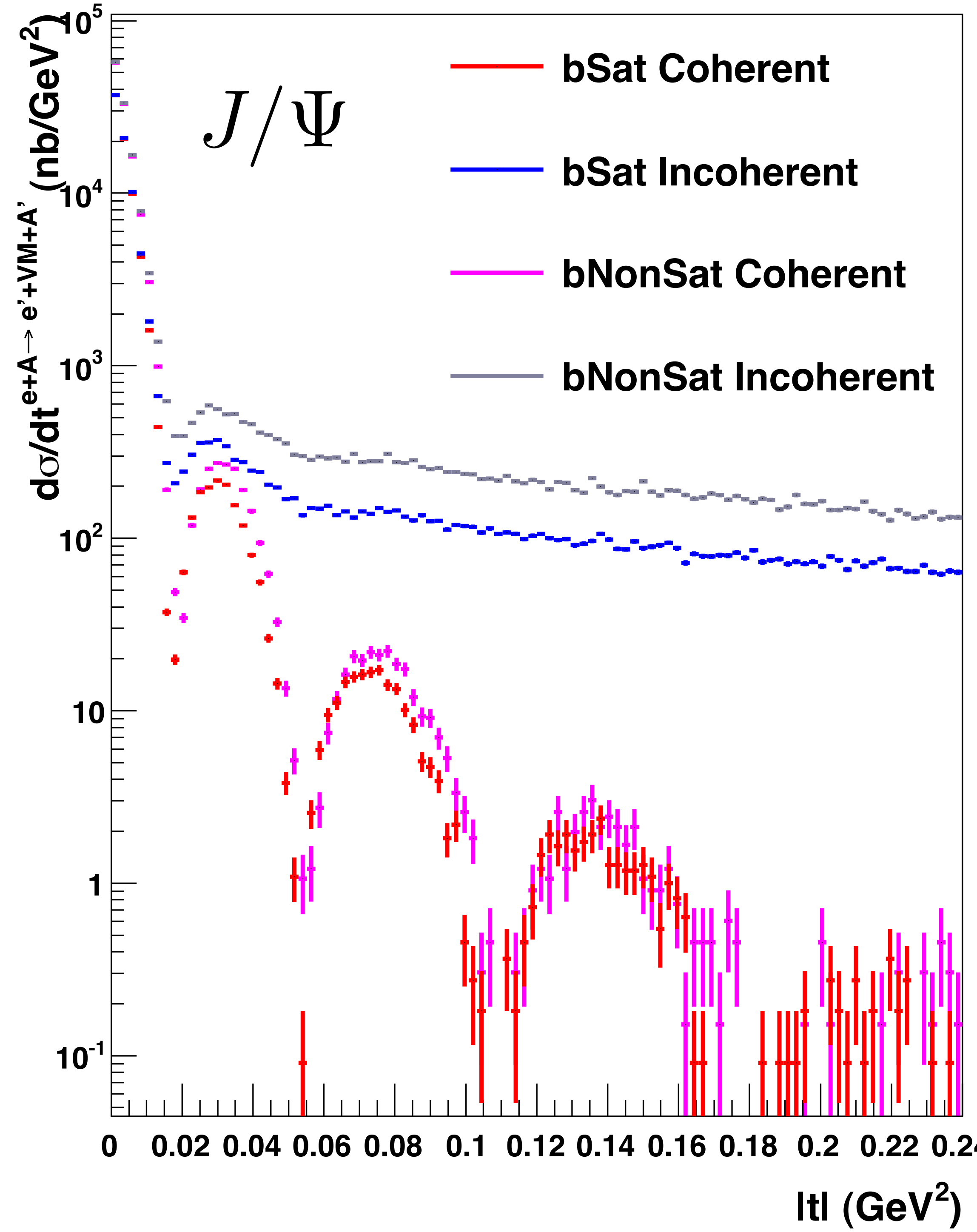
LHeC modelling



Some eA generated results

1M events, 5 GeV x 100 GeV

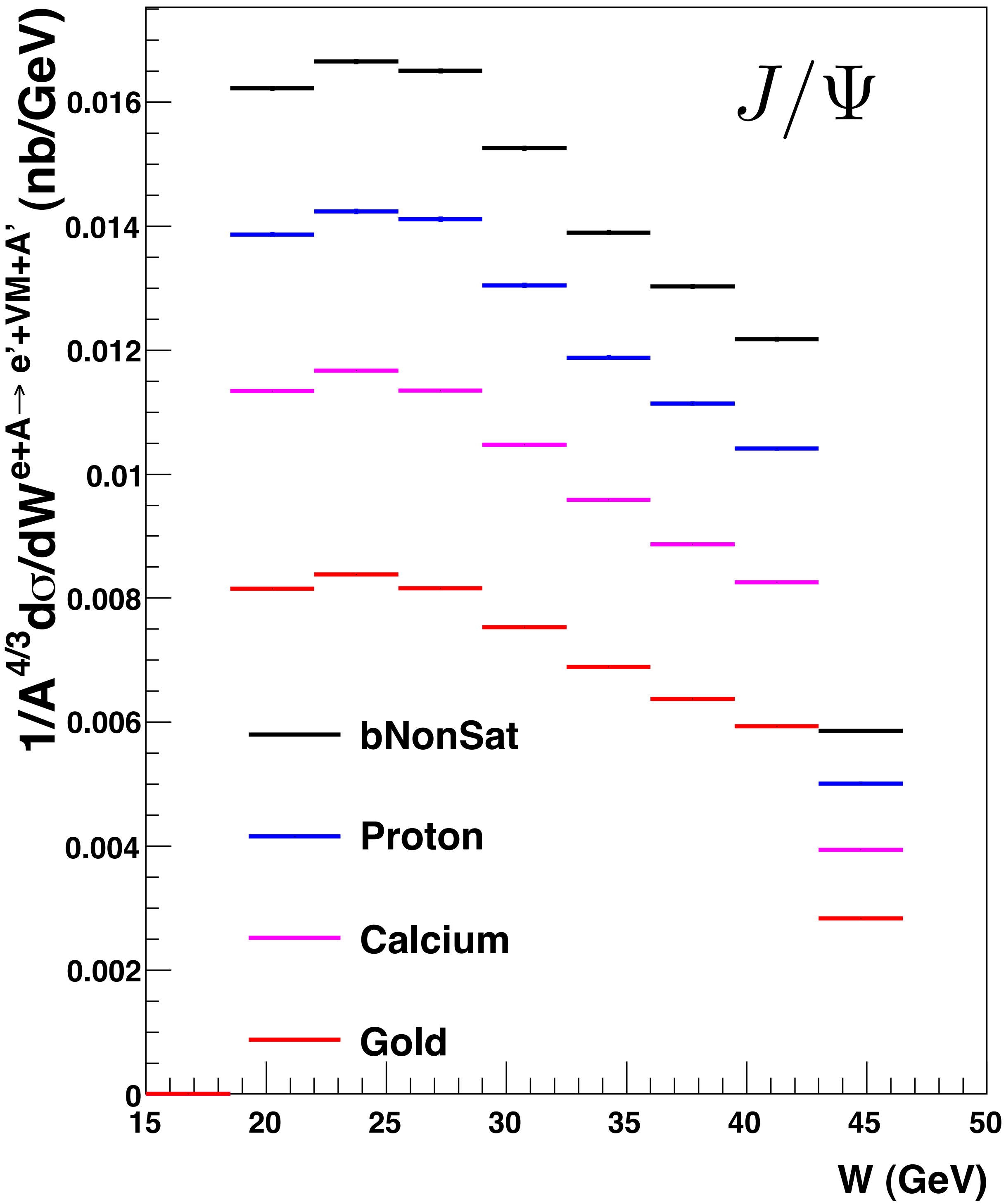


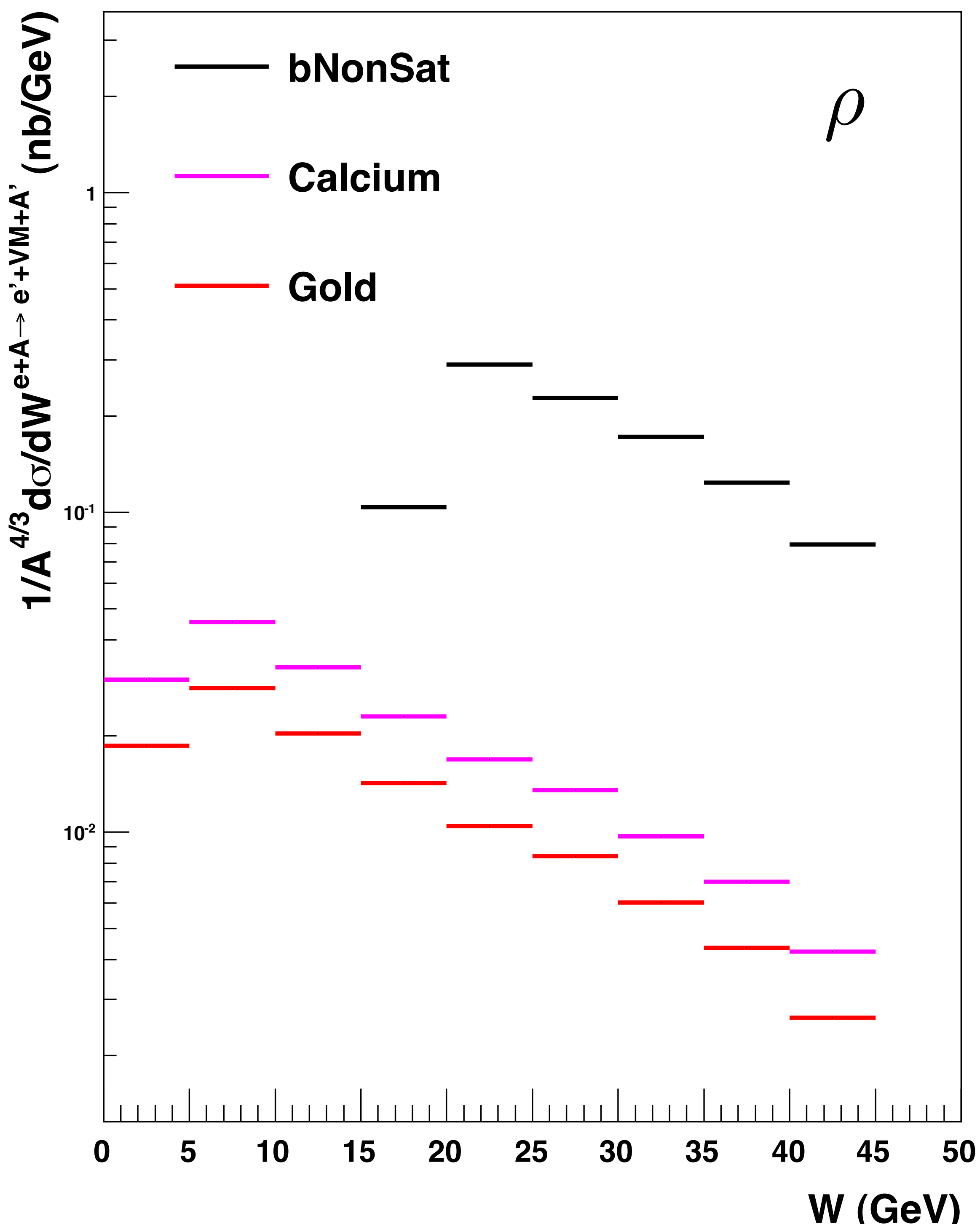


$|t| < 0.01\ \mathrm{GeV}^2$

Some eA generated results

1M events, 5 GeV x 100 GeV





$Q^2 > 1\ \mathrm{GeV}^2$

Outlook

Sartre can also be extended to the general diffractive process:

$$e + A \rightarrow e' + X + A'/Y$$

Have ideas and developed plans to create nuclear uPDF and use as input for the CCFM evolution in CASCADE for non-diffractive eA studies (collaboration with H. Jung)

Earlier comparison with data: nuclear UPC at RHIC
First comparisons look very promising

$$\mathrm{AU} + \mathrm{AU} \rightarrow \mathrm{AU}' + \rho + \mathrm{AU}'$$

Summary

It will be very important for the EIC to measure diffraction.

To design the interaction region in the detectors MC event generator simulations are essential.

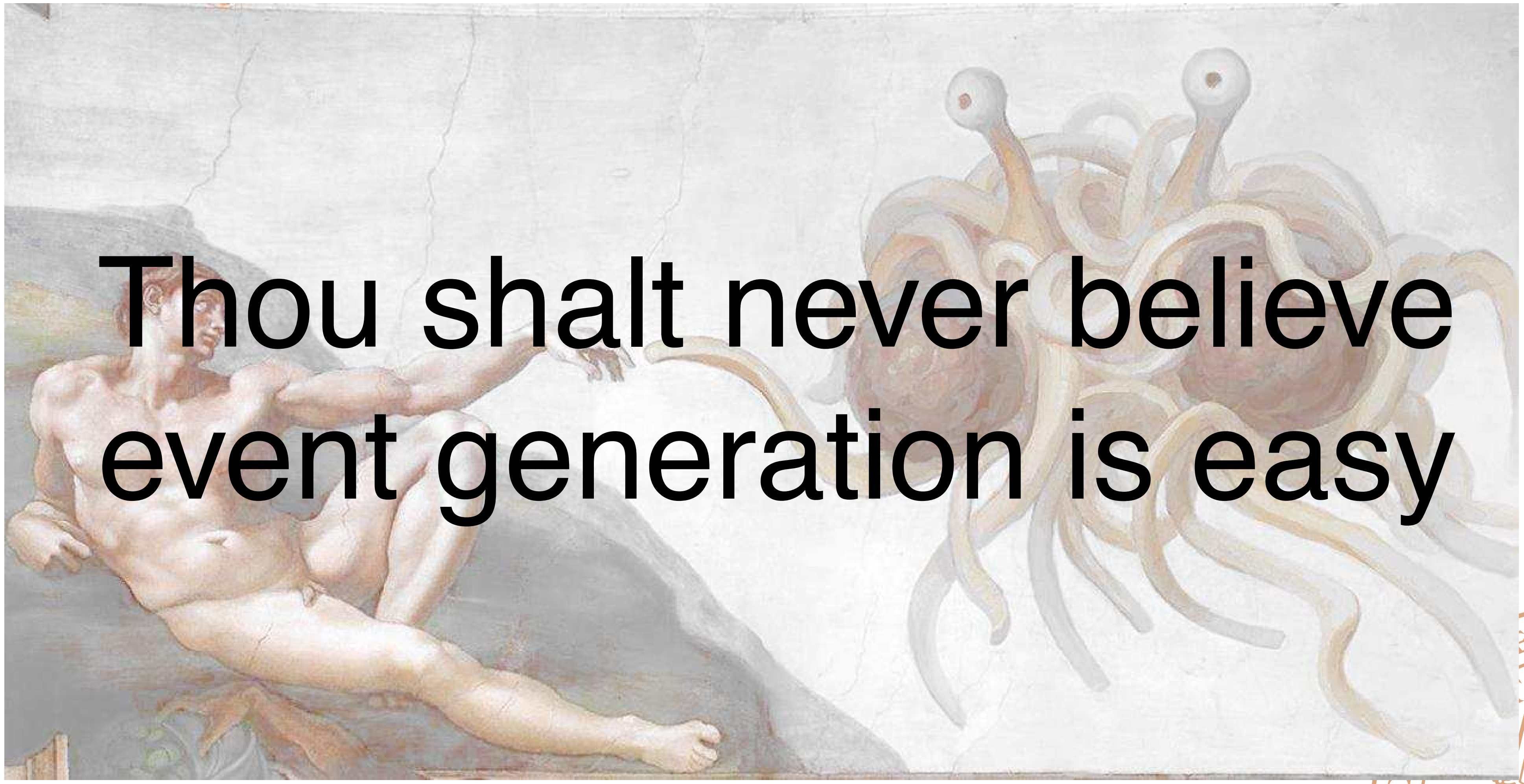
We have developed a method to calculate exclusive diffractive vector meson production and DVCS in eA collisions.

It has been implemented in a Monte Carlo event generator called Sartre.

BACKUP

Final notes:

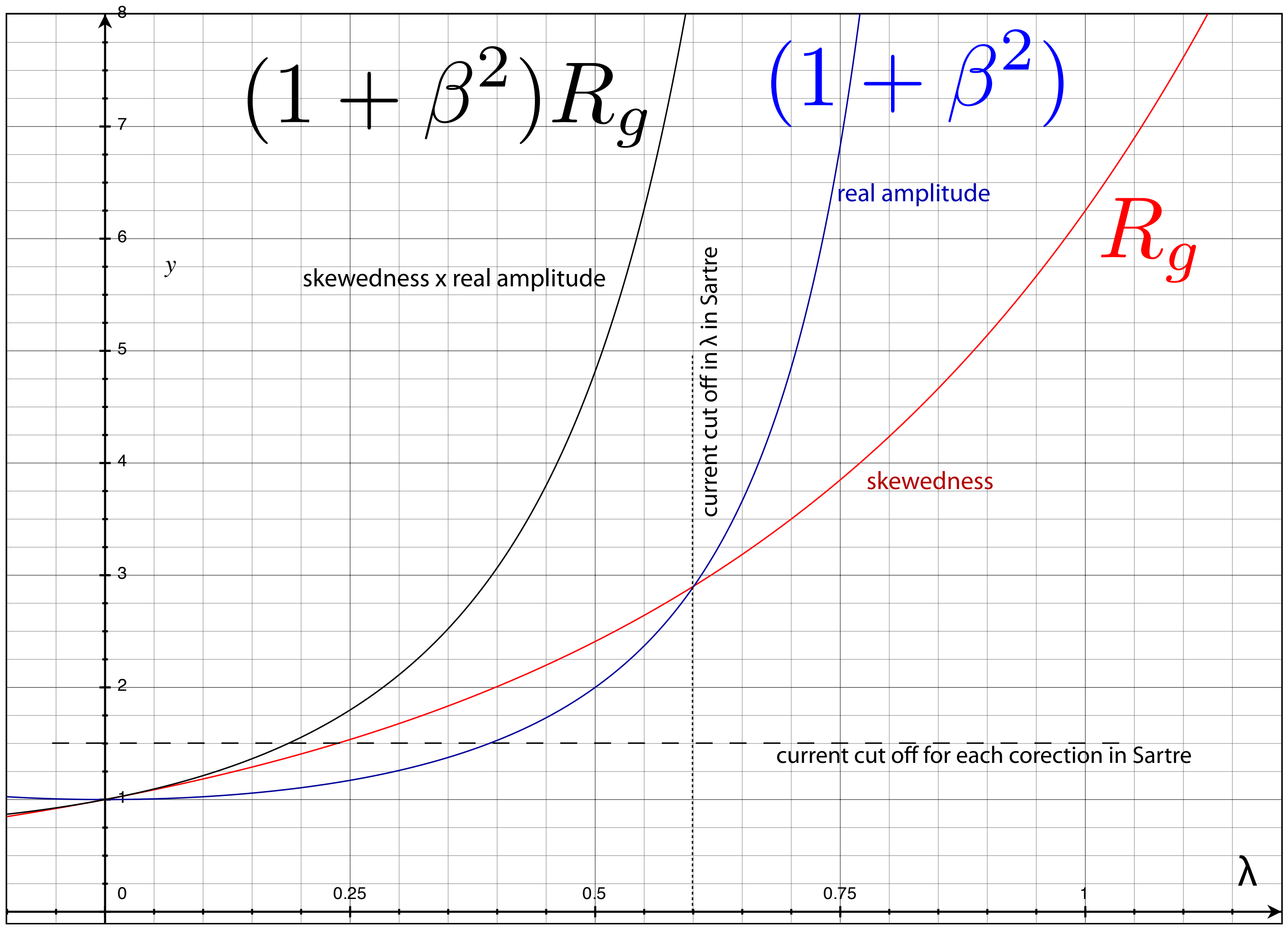
The First Commandment of Event Generation



Final notes:

We've had (and still have) a plethora of technical and numerical problems:

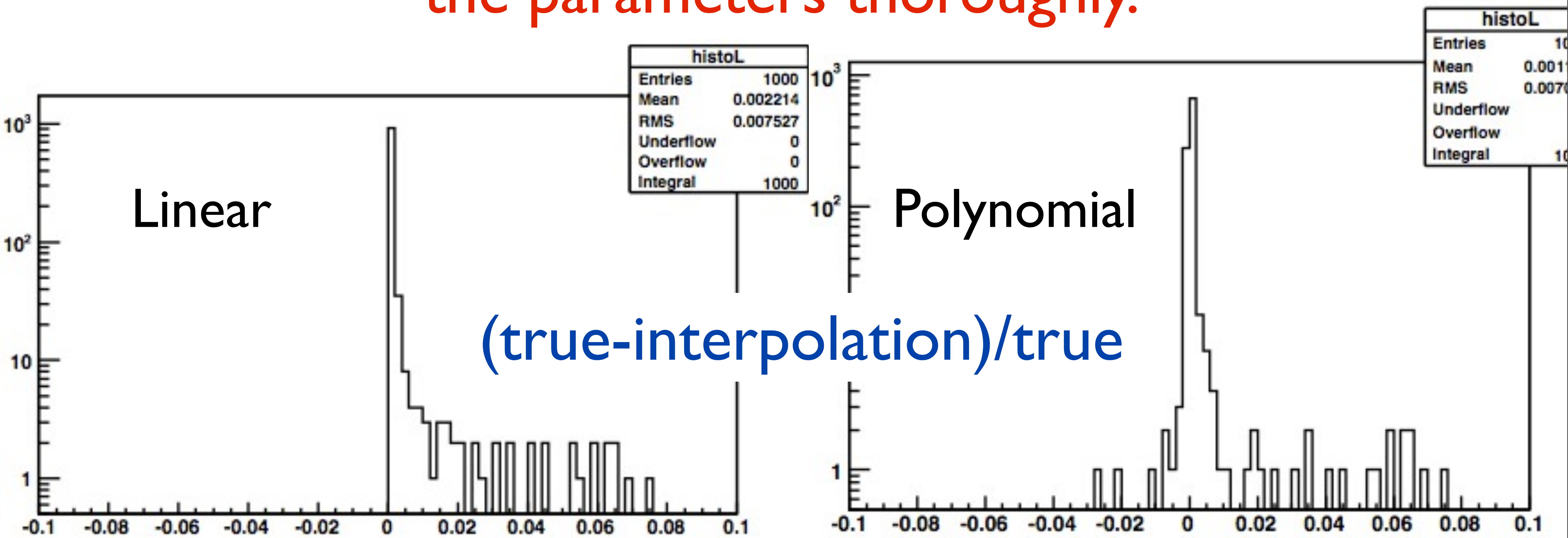
Real and skewedness corrections can be tweaked to better describe the cross-sections



Final notes:

We've had (and still have) a plethora of technical and numerical problems:

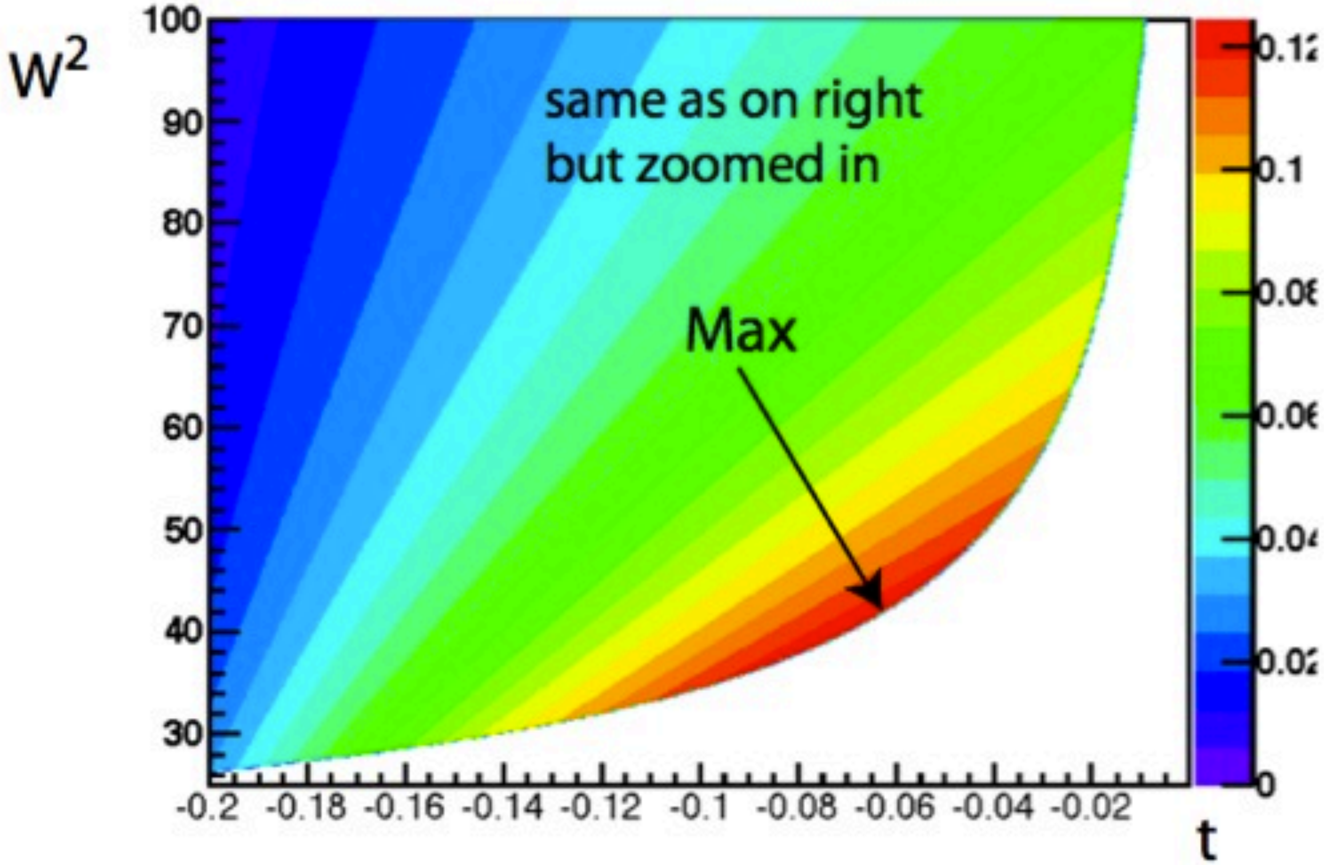
Linear interpolation -> a bias to small values, switched to a polynomial interpolation, need to adjust the parameters thoroughly.

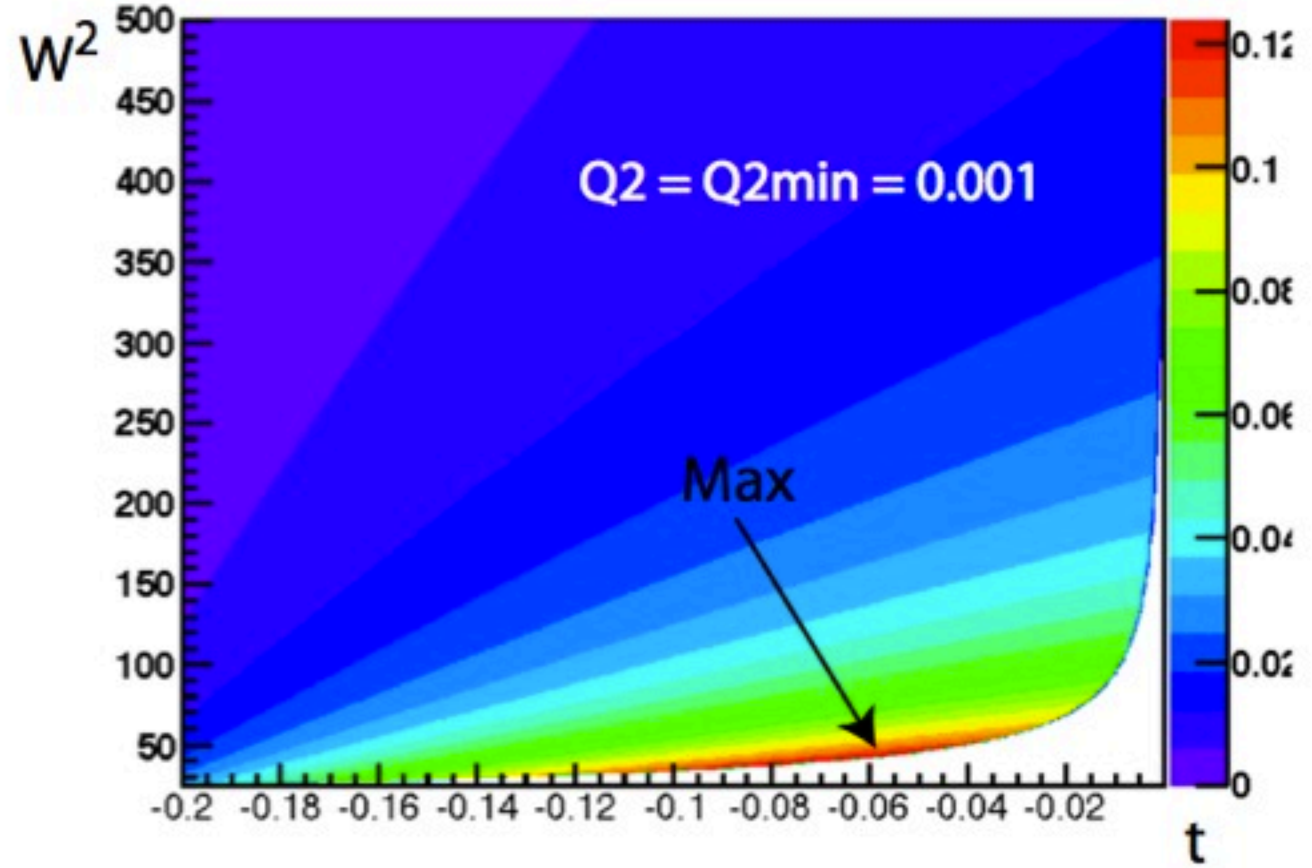


Final notes:

We've had (and still have) a plethora of technical and numerical problems:

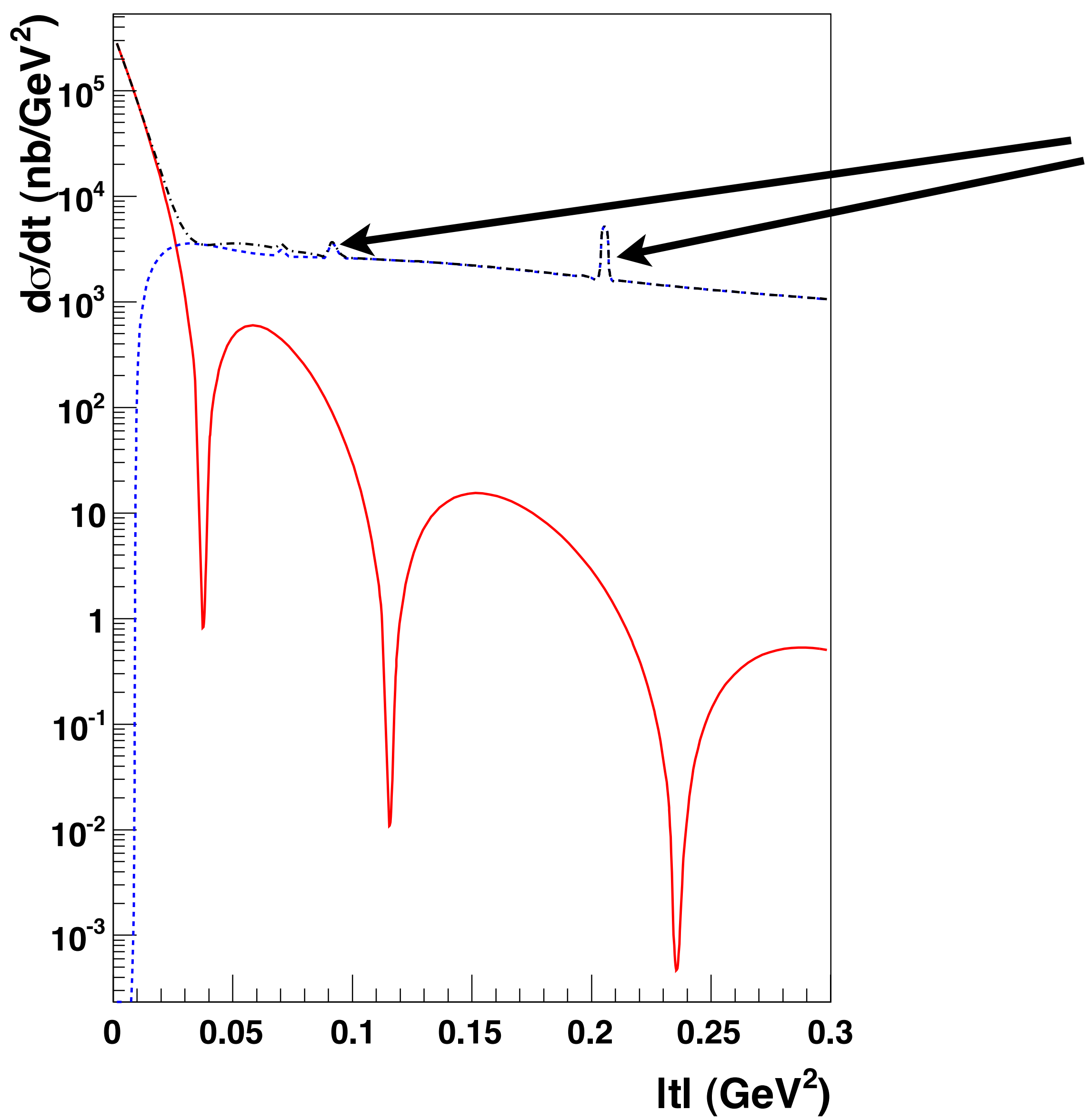
Using UNU.RAN to generate events from the distribution. This has to be set-up with the maximum value in the distribution. It's been a lot of cooking and trial and error to find a reliable method for this.





Final notes:

We've had (and still have) a plethora of technical and numerical problems:



Spikes in the distribution!!

Each phase-space point is the result of 1600 4d integrals.

In a few % of the points, there is a spike.

This will ruin the MC-generation, unless controlled!

Problem fixed!

Generating a Nucleus

Generate radii according to the Woods-Saxon distribution

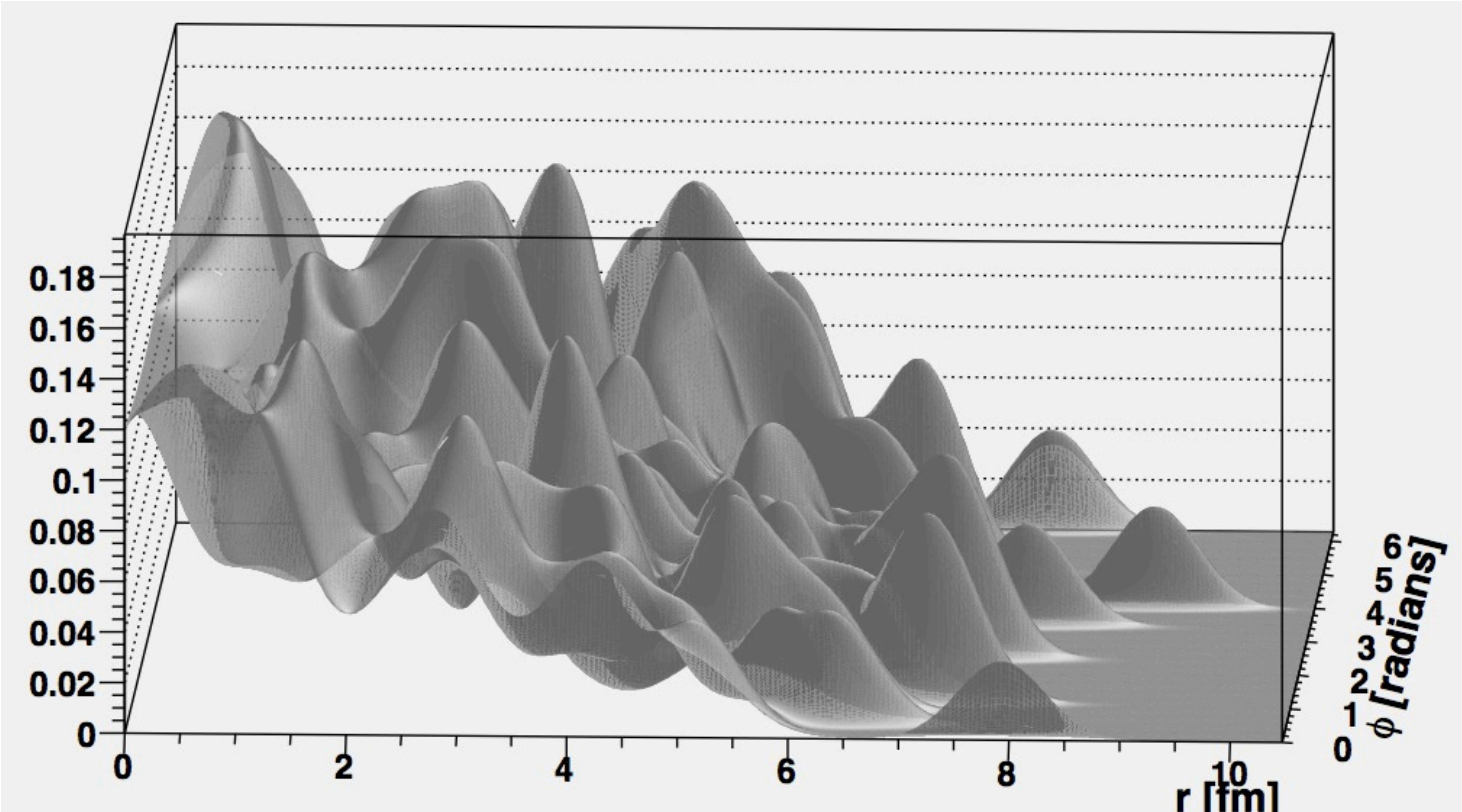
$$\rho(r) = \frac{\rho_0}{1 + e^{\frac{r - R_0}{d}}} \qquad \rho(r) = \frac{\mathrm{d}^3 N}{\mathrm{d}^3 \mathbf{r}}$$

First generate according to r: $\frac{\mathrm{d}N}{\mathrm{d}r} = 4\pi r^2 \rho(r)$

Then generate angular distributions uniform in ϕ and $\cos(\theta)$

This is done with a condition that two nucleons can not be within a core distance of ~0.8fm.
If they are: regenerate angles (not radius!)

Generating a Nucleus



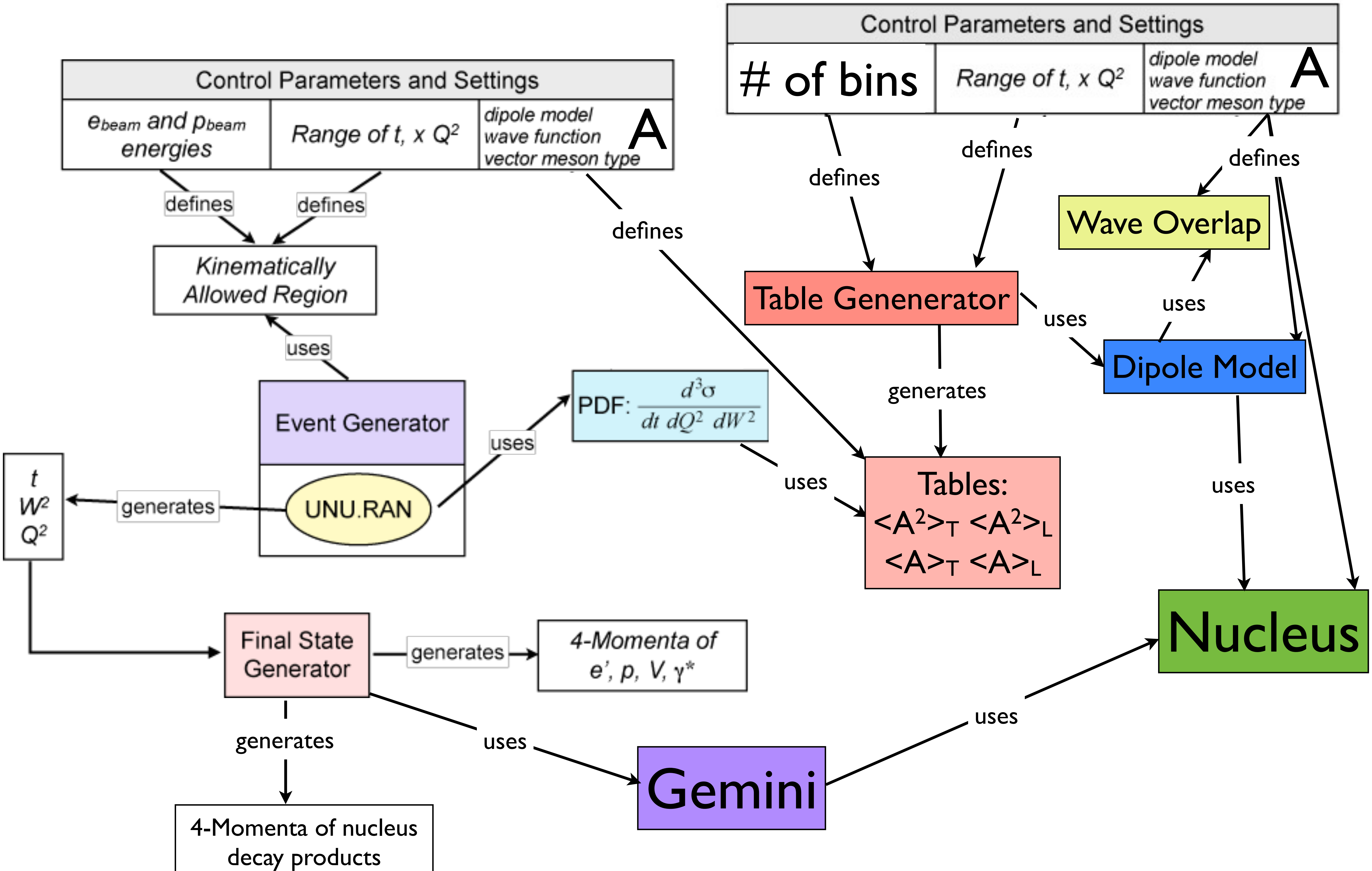
Lead 208 in the r-phi plane, each nucleon is supplemented with a Gaussan width (bSat).

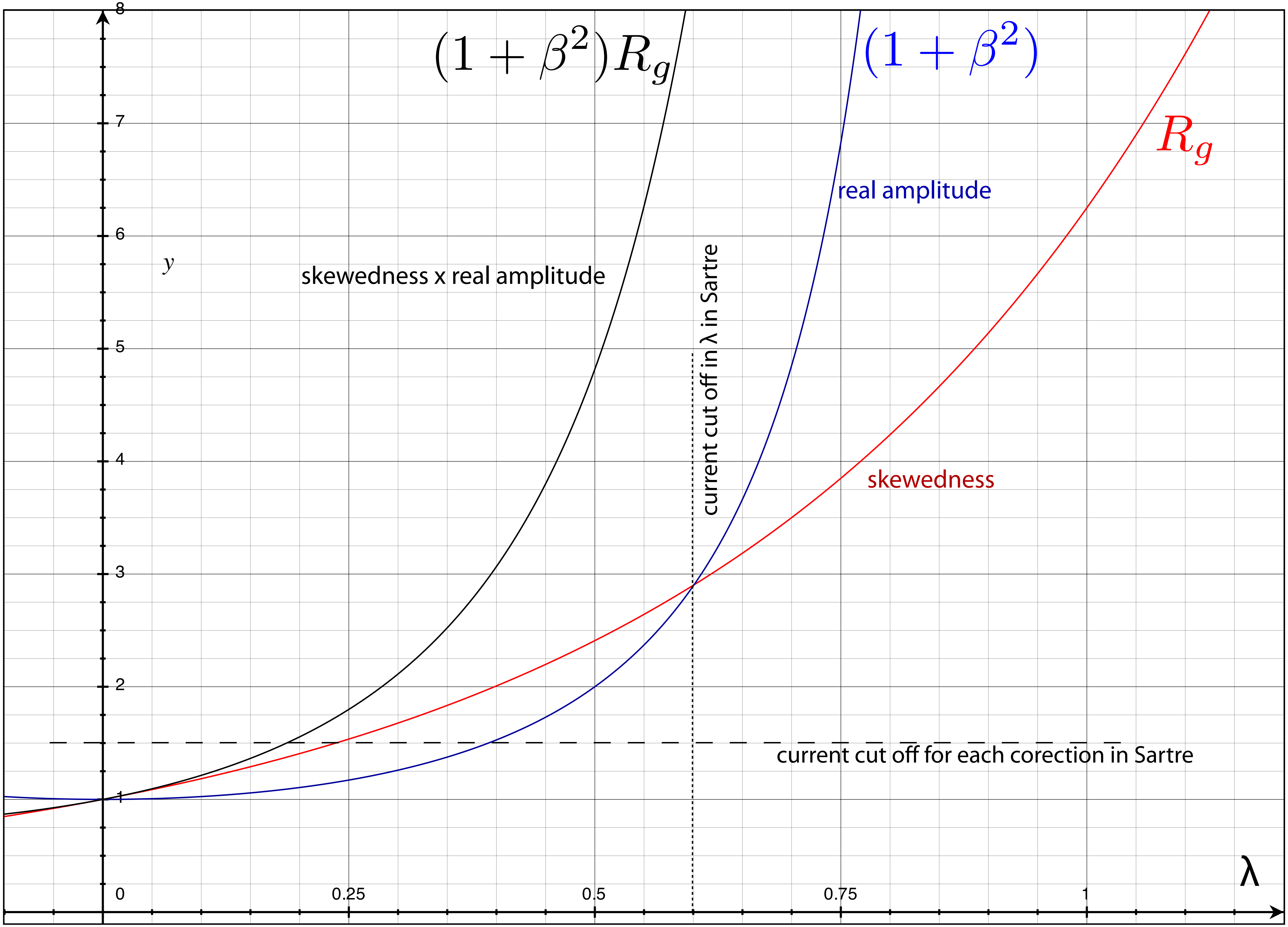
The ten commandments of event generation:

1. Thou shalt never believe event generation is easy
2. Thou shalt always cover the whole of phase space
3. Thou shalt never assume that a jet is a parton or a jet
4. Thou shalt never double-count emissions
5. Thou shalt always remember that an NLO generator does not always produce NLO results
6. Thou shalt always be independent of Lorentz frame
7. Thou shalt always conserve energy and momentum
8. Thou shalt always resum when NLO corrections are large
9. Thou shalt not be afraid of parameters
10. Thou shalt only have nine commandments of event generation

By Leif Lönnblad

How Sartre works




$(1+\beta^2)R_g$
$(1+\beta^2)$
R_g
real amplitude
y
skewedness x real amplitude
current cut off in λ in Sartre
skewedness
current cut off for each corection in Sartre
λ
8
7
6
5
4
3
2
1
0
0.25
0.5
0.75
1