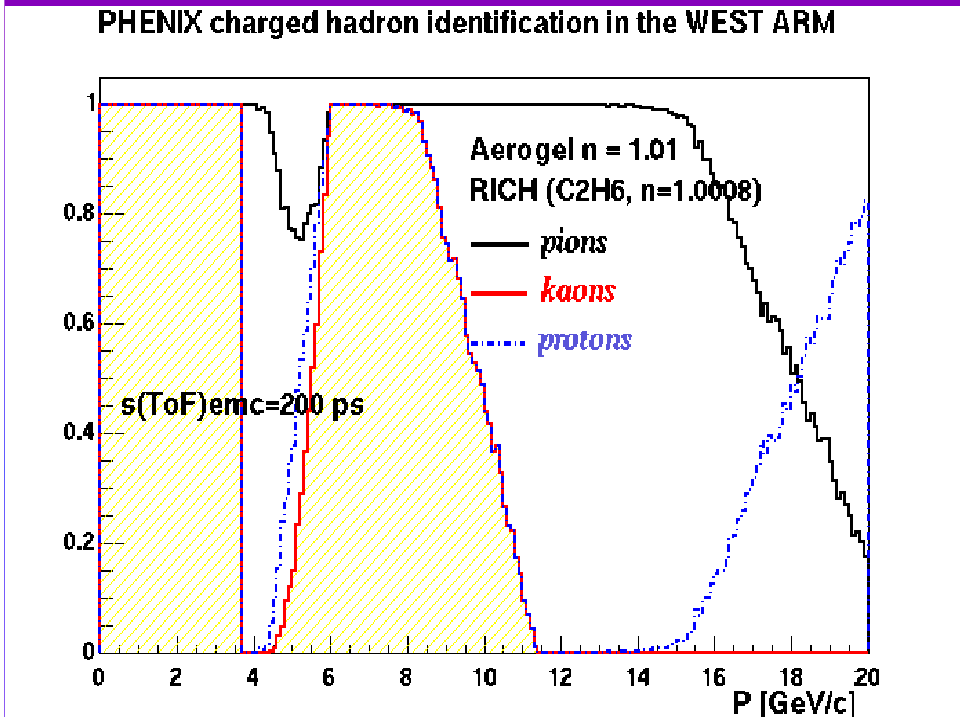
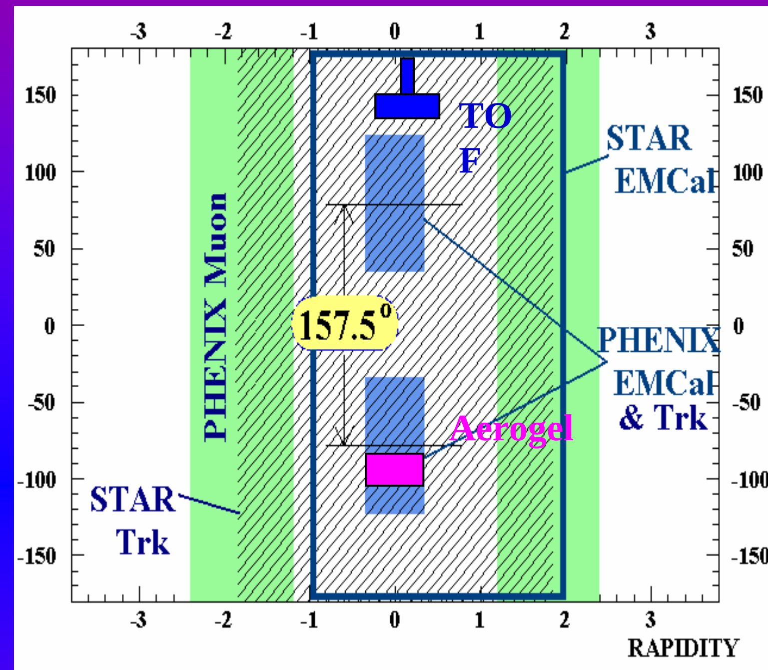
PHENIX High pT PID Project (central region)





RHIC II luminosity is required to reach the desired potentials: see Rene's talk

RHIC 2 : 15 nb-1

10^{11} MB events 10^{10} central

R.Seto

RHIC: 1.5 nb-1 (run 8)

10^{10} MB events 10^{9} central

Started in 2002

Cherenkov component completed in 2004

TOF component – installation in 2005

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Future of the High pT measurements in PHENIX at MIDRAPIDITIES

Prehistory

Hard scattering and PWF

Highlights of the past

Plans

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A historic perspective

- Perturbtive QCD and Λ_{QCD} are formally established, Fritzsch *et al.*, 1973; Gross and Wilczek, 1973; Weinberg, 1973
- Hard Scattering and Large pT hadrons formally became resposible for the evolution in our understanding of strong interaction dynamics
- Two decades ago when QGP first became a popular subject we've already been past
  - DIS formalism and PWF
  - Feynman(1969) – parton model.
  - scaling behavior of the nucleon structure function - breakthrough by Panofsky(1968), Breidenbach(1969), Bjorken(1969)

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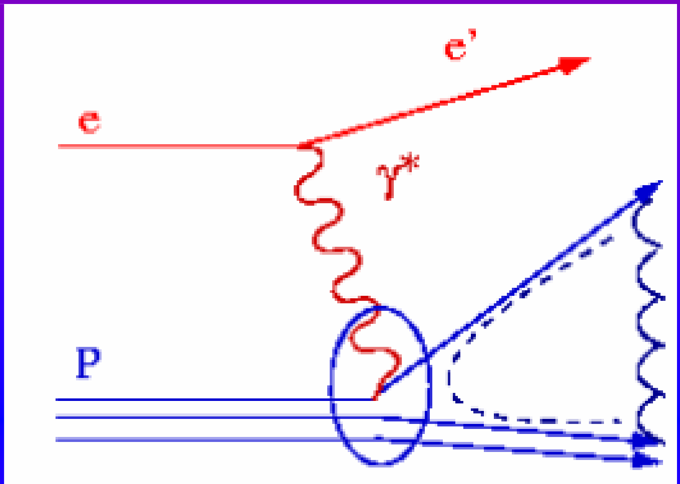
The formalism of "probing" the nucleon (nucleus) structure was first applied to DIS



$$Q^2 \equiv -q^2 = 4EE'\sin^2\frac{\theta}{2} > 0$$

$$x \equiv \frac{Q^2}{2p\cdot q} = \frac{Q^2}{2m\nu}$$

$$\nu \equiv E - E'$$

$$\frac{d^2\sigma}{dE'd\Omega'} = \frac{1}{16\pi^2}\frac{E'}{E}\left|\overline{M}\right|^2 = \frac{e^4}{16\pi^2 Q^4}\frac{E'}{E}L^{\mu\nu}W_{\mu\nu}$$

$$W_{\mu\nu} = -\left(g_{\mu\nu} - \frac{q_\mu q_\nu}{q^2}\right)W_1\left(x,Q^2\right) - \left(p_\mu + q_\mu\left(\frac{1}{2x}\right)\right)\left(p_\nu + q_\nu\left(\frac{1}{2x}\right)\right)W_2\left(x,Q^2\right)$$

Dimensionless Structure Functions:

$$F_1\left(x,Q^2\right) = W_1\left(x,Q^2\right)$$

$$F_2\left(x,Q^2\right) = p\cdot q W_2\left(x,Q^2\right) \quad = \Sigma_i[e_i^2 x F_{2i}(x,Q^2)]$$

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The foundation to this amazing progress is in the data exibiting surprises and "there is more to it" attitude towards data

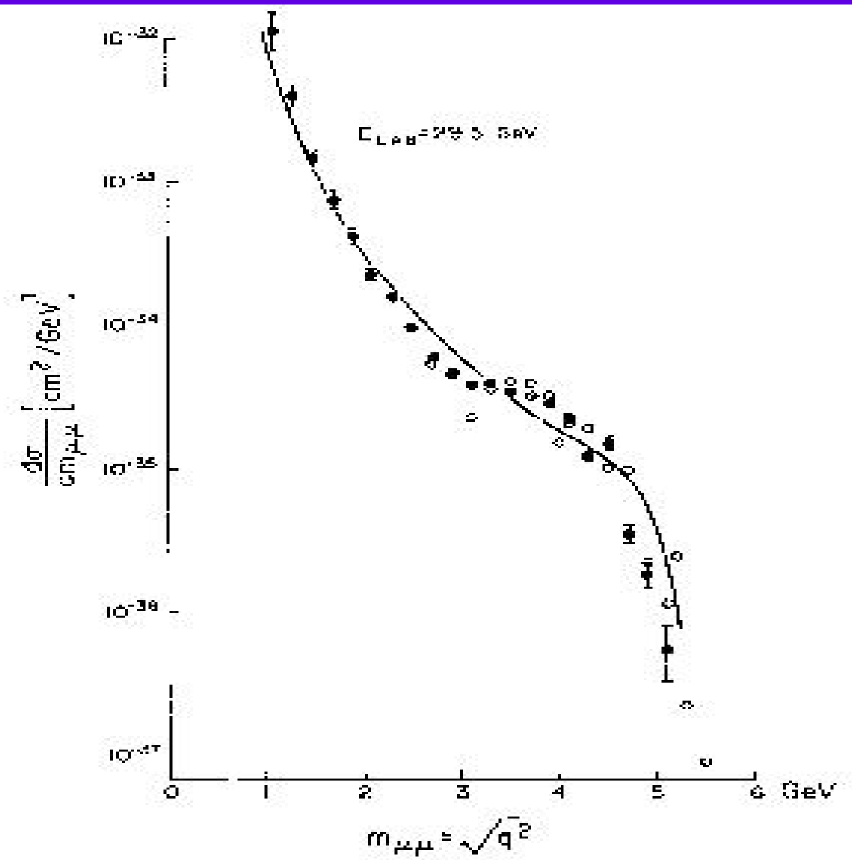

FIG. 2. Experimental cross section of Christenson *et al.*, Ref. 8.

Data from *Christenson et al., Phys. Rev. Lett. 25, 1523 (1970).*

Theory curve from *Altarelli, Brandt and Preparata PRL26, 42 (1971)*

Regrets are from Nobel lecture of L.Lederman: (in 1996) *we could only note that: "Indeed, in the mass region near 3.5 GeV, the observed spectrum may be reproduced by a composite of a resonance and a steeper conti- nuum."*

It took 8 more years

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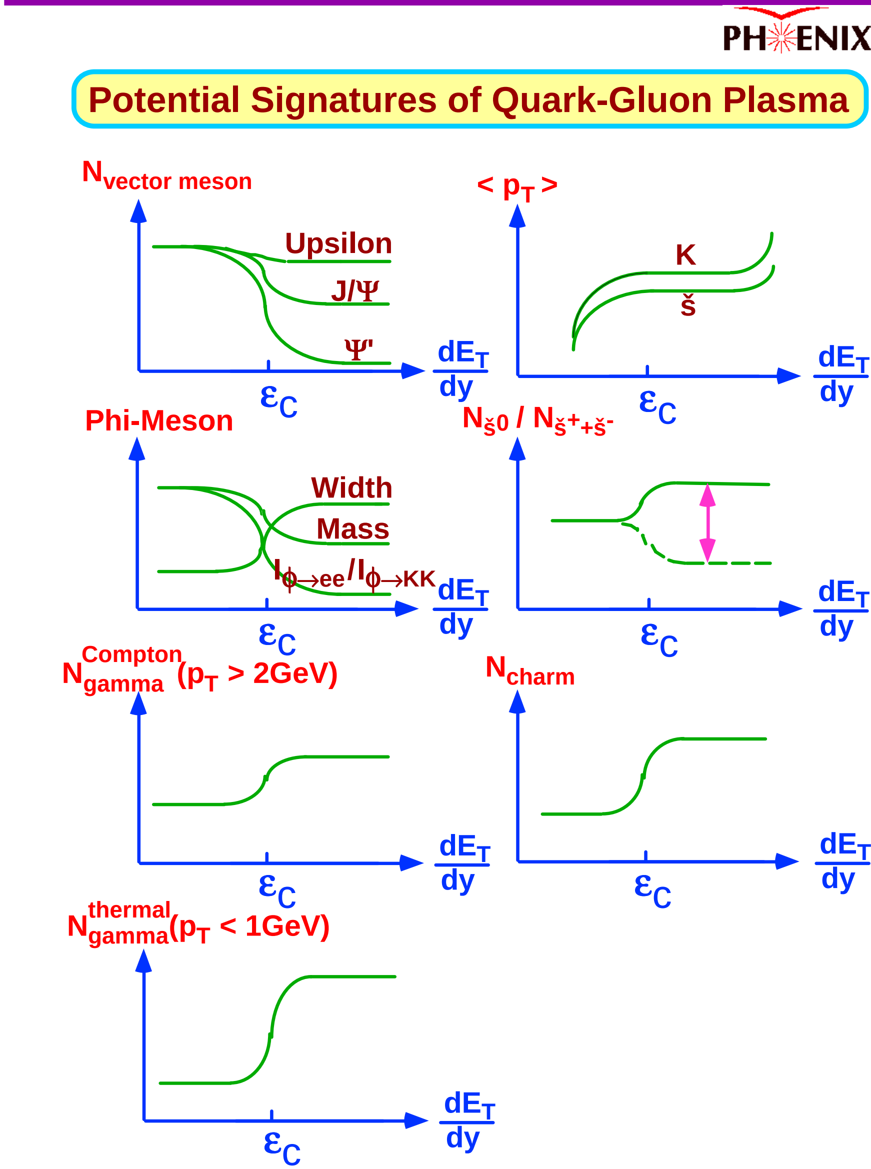
I Respect Shoji Nagamija with the deepest of my hart and still can't hold myself from showing this great picture



QGP signatures back in SPS days

~as late as 1993

I do have some old e-mails written by very much respected friends of mine even questioning the wisdom of building a calorimeter for RHIC experiment !!!!!

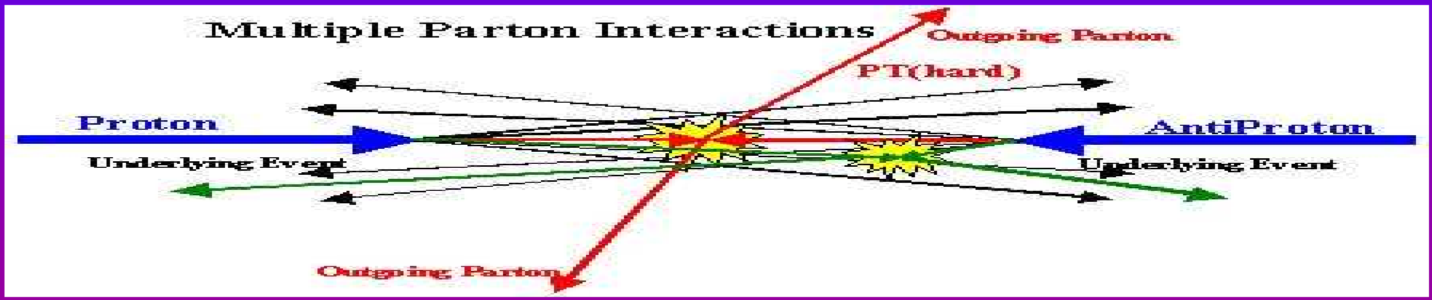
No Hard Probes in the Nuclear Physics Land

Something was really missing .....

The misconception was probably due to oversimplified picture of high pT hadron resulting from a binary collision with all remaining partons acting as bystanders and final state interactions playing only a minor role. In the collinear approximation the three ingredients:

- The parton wave function within colliding hadrons;
- The scattering matrix;
- The fragmentation function of the scattered partons.

were totally factorized



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Reconing ~ 1997

There exists a bibliography of earlier works

D.A. Appel et al, 1986, J.P.Blaizot, L.McLerran, 1986 …

but the bible establishing Hard Scattering as a tool of choice to study matter in HI collisions and quantitativly predicting matter effects on high pT particles in correlated production of photons and jets is

Xin-Nian Wang, Zheng Huang, Phys. Rev. C55, 1997

W.Zajc, 1999

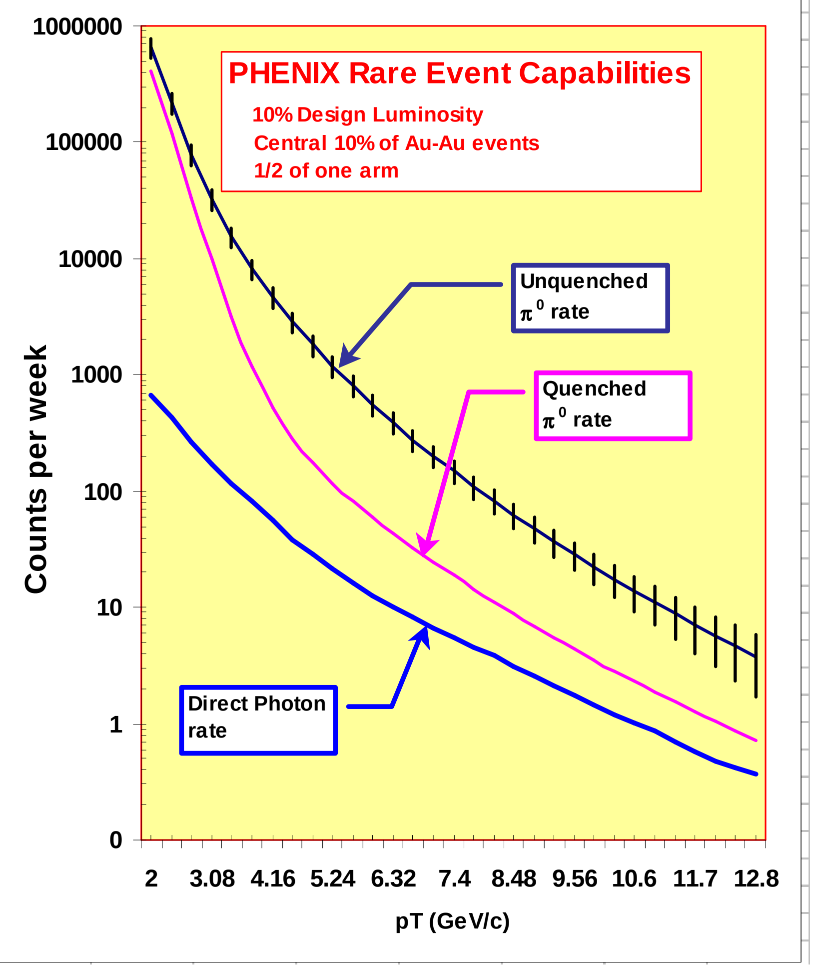
Measurement of hard processes:

General: an auto-generated plasma diagnostic

Specific: Prediction that dE/dx in deconfined phase

~10 x larger than normal nuclear matter

Measure high pT π^0's, γ / π^0, …



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Similar to High Energy Particle Physics Hard Scattering in Nuclear Physics

- is a major tool to understand physics of HI collisions;
- new physics in HI collisions will manifest itself primarily through modifications to already established pQCD picture of HS.

PWF (parton wafe function)

-Baseline from DIS;

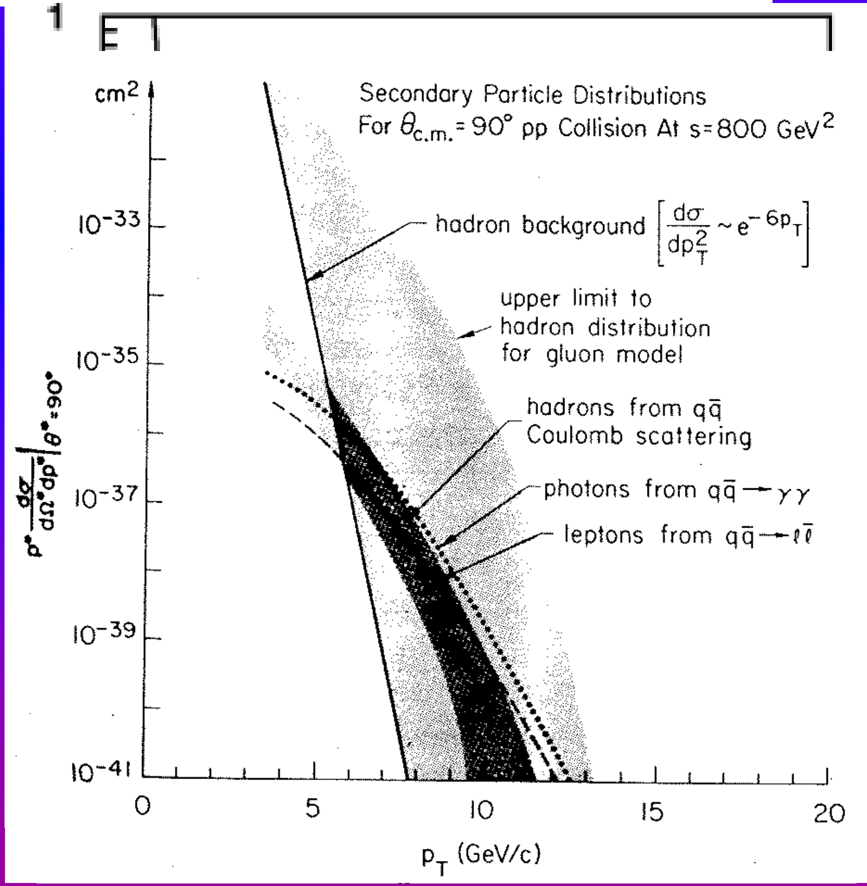
SM (scattering matrix)

-Select pQCD dominated pT range,

- Apply Collnear Factorization Scheme

FF (fragmentation function)

-Baseline from jets in e+e-;



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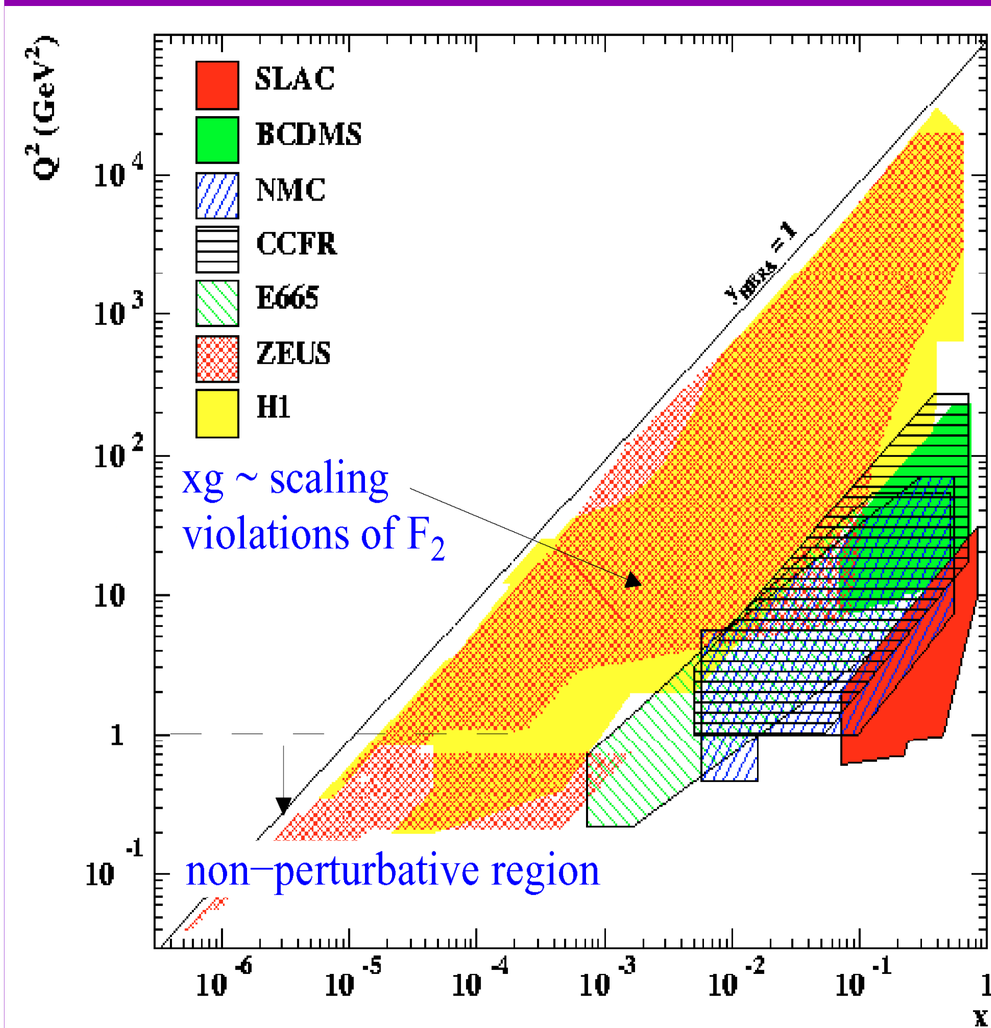
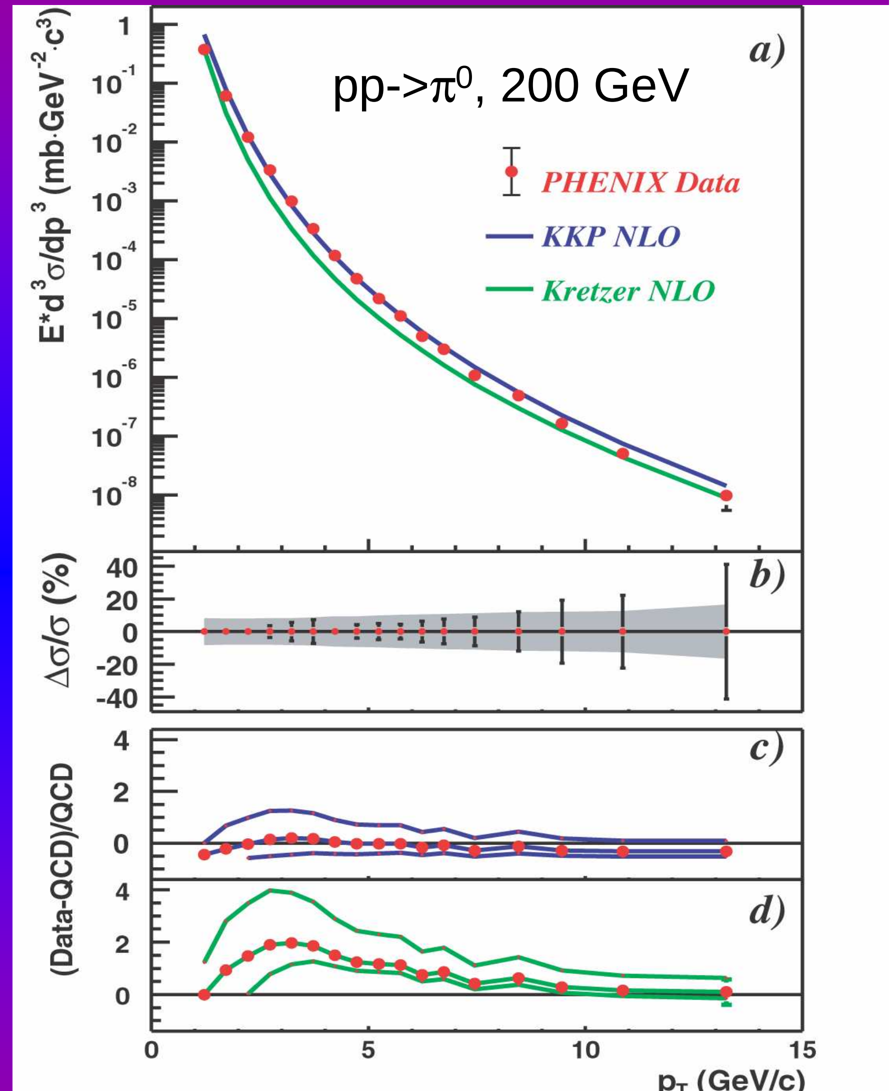
Projecting existing knowledge to the PHENIX pp-data





The kinematic domains probed by the various experiments, shown together with the partons that they constrain

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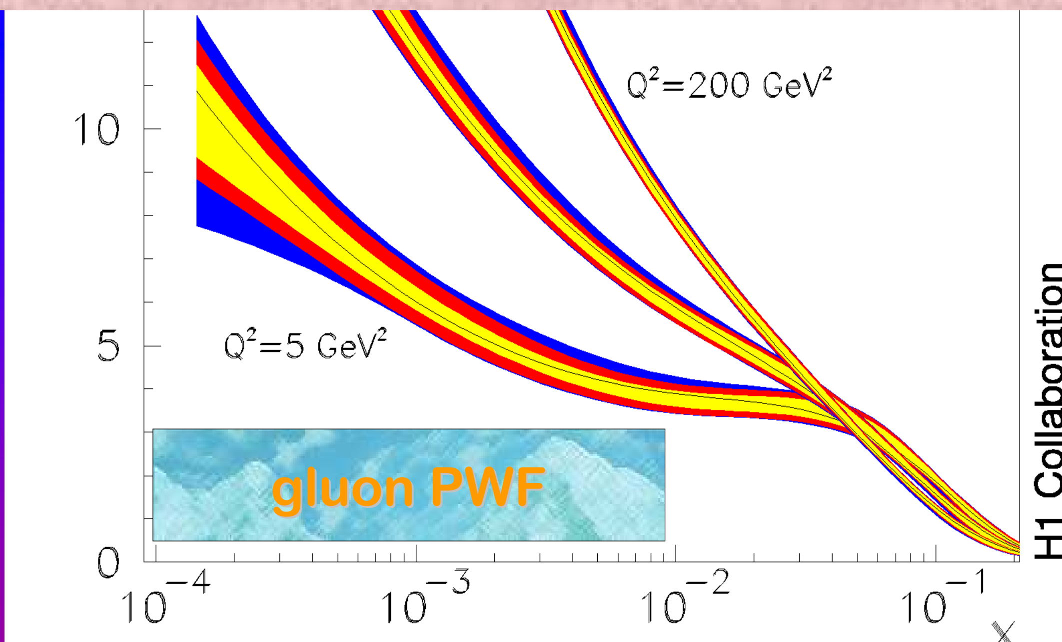
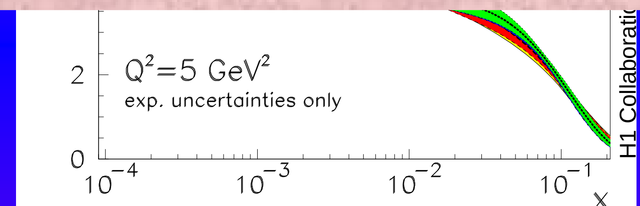
Small-x gluon PWF in proton is badly defined

Never measured in nucleus: typical recipe from theorist – make it flat below x~0.02





needs precision data at all Q^2, all x!

H1 EPJ C21(01)33

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Direct γ(J/Ψ) + jet reaches

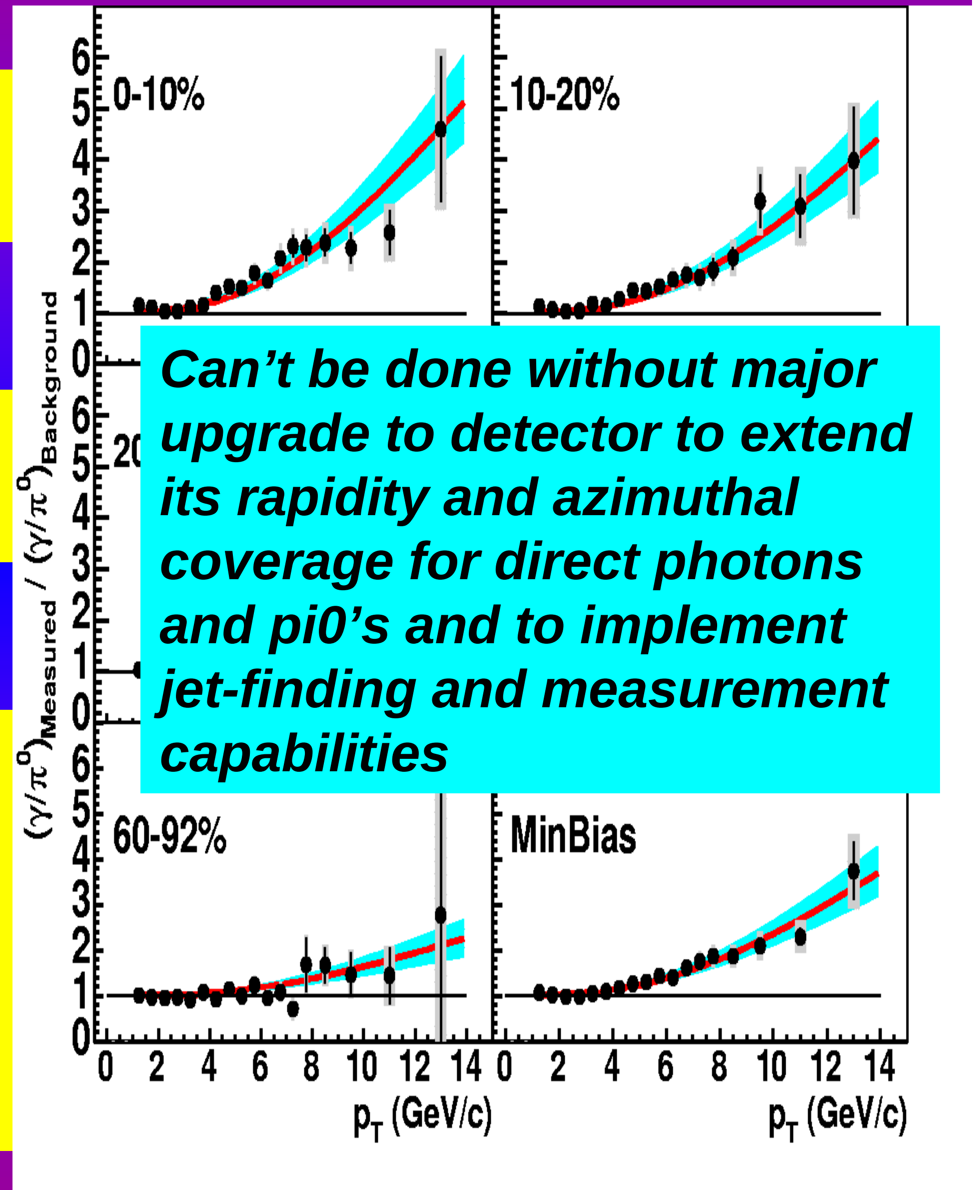
❖Shadowing, Saturation, Color Glass Condensation

Ex
ph
rapidity region (large partonic x)

❖Anti-shadowing, p_T broadening

❖Nature of Nuclear Effects:

are the partons to hard scatter in HI collisions really there



Can't be done without major upgrade to detector to extend its rapidity and azimuthal coverage for direct photons and pi0's and to implement jet-finding and measurement capabilities

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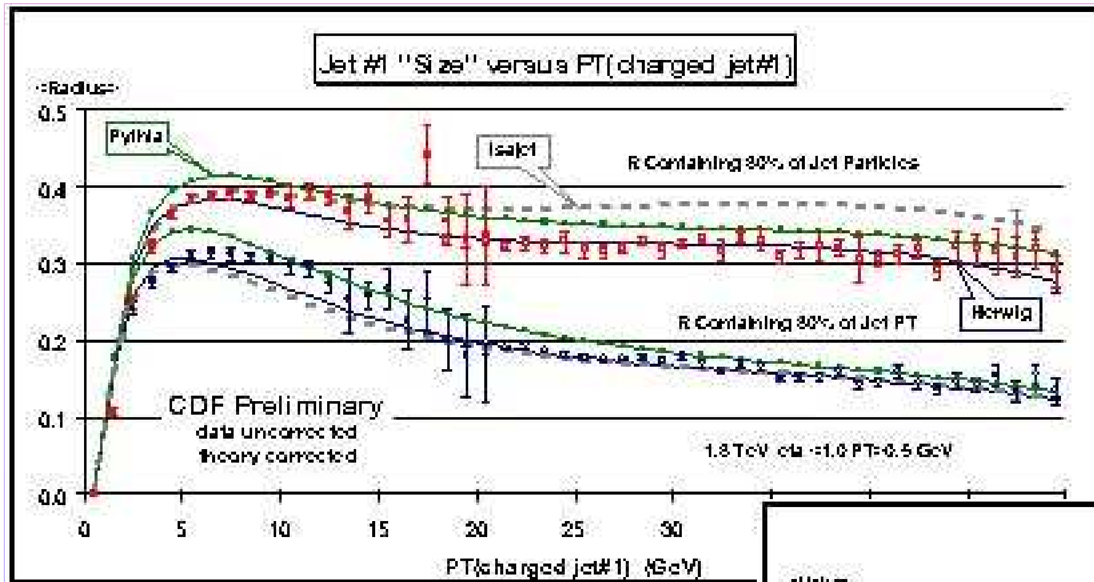
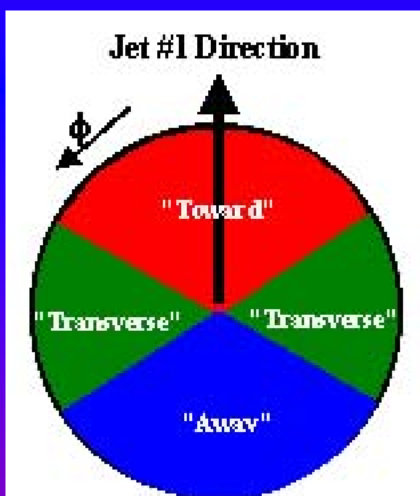
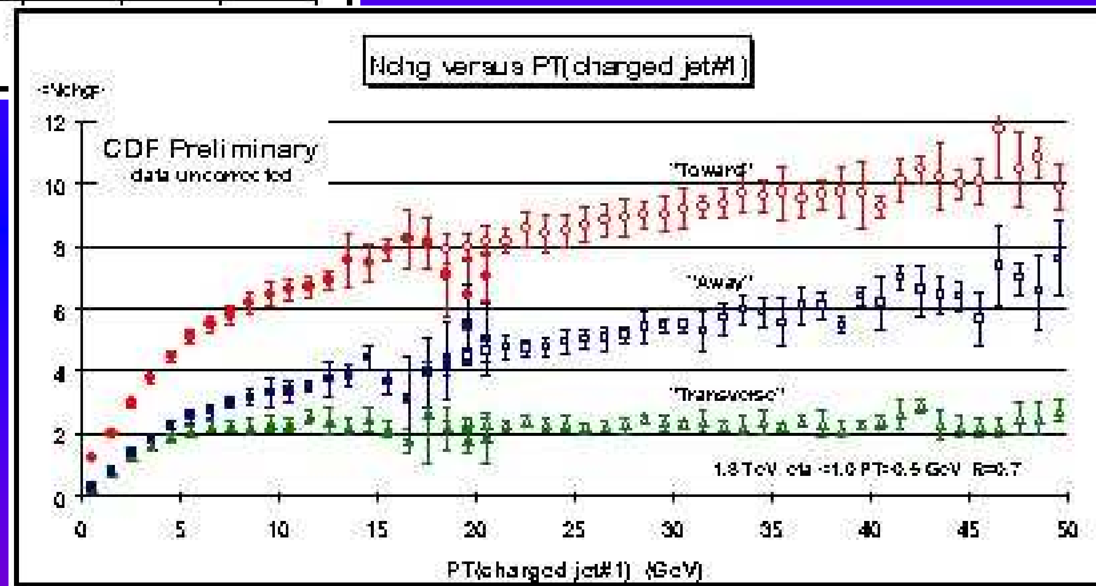
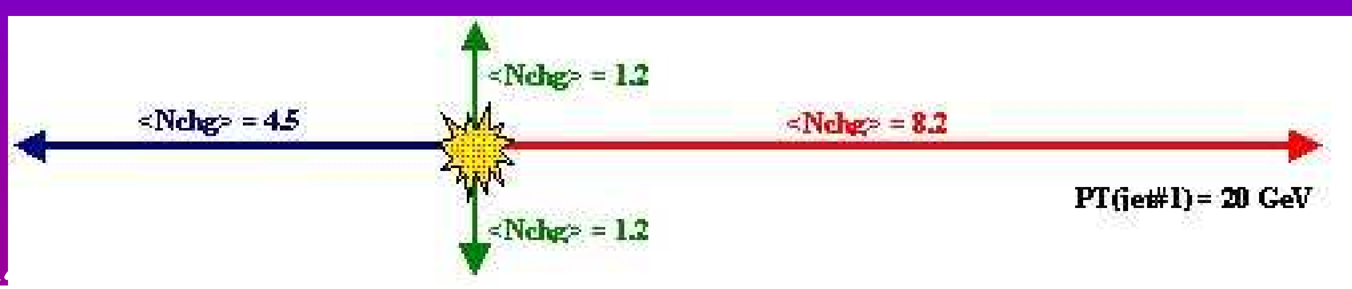
Jets in CDF









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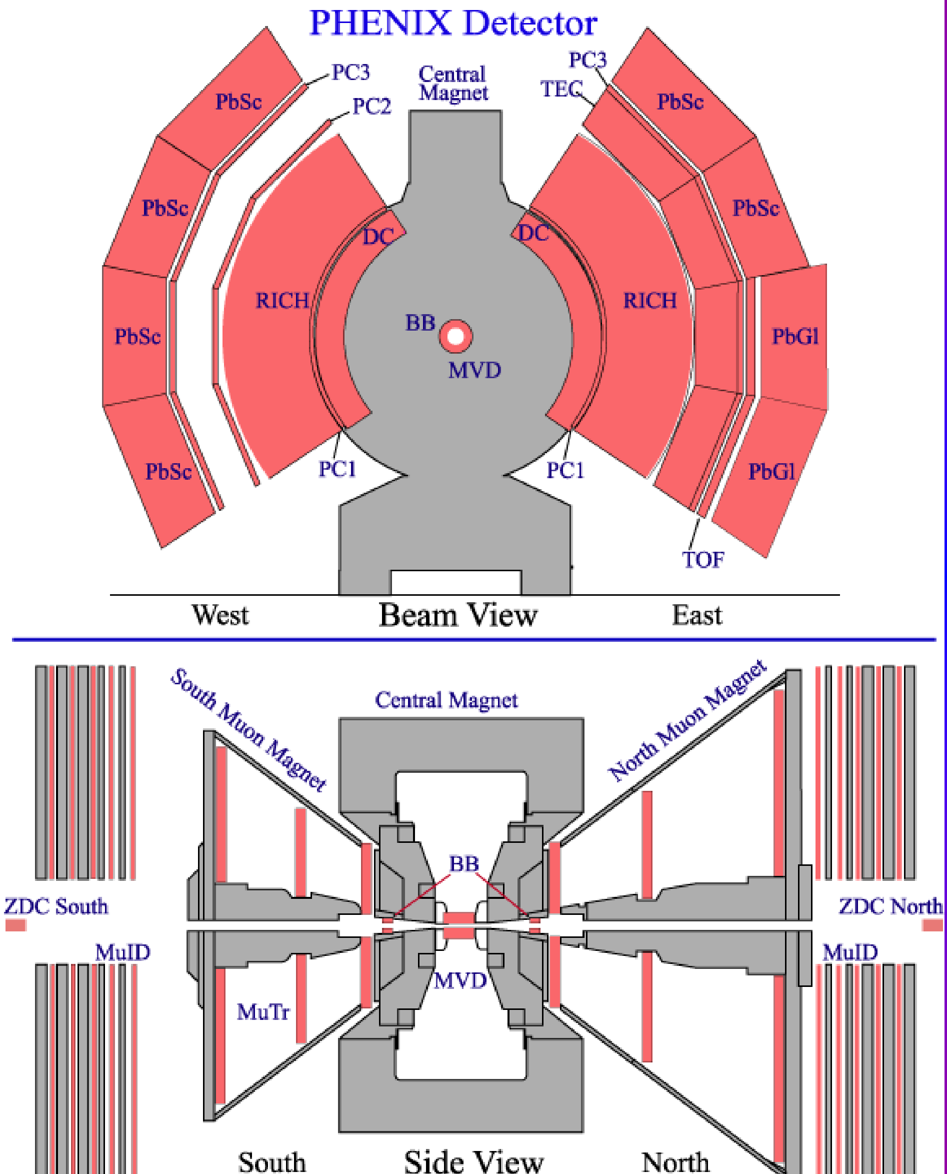
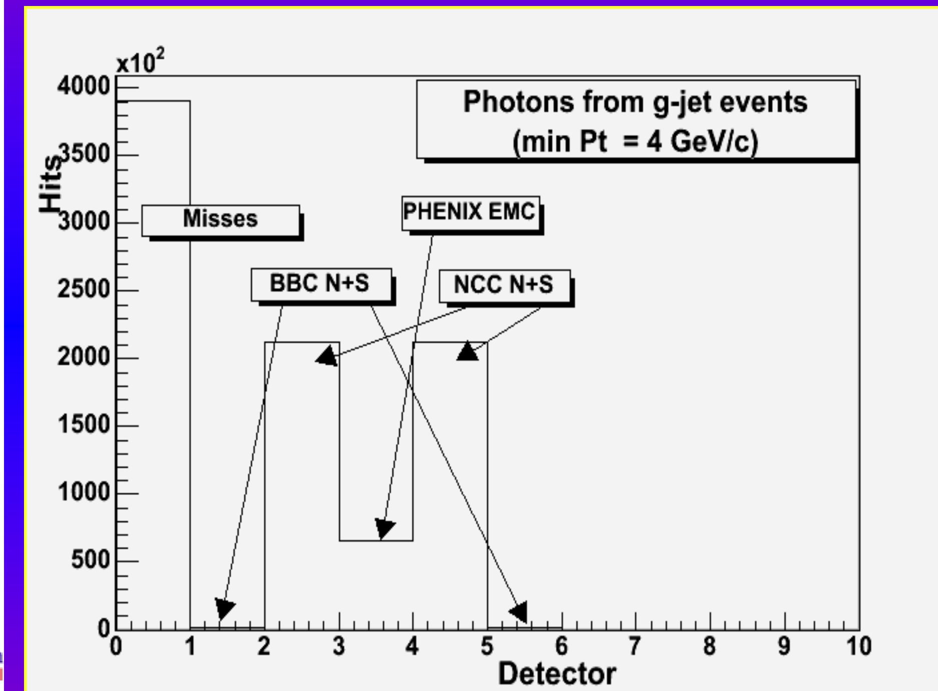
γ-jet events in PHENIX





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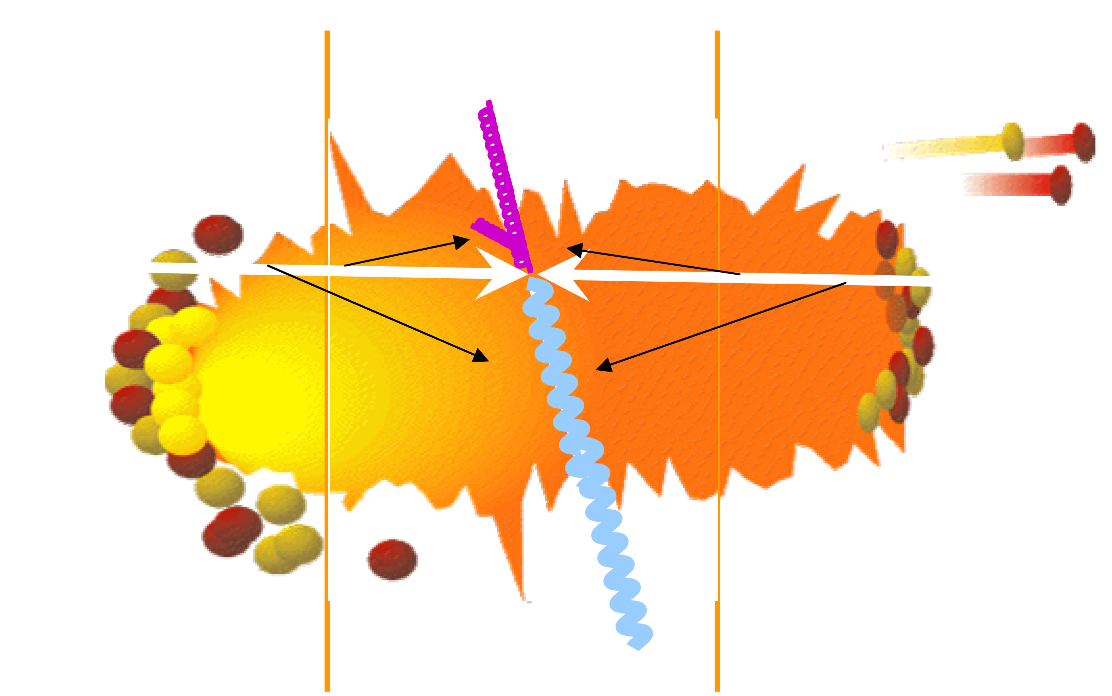
Interpretation problems

initial-state interactions cause an imbalance between photon and jet transverse momentum

final-state interactions change the jet profile;

gluon radiation in the final (initial) state gives origin to secondary jets



Energy of the partons at the origin is not known. We can try to use direct photons to tag the energy of jets.

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Example from the founding fathers…

Just ask PYTHIA for the total transverse energy of the final state particles tracable to scatted parton … nothing even resembling your imaginary back-to-back, well balanced topology.

Need to be real high pT to see full effect of the kinematical constrains.

Xin-Nian Wang, Zheng Huang, Phys. Rev. C55, 1997

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Experimental problem new to PHENIX

Jet Algorithm:

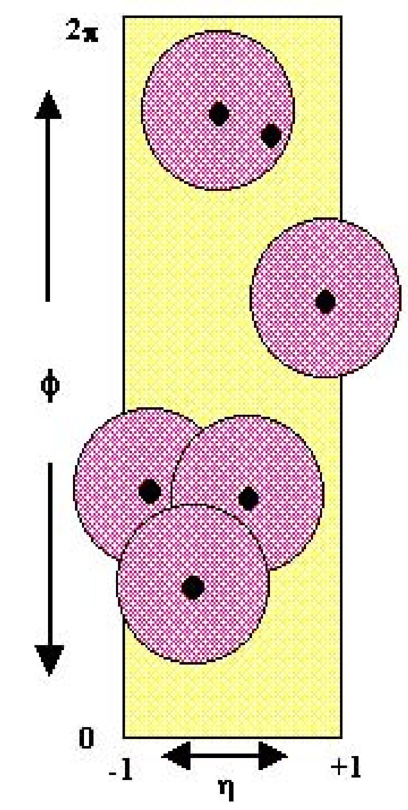
Order all charged particles according to their PT.

Start with the highest PT particle and include in the "jet" all particles within the "distance" R = 0.7 in eta-phi space.

Go to the next highest PT particle (not already included in a jet) and include in the "jet" all particles (not already included in a jet) within the "distance" R =0.7.

Continue until all particles are in a "jet".

We consider all charged particles (PT > 0.5 GeV and |eta| < 1) and allow the jet radius to extend outside |eta| < 1. The figure illustrates an event with six charged particles and five jets.



Be aware of underlying event. Use jets for tagging, use photon 4-vector and jet 3-vector to reconstruct hard-scattering kinematics

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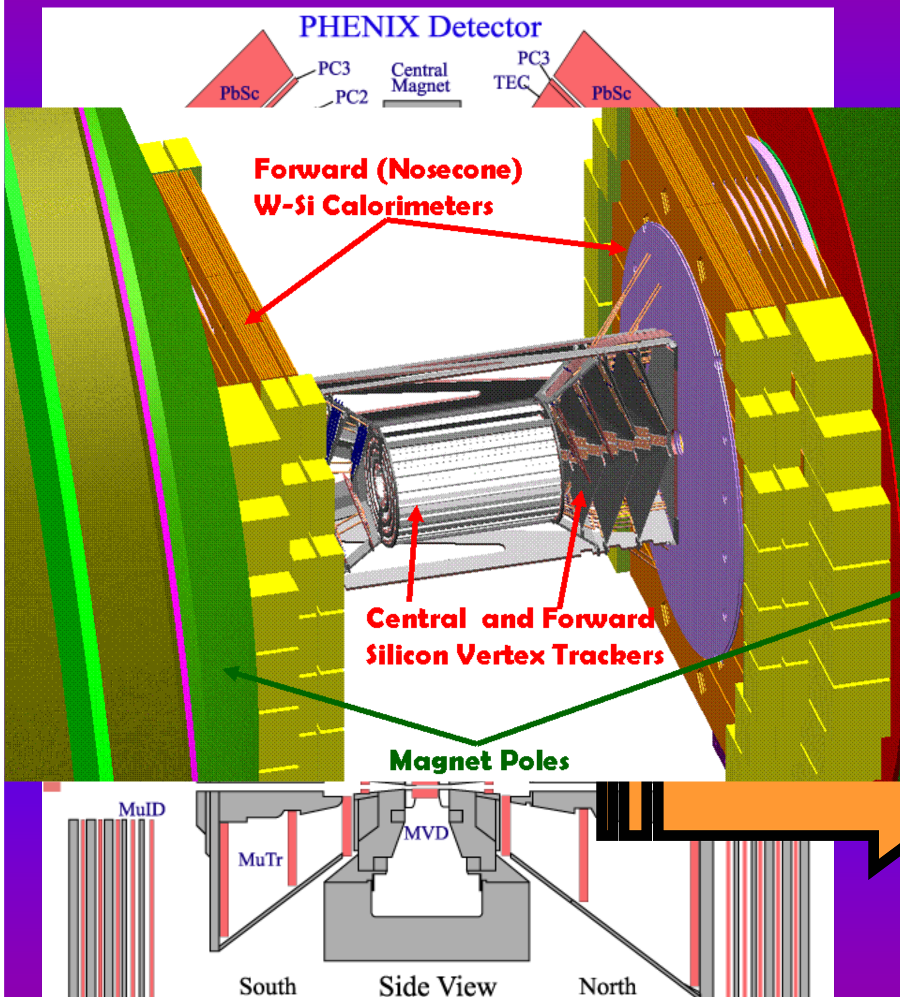
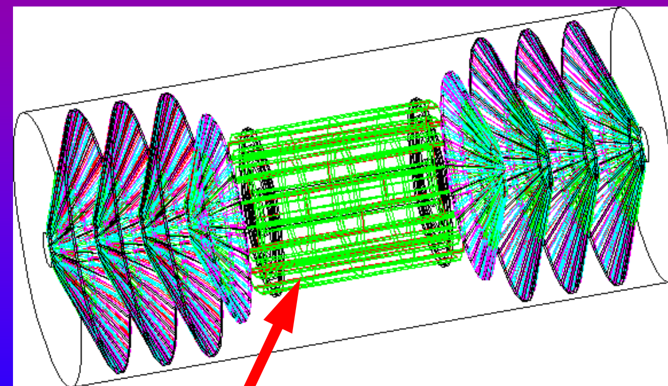
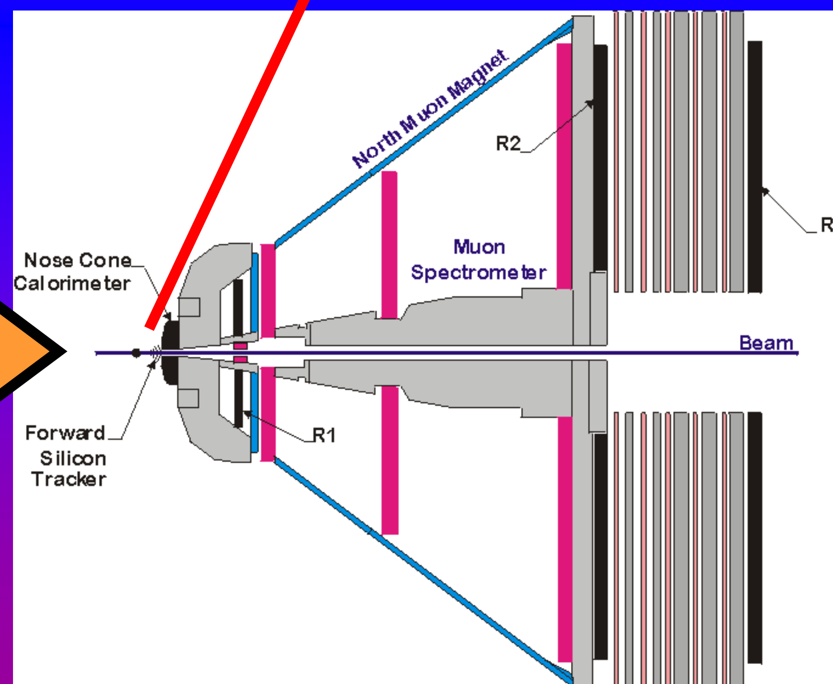
PHENIX Upgrade







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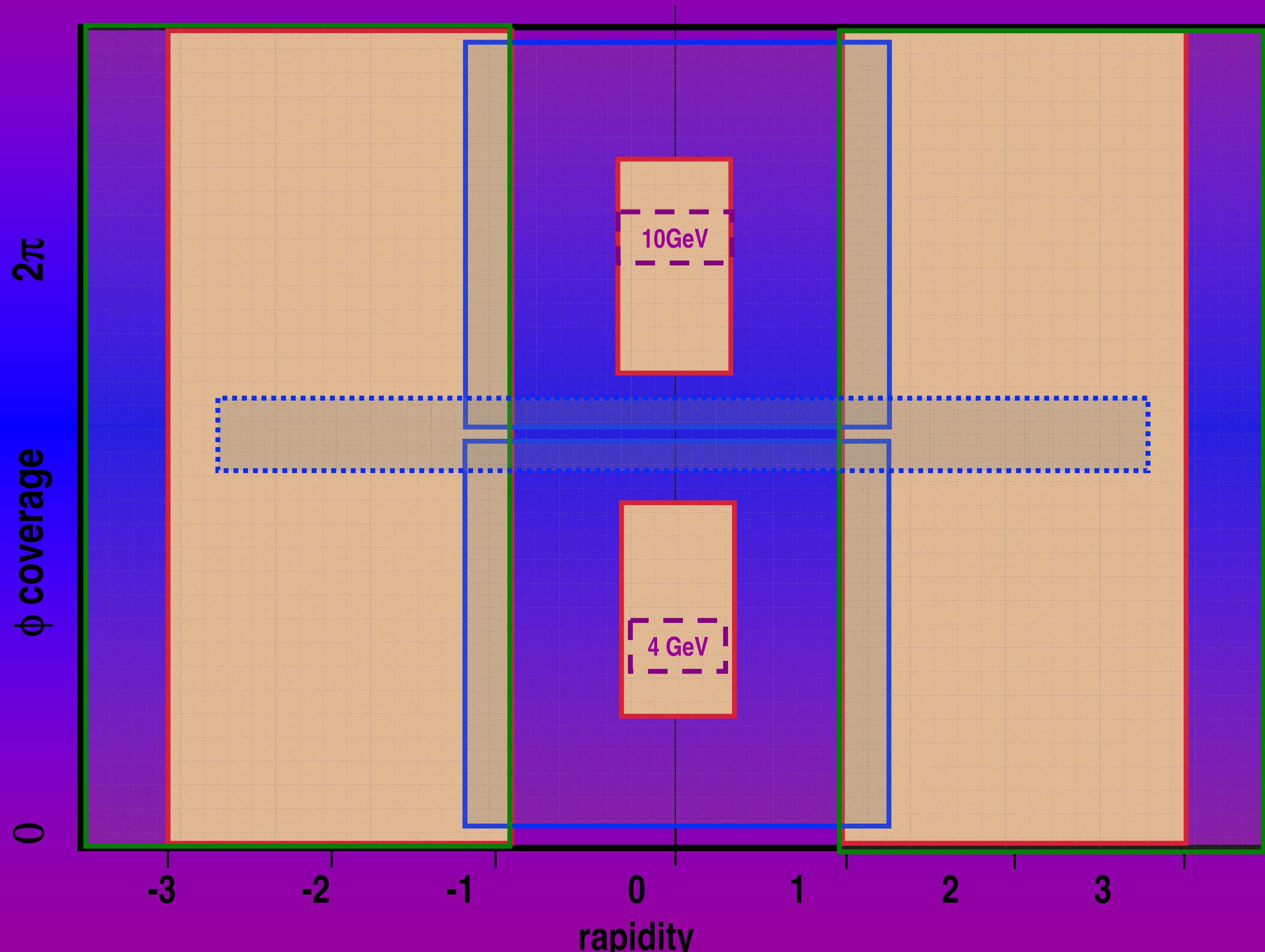
Upgraded PHENIX



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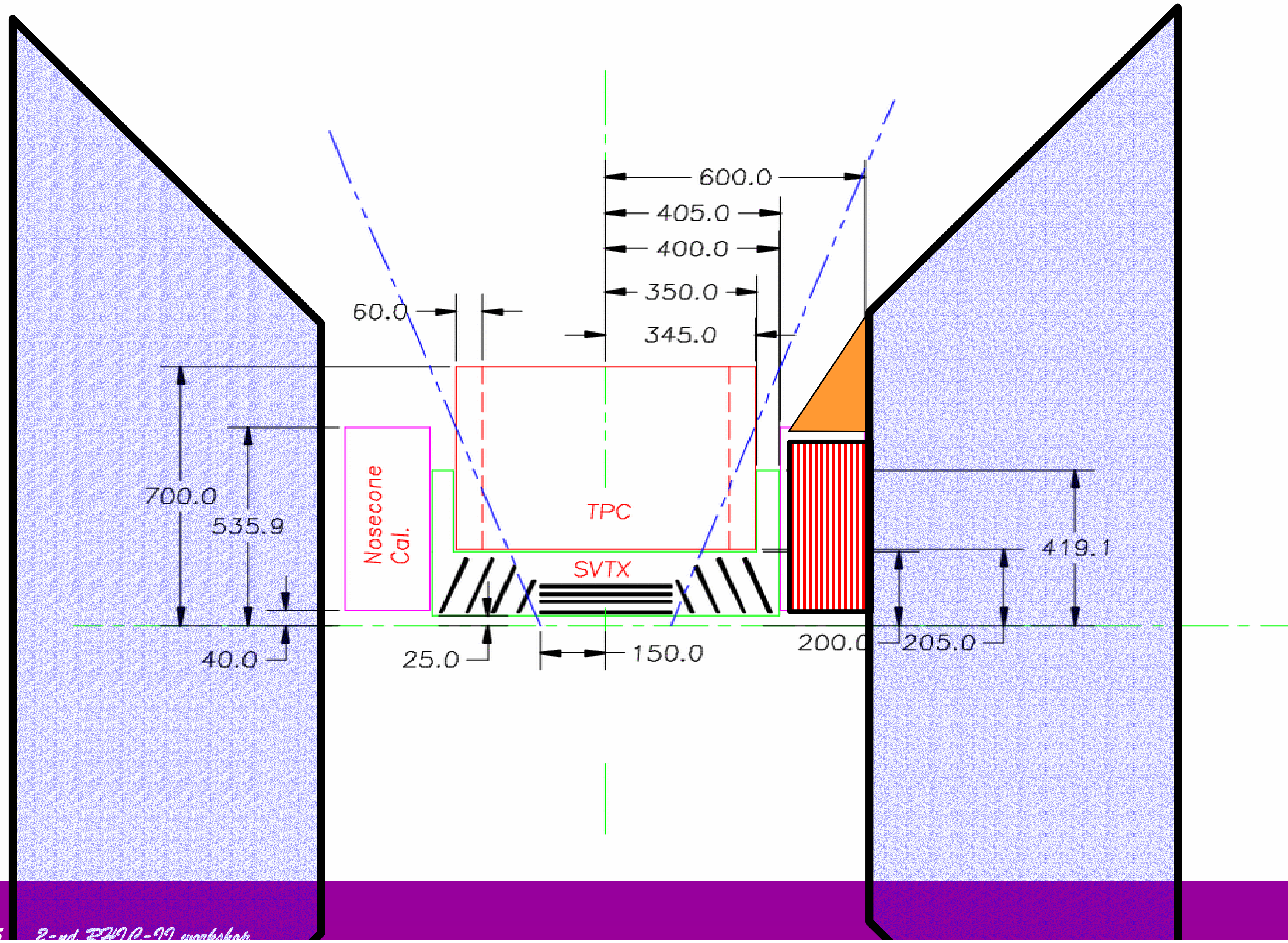
Real estate ....



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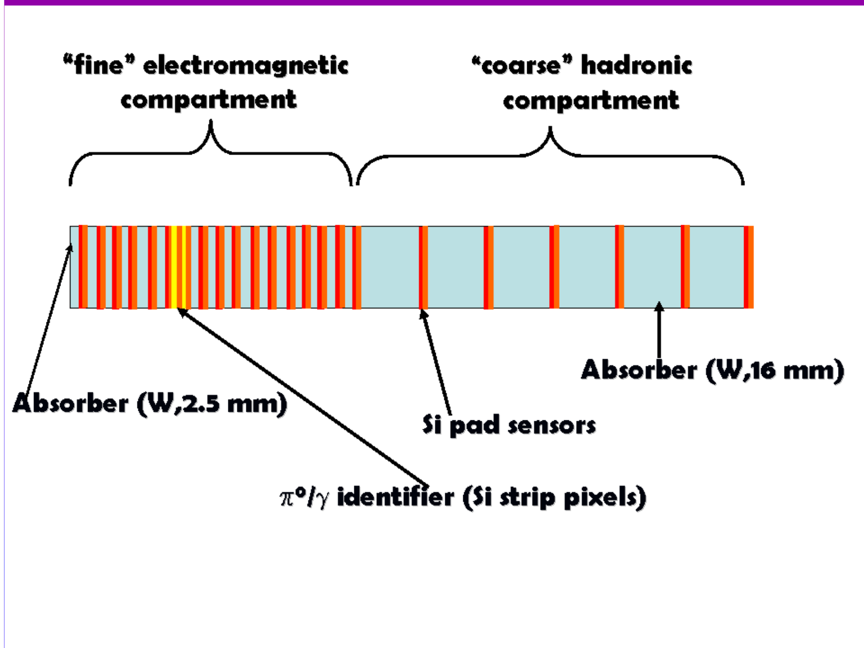
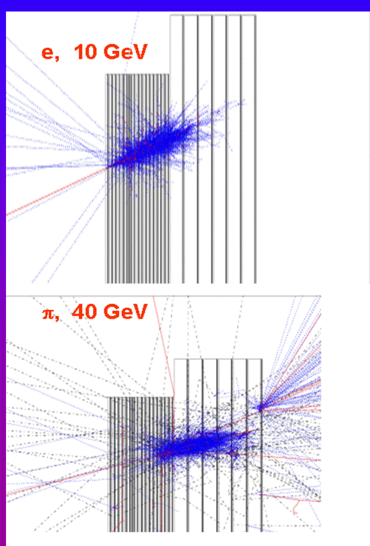
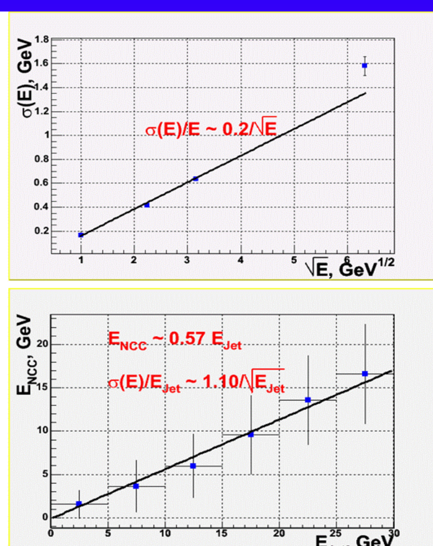
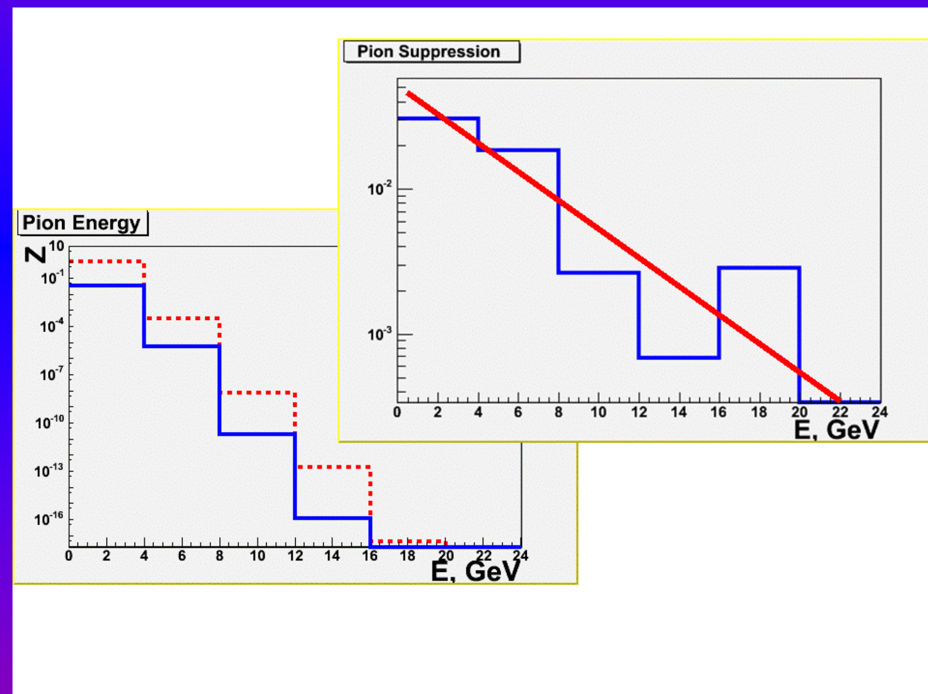
Few words on performance









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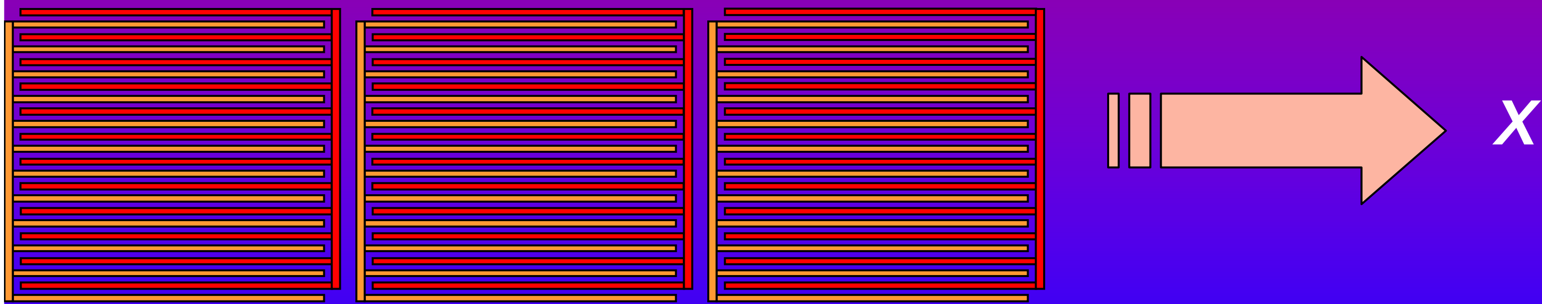
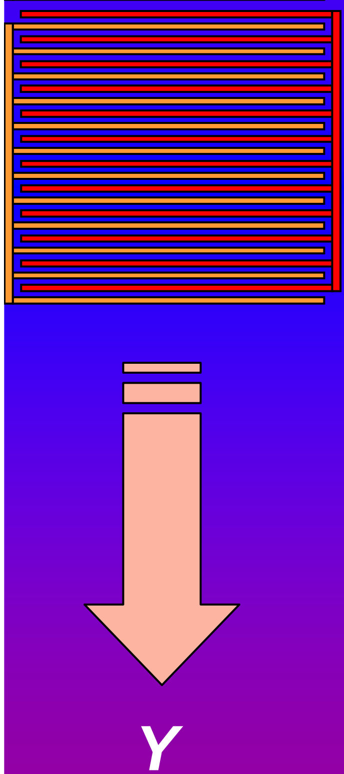
γ-π^0 identifier: Strip-Pixels





- PHENIX today resolves π^0's upto 15 GeV/c
- NCC is x10 closer to production vertex

  1.5 GeV/c

- x10 better lateral granularity (and x3 smaller molier radius) resulting in x 3.5 two photon separation

  5 GeV/c

- With 0.5 mm strips in the shower max we can separate two close photons down to ~2 mm compared to ~ 2 cm assumed for NCC itself

  ~30 GeV/c

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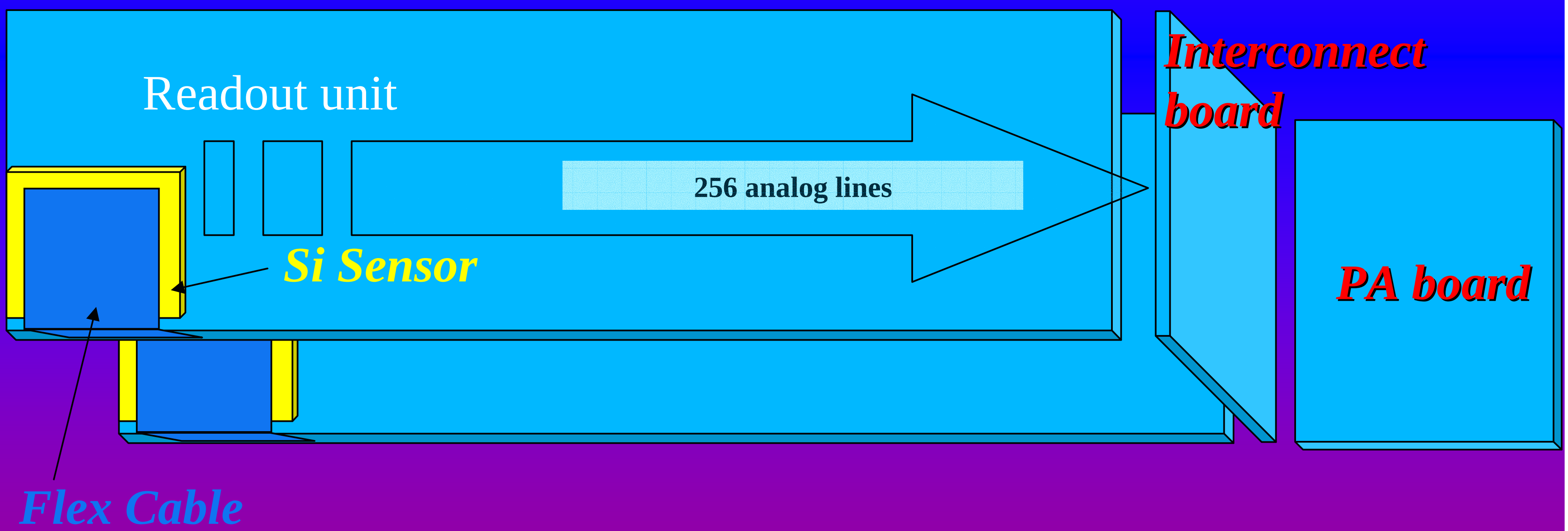
NCC signal packaging concept

-This is the calorimeter – all pads in the subtower are contributing to signal;

-Noise budget is set by physics: better is an enemy of the good;



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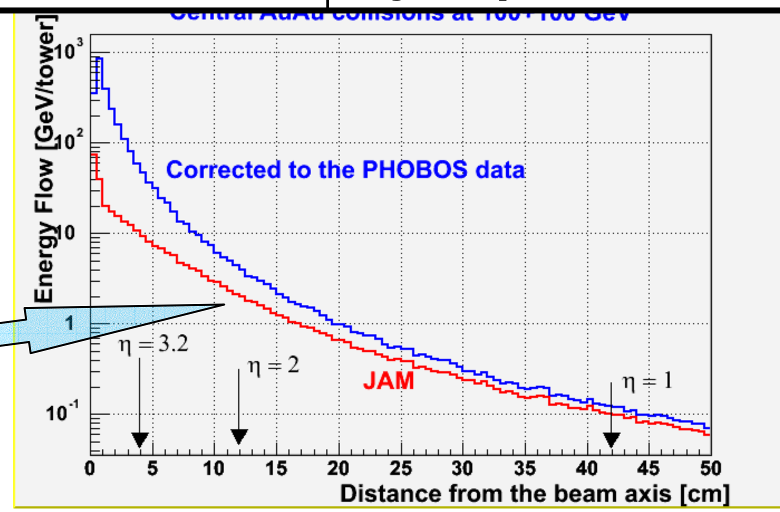
Readout: Dynamic range

Dynamic range [GeV]	~100	Kinematical limit
MIP in a single Si layer (e)	24k	~300 mkm Si
MIP in a subtower (e)	144k-240k	6 to 10 Si layers
Max. charge per event in a subtower(e)	2.1 10^8 or ~ 40 pC	50 GeV deposition, 1.7% sampling fraction
Dynamic range	>10000 MIP >1000 MIP_{10}	MIP_{10} (sum over 10 layers)



Underlying event contribution can be neglected even in the central AuAu collisions

Summary

o PHENIX has great plans for a program of new physics. It spans the whole range of pp (including polarized), pA and dA collisions at RHIC.

o Integrated forward spectrometer upgrade is the precondition for PHENIX to become uniquely positioned to study nuclear effects on PWF;

o We have technical solutions which match physics and present an excellent opportunity for new groups both in physics and instrumentation!

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MJT summary of Parton Model---1968

- The discovery that the DIS structure function

$$F_2(Q^2,\nu) = F_2(\frac{Q^2}{\nu}) \quad \nu = \frac{Q^2}{2Mx} \qquad (1)$$

"SCALED" i.e just depended on the ratio

$$x = \frac{Q^2}{2M\nu} \qquad (2)$$

independently of Q^2 $(\sim 1/r^2)$

- as originally suggested by **Bjorken** Phys. Rev. **179**, 1547 (1969)
- Led to the concept of a proton composed of point-like **partons**. Phys. Rev. **185**, 1975 (1969)
  - The probability for a parton to carry a fraction x of the proton's momentum is measured by $F_2(x)$

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