XXXIII ISMD Kraków 2003

Summary talk

G. Gustafson, Lund U

QCD Lagrangian simple
Solution complicated
Vacuum not understood
q & g always in a **medium**
(also in vacuum)

Cf QED: Lightning
Superconductivity

medium → new degrees of freedom relevant

quasiparticles:
massive electrons
fonons
quasiparticles in supercond.
spin waves
rotons
polarons
plasmons

topological defects: monopoles
vortex lines
fractional charges

Liquid ^3He

Lots of phases dep. on T, p, B

Different effective field theories

Gauge symmetry and general relativity

Lorentz inv. a low energy phenomenon. (cf Teshima)

Lower energy symmetry breaking

Result critically dep. on the symmetry of the medium.

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QCD

Diff. degrees of freedom active in

vacuum
nuclear matter
hadronic soup] in lab. non-static
qg plasma] prop. dep. on $\bar{r}, t$
not in therm. equil.

Reactions:

e^+e^- ep eA hh hA AA

⟶

higher complexity

This talk follows the same direction

A) "No medium"

Short distances: Medium less important

Pert. QCD works well

α_s runs

W. Metzger e^+e^- Shape variables
(power corr. not reliable descr.) (fig)

C. Gwenlan DIS: 3 jet events

(fig)

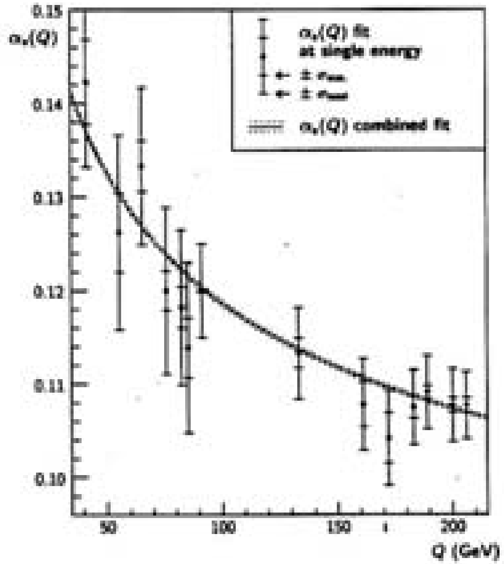
M. Przybycień $F_{2,c}^{\gamma}$ NLO OK

(fig)

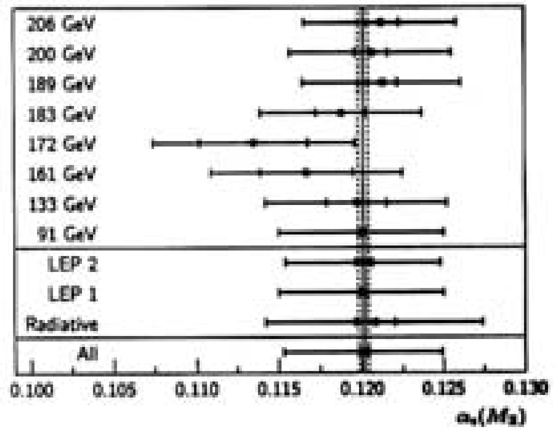
More 'pure'?

W. Metzger

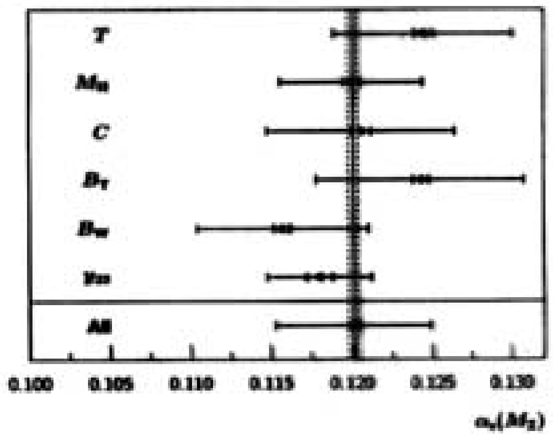
LEP QCD Working Group α_s combination – preliminary



Different energies are consistent



Different variables are consistent



LEP I:

$\alpha_s(M_Z) = 0.1200 \pm 0.0002$ (stat) ± 0.0008 (exp) $\pm$ **0.0010 (had)** ± 0.0048 (theo)

LEP II:

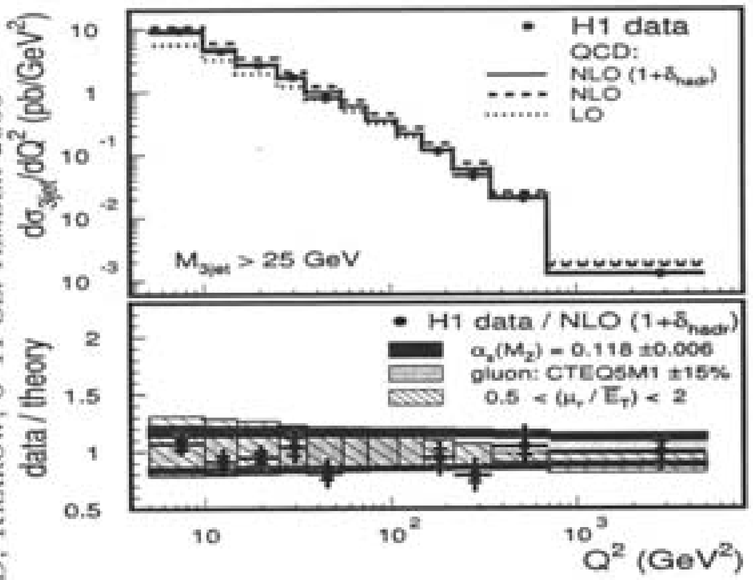
$\alpha_s(M_Z) = 0.1201 \pm 0.0005$ (stat) ± 0.0010 (exp) $\pm$ **0.0007 (had)** ± 0.0045 (theo)

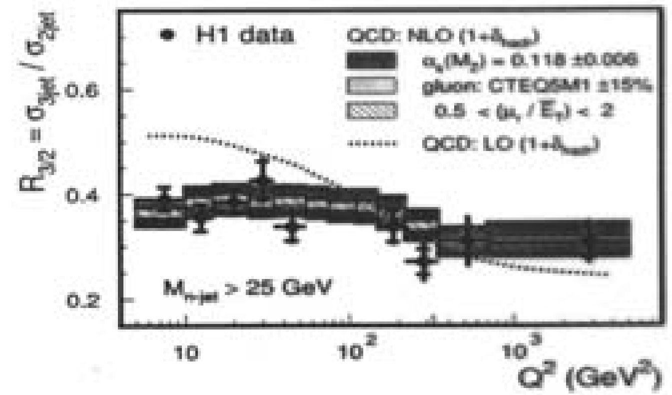
LEP I radiative (L3) + LEP I + LEP II:

$\alpha_s(M_Z) = 0.1201 \pm 0.0003$ (stat) ± 0.0009 (exp) $\pm$ **0.0009 (had)** ± 0.0047 (theo)

C. Gwenlan

Three-Jet Production in NC DIS





Three-Jet Production (H1 Data)

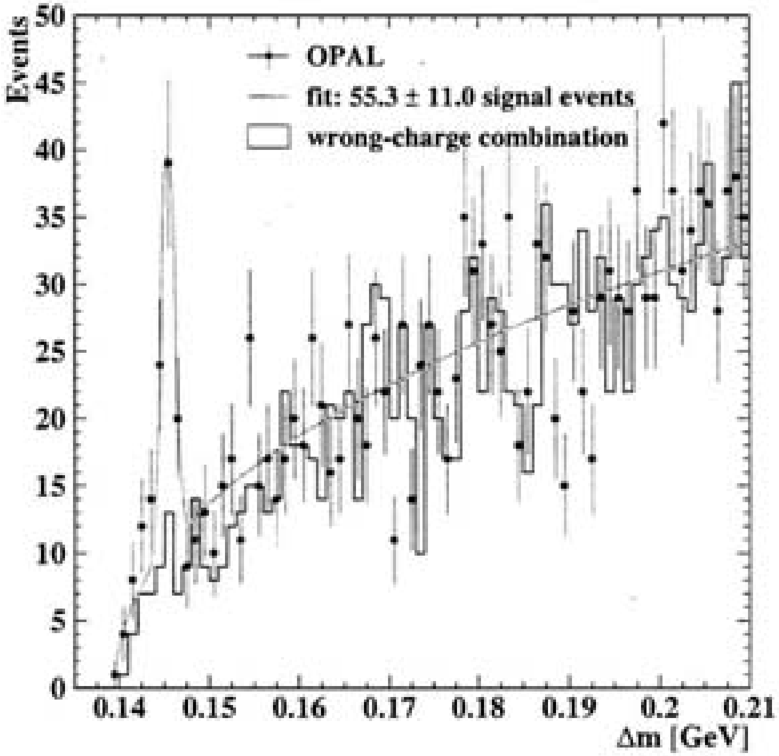
[Phys. Lett. B515 (2001) 17]

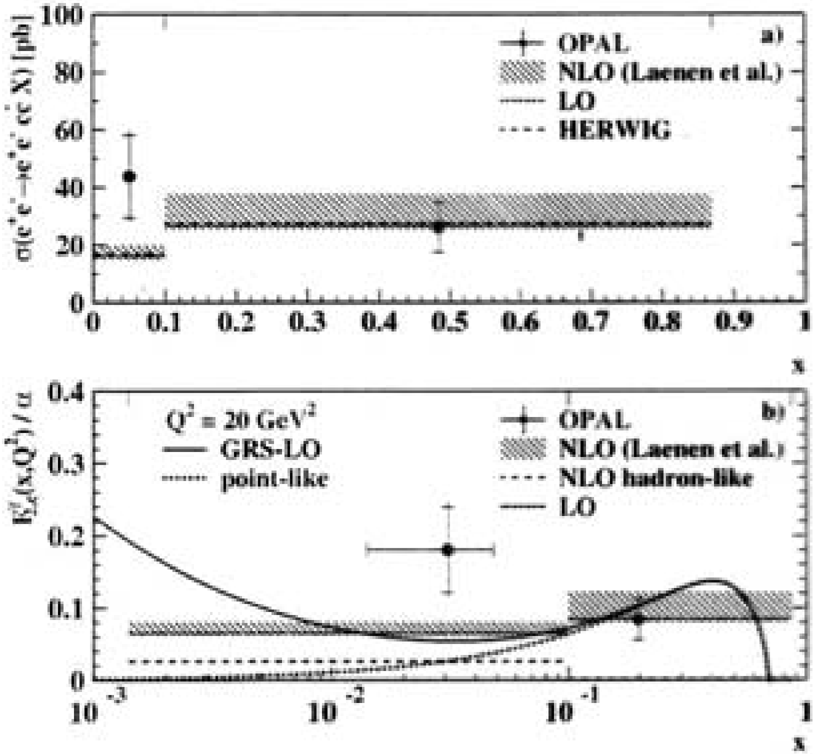
- $5 < Q^2 < 5000$ GeV^2
- $E_T^{\mathrm{Breit}} > 5$ GeV, $-1 < \eta^{\mathrm{Lab}} < 2.5, m_{3\mathrm{jet}} > 25$ GeV

- Tests understanding of pQCD at higher orders
  - → three jet production is $\mathcal{O}(\alpha\alpha_s^2)$ at Leading Order
- Good agreement between data and NLO calculation (NLOJET)
- In three-to-two jet rate, $R_{3/2}$:
  - → systematics partially cancel; reduced dependence on dynamics of jet production
  - → reduced uncertainties from proton gluon density and renormalisation scale

M. Przybycień

Measurement of charm structure function $F_{2,c}^{\gamma}$ – OPAL





Charm production tagged by D^*s. A clear signal in $\Delta M = M(D^*) - M(D^0)$ mass spectrum. High x: well described by pQCD. Low x: Higher than predicted, but large errors.

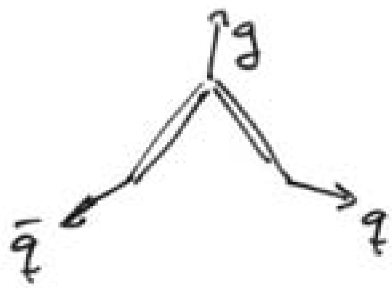
B) In Vacuum

Vacuum ~ dual superconductor ('t Hooft)

⇒ confinement

flux tubes or strings

e^+e^--ann.



gluon ~ transv. excit.

Works well for e^+e^--ann.

L. Zawiejski: DIS and e^+e^- similar

BE correl. the same

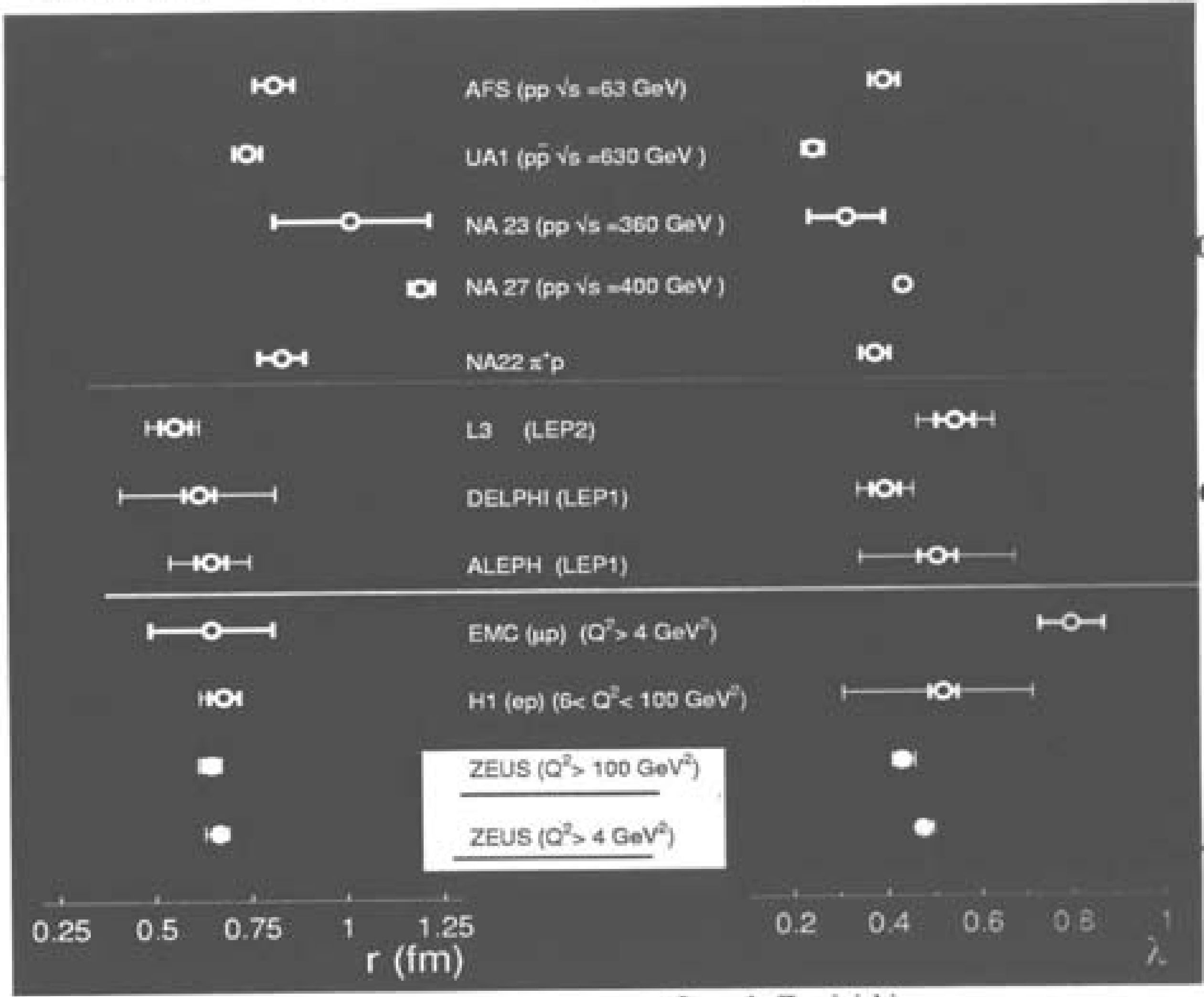
(at least outside p fragm. region)

No Q^2-dep. (figs)

Problem: Why is R_Λ so small?

G. Alexander

Results - 1D L. Zawiejski Comparison with other experiments



π^+ p

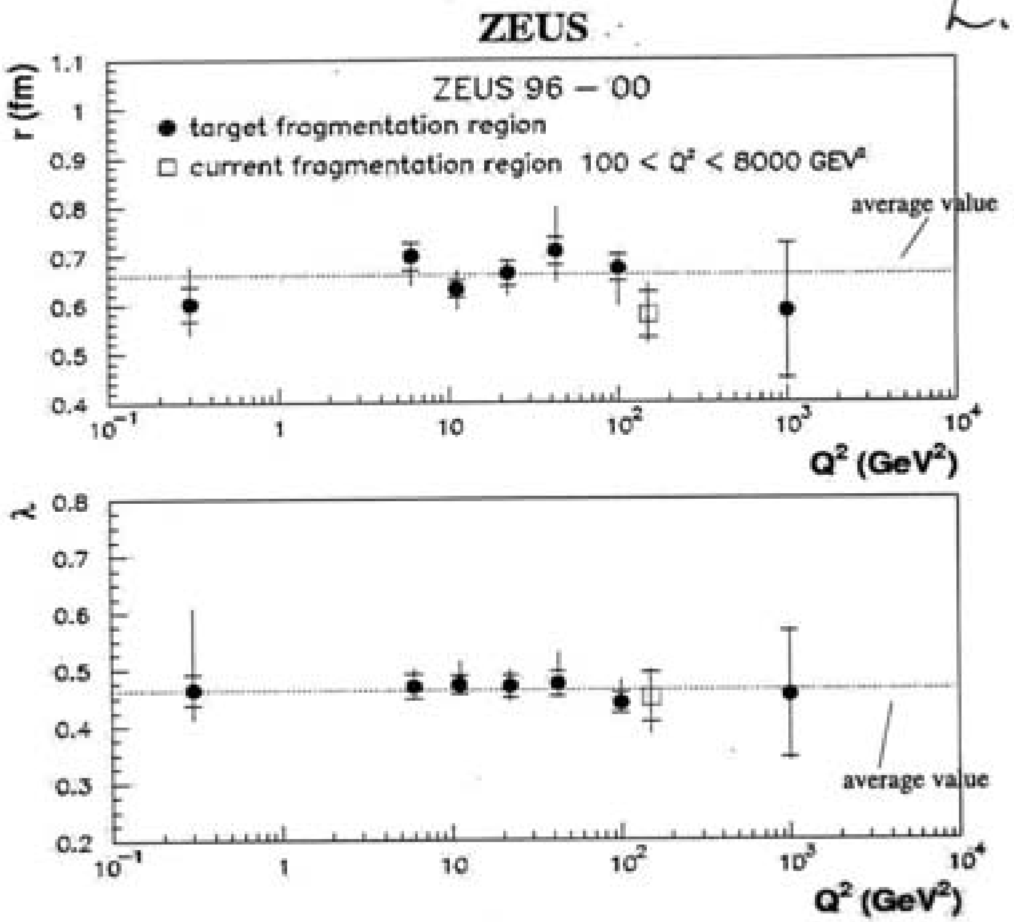
ons

ctions

filled band - ZEUS measurement for $Q^2 > 4$ GeV^2

Results - 1D The target and current regions of the Breit frame

L. Zawiejski



Target and current fragm. -

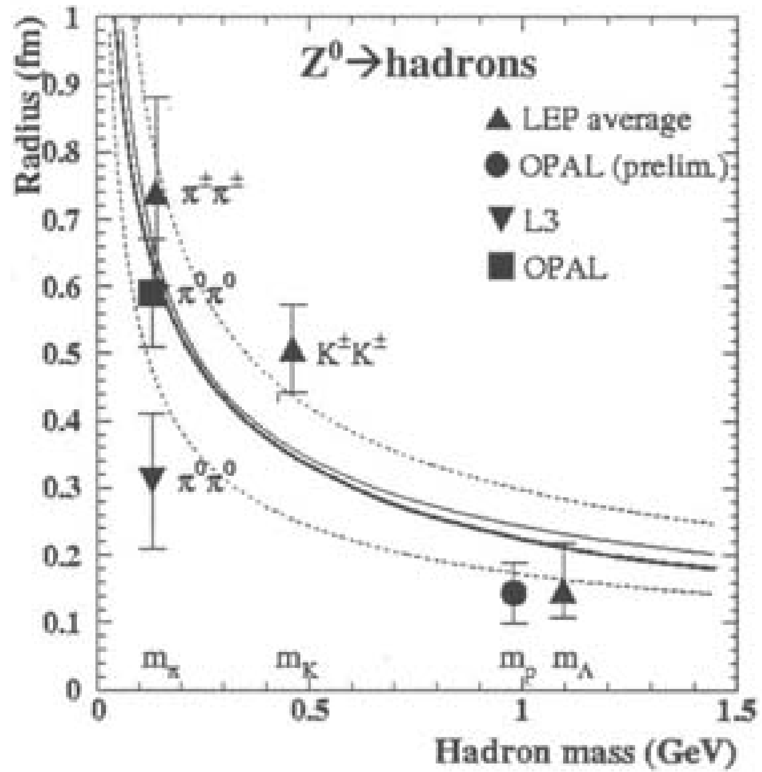
the significant difference in the underlying physics -

but the similar independence
r and λ
on the energy scale Q^2.

The global feature of hadronization phase?

G. Alexander

r(m) from BEC and FDC analyses



Uncertainty relations

$$r = c\sqrt{\hbar\Delta t / m}$$

with $\Delta t = 10^{-24}$ sec

QCD potential

$$V = \kappa r - \frac{4}{3}\frac{\alpha_s \hbar c}{r}$$

$$\kappa = 0.7\, GeV / fm$$

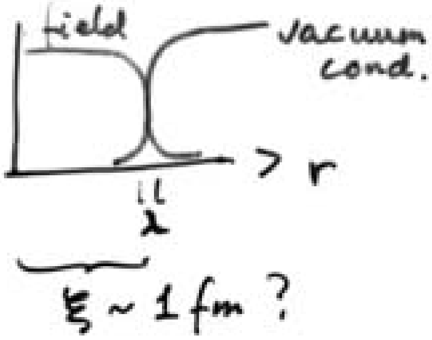
$$\alpha_s = \frac{2\pi}{9\ln(2 + 1.87/r)}$$

String interaction?

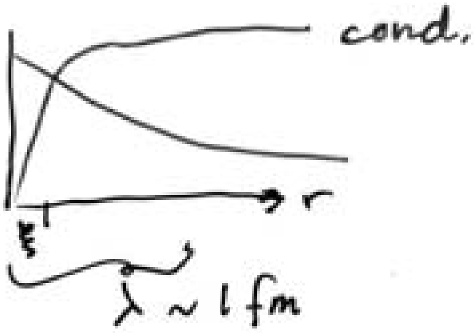
How wide are the strings?

~ Type I supercond. ~ bag

large interaction expected for overlapping fluxtubes



~ Type II supercond. ~ vortex line

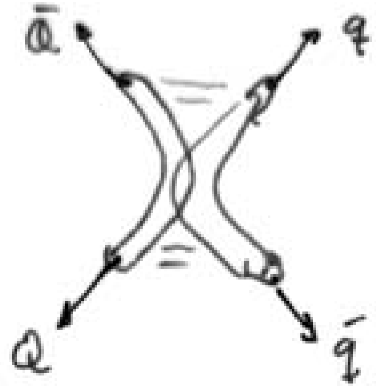


Interact when distance ~ $\xi < \lambda$

1) $e^+e^- \to WW$ <u>N. van Remortel</u>

$\hookrightarrow q\bar{q}$

$\hookrightarrow Q\bar{Q}$



Crosstalk hardly seen

Weak interaction $\neq 0$

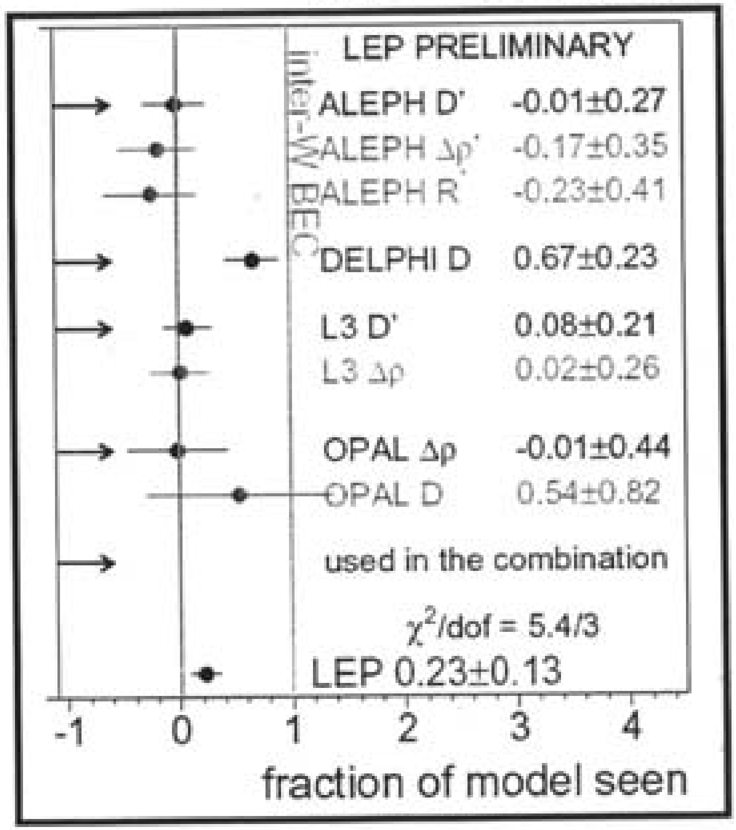
(fig)

2) 3 jet events

Strings seem to interact very weakly

<u>W. Metzger</u>

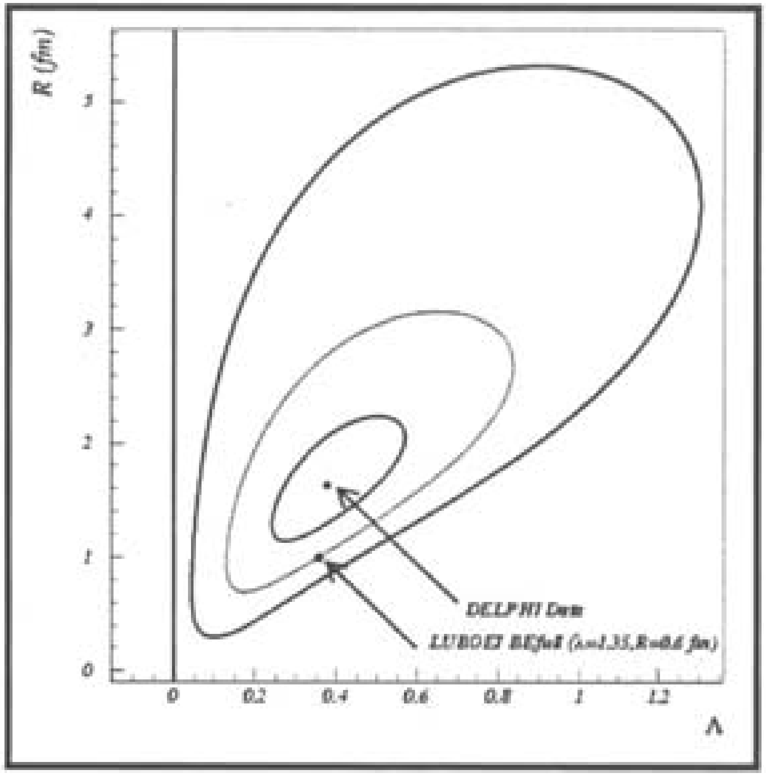
LEP-wide combination of WW BEC results



Measurements cannot be directly combined. ➡ Observed fraction of BEfull model is used.

Combined results observe 23% of the LUBOEI BE32 model With inter-W BEC.

This results in a small W mass uncertainty due to BEC: [redacted]



Data tend to prefer a larger source size than the Befull MC, tuned to Z0 data.

⇓

Might be an indication of HBT-like BEC at work

3) String percolation in AA

C. Pajares , J. Ranft

Possible to describe multiplicity and $p_\perp$ distributions.

But these observables can also be described by other models.

More work needed to find discriminating observables

4) $c \to \Psi$ problem

singlet - octet contributions
↑
How does the colour disappear?

Vacuum medium active?

P. Pakhlov

$$\frac{e^+e^- \to \Psi c\bar{c}}{e^+e^- \to \Psi \Sigma} \sim 60\%$$

>> expected from pQCD

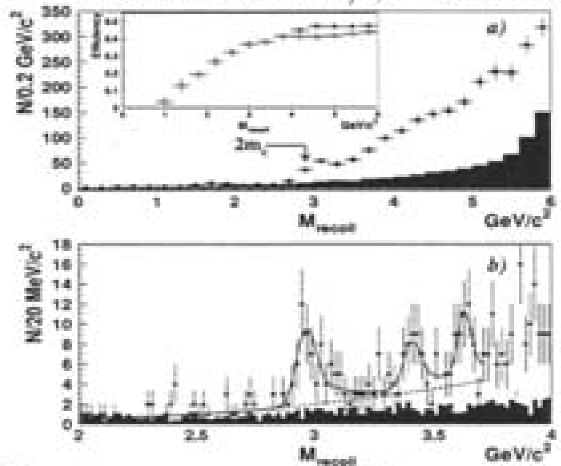
P. Paklov

First observation of $e^+e^- \to J/\psi c\bar{c}$

BIG SURPRISE #2:

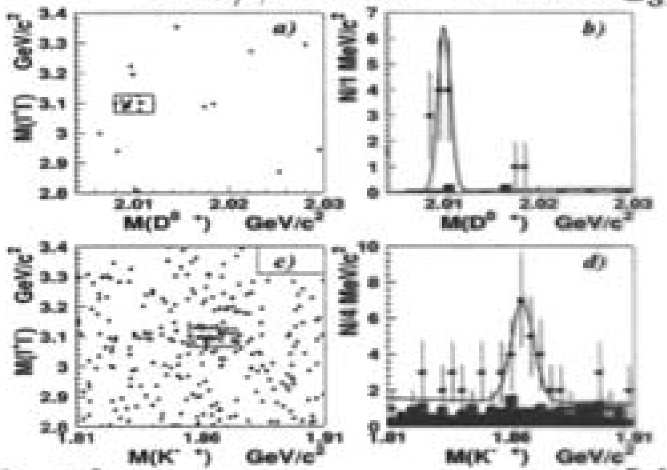
Belle observed many processes with prompt J/ψ accompanying by charm particles (PRL *89*, 142001 (2002)):

- Threshold in J/ψ recoil mass



- Charmonium in J/ψ recoil mass spectrum

- D^{*+} in J/ψ event: $\mathrm{N} = 10.5^{+3.6}_{-3.0}$



- D^0 in J/ψ event: $\mathrm{N} = 14.9^{+5.4}_{-4.8}$

$$\sigma(e^+e^- \to J/\psi\, c\bar{c})/\sigma(e^+e^- \to J/\psi\, X) = (0.59^{+0.15}_{-0.13} \pm 0.12)$$

$$\sigma(e^+e^- \to J/\psi\, \eta_c) \times \mathcal{B}(\eta_c \to > 2\,\mathrm{charged}) = (0.033^{+0.007}_{-0.006} \pm 0.009)\mathrm{pb}$$

Another problem

A Sciaba : b fragm. OK in string model
(with Bowler correction)

but $\gamma\gamma \to b\bar{b}$ = 2 × expected

(fig)

÷

Related both to vacuum and no medium

S. Campana : Nonbiased gluon
fragmentation

(fig)

÷

Related to vacuum?

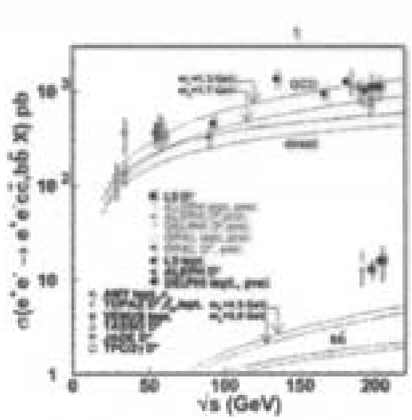
M. Negrini : p form factor in
time-like region
gas-jet target

(fig)

Andrea Sciabà

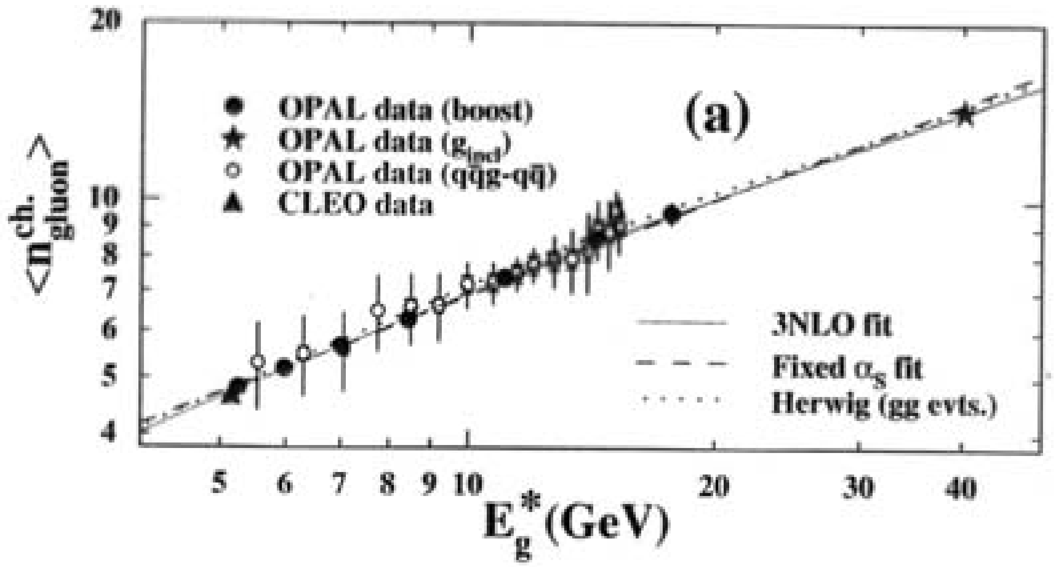
$\gamma\gamma \rightarrow bb(cc)$ summary

- Consistent results among LEP experiments
- Good agreement with Drees et al. model for charm data
- EXCESS for beauty data:
  4σ discrepancy
- No satisfactory explanation at present



S. Campana

Results : mean multiplicity



- Results **consistent** with previous measurements of unbiased gluon jets
- Most precise results for $5.25 < E^*_g < 20GeV$
- Theoretical expressions **successfully fitted** to experimental data:

→ **3NLO** : takes into account the running nature of α_S

→ **Fixed** α_S: incorporates more accurately higher order effects

M. Negrini

Proton form factor in the time-like region

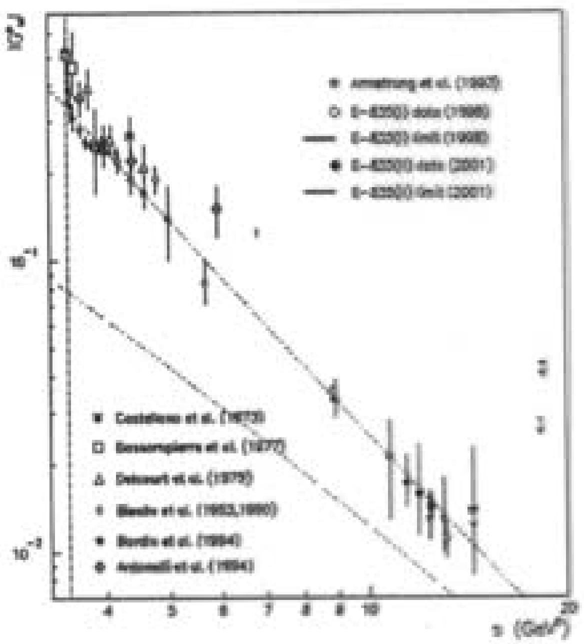
- Measurement of non resonant cross section for the process $\bar{p}p \rightarrow e^+e^-$
- First order QED prediction:

$$\frac{d\sigma}{d\Omega}=\frac{\alpha^2\beta_p C}{4s}\left[|G_M|^2(1+\cos^2\theta^*)+\frac{4m_p^2}{s}|G_E|^2\sin^2\theta^*\right]$$

  - At threshold: $|G_E|=|G_M|$ (uniform angular distribution)
  - At high s: $|G_E|$ contribution negligible
- QCD asymptotic behavior:

$$\frac{|G_M|}{\mu_p}=\frac{C}{s^2\ln\left(s/\Lambda^2\right)}$$

C and Λ free parameters



Upper limits at 90% C.L.

M. Andreotti *et al.*, Phys. Lett. B 559 (2003) 20

c) Dense gluonic state

Small x (Overview N. Armesto)

$k_\perp$ - factorization

BFKL : $k_\perp$ -nonordered ladders

saturation

scaling (fig)

colour glass condensate (classical gluon field)

E. Łobodzinska

F_L determined by H1

sensitive to gluon pdf

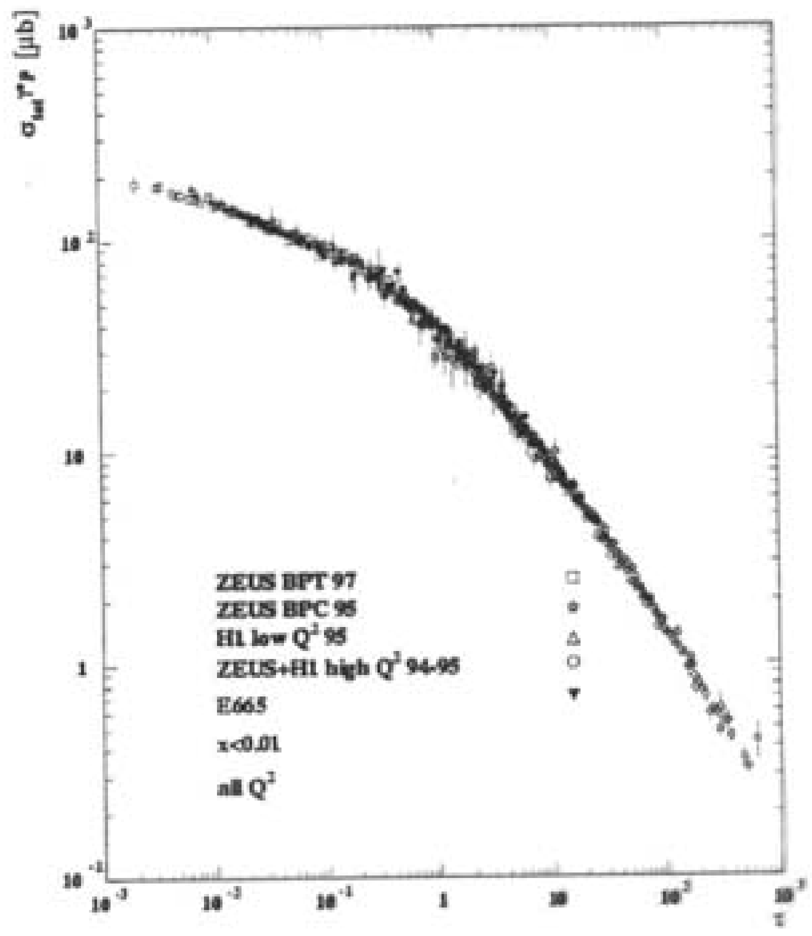
important to constrain fits

P. Steinberg

Saturation predicts that a single scale dominates low-x gluon structure

Predicts "geometrical scaling"

$$\tau = \frac{Q^2}{Q_0^2}\left(\frac{x}{x_0}\right)^{\lambda} \sim \frac{Q^2}{Q_s^2}$$



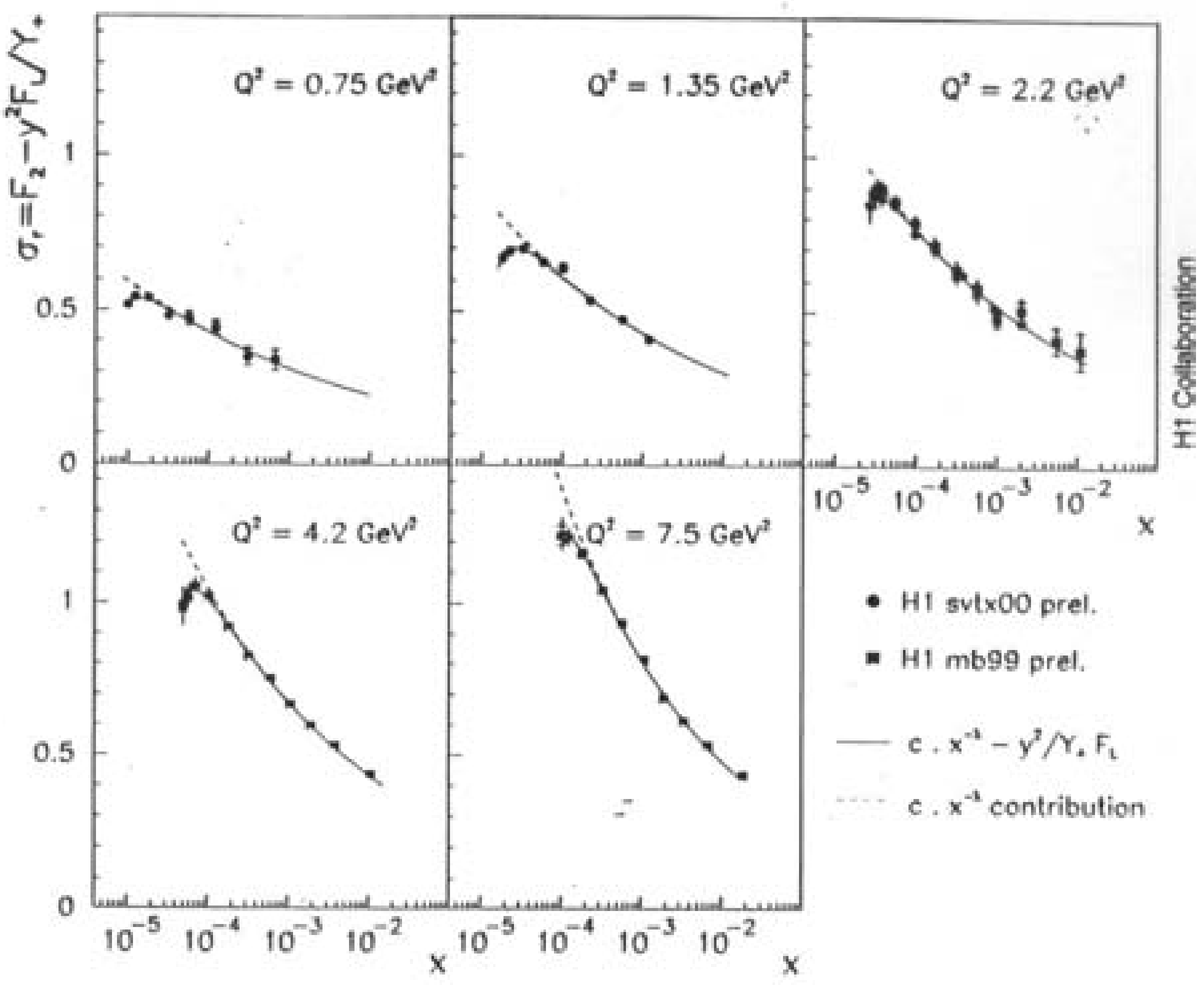
Stasto, Golec-Biernat, Kwiecinski (2001)

F_L determination in H1 with "shape method"

E. Łobodzińska

- shape of σ_r driven by kinematic factor y^2/Y_+ rather than by F_L
- constant F_L for small x range
- whole x range of measured data used to fit F_2 and F_L $\Leftrightarrow$ no extrapolation of F_2 $\Leftrightarrow$ full information used $\rightarrow$ smaller errors
- fit in Q^2 bins: $\sigma = F_2 - y^2/Y_+ \cdot F_L$

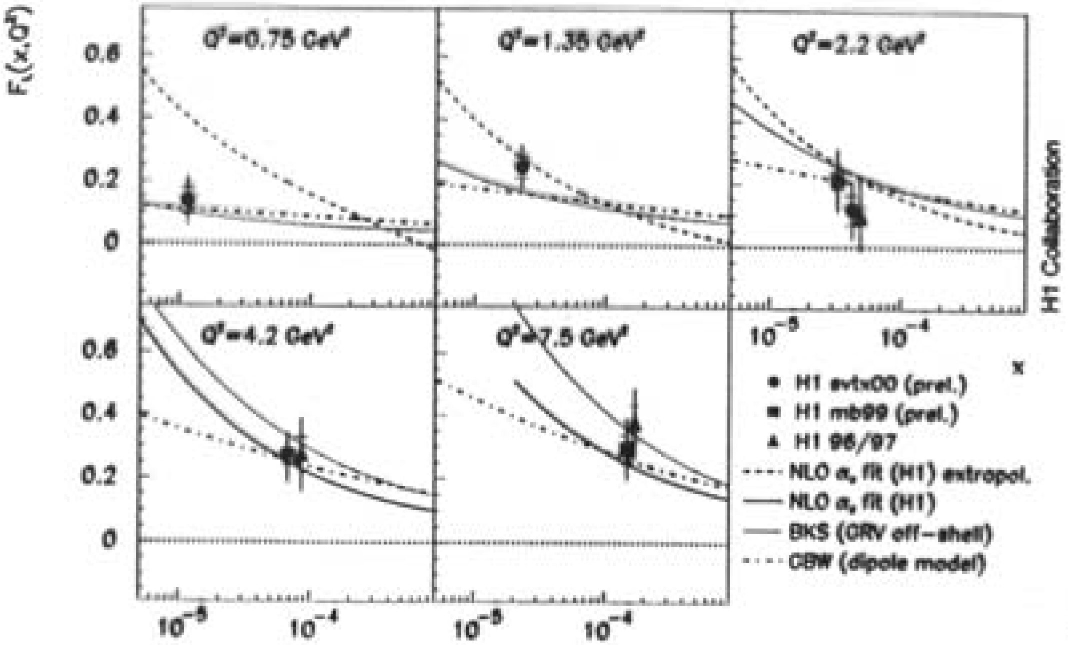
$$F_2 \uparrow \; c \cdot x^{-\lambda}$$

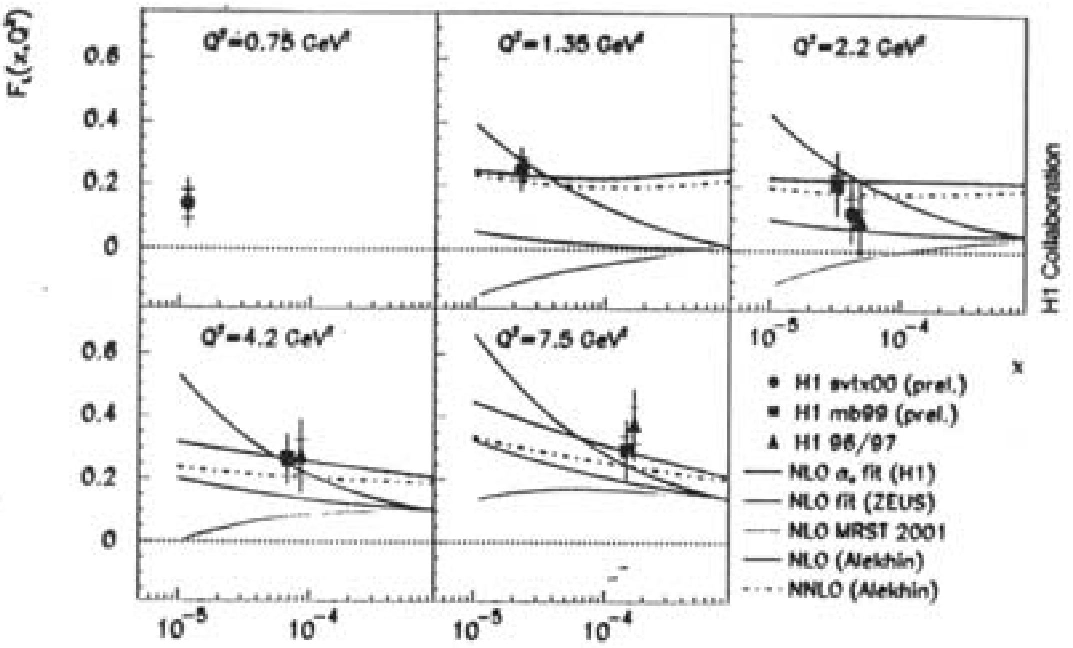


- excellent description of σ_r by the "shape" fit in full kinematic region

F_L extraction in H1

E. Łobodzińska

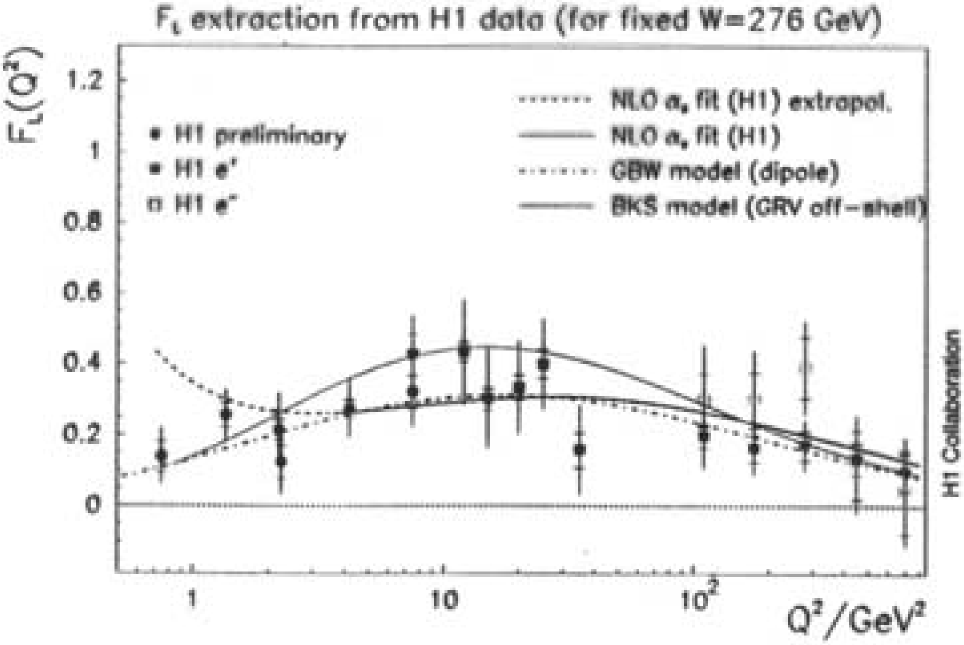




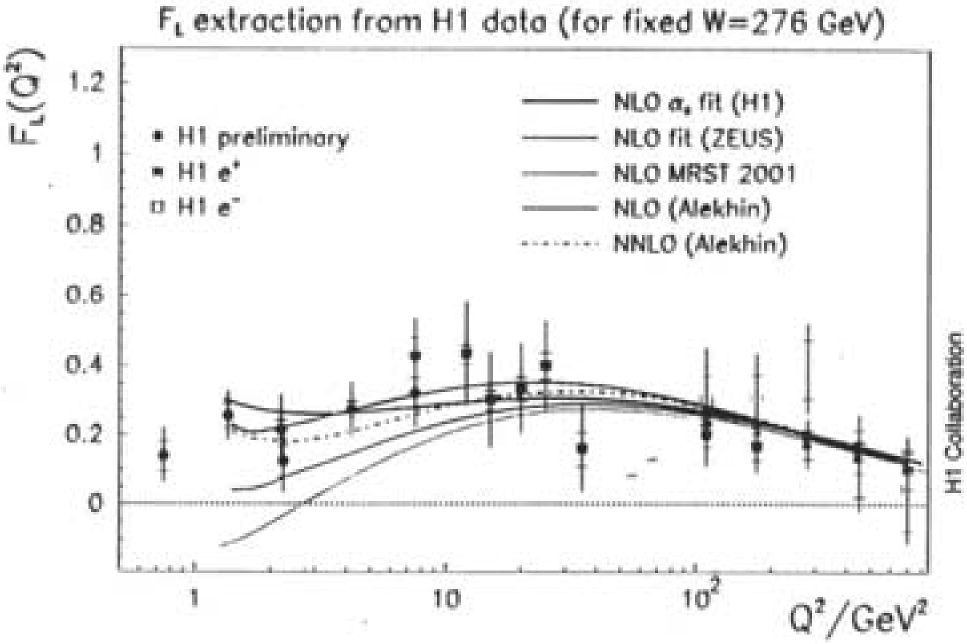
- first extraction of F_L for $Q^2 \sim 1$ GeV^2
- extracted $F_L > 0$ in all Q^2 bins
- extracted F_L is able to constrain theoretical predictions
- measurement of x dependence of F_L is desirable – can be achieved by running with dedicated low E_p beam

F_L extraction in H1

E. Łobodzińska



- **GBW dipole model describes the data in the whole region**
- **BKS model goes steeper but still in agreement with the data**



- **H1 NLO QCD fit consistent with the data in the DIS region**
- **Alekhin NLO (and NNLO) in agreement with data**
- **MRST 2001 NLO QCD fit too low at low Q^2**
- **ZEUS NLO QCD fit also tends to be low at low Q^2**

H. Jung MC result for $k_\perp$-factoriz formalisms

CCFM – CASCADE

LDC – LDCMC

Heavy quarks at Tevatron

Forward jets at Hera (cf. S. Magill)

Earlier problems better understood.

(fig)

B. Olivier

b-quarks at Hera

also in agreement with NLO calc

CCFM solves the problems

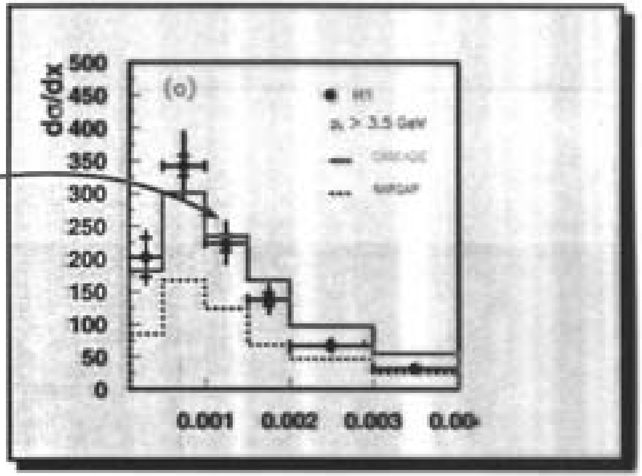
H. Jung

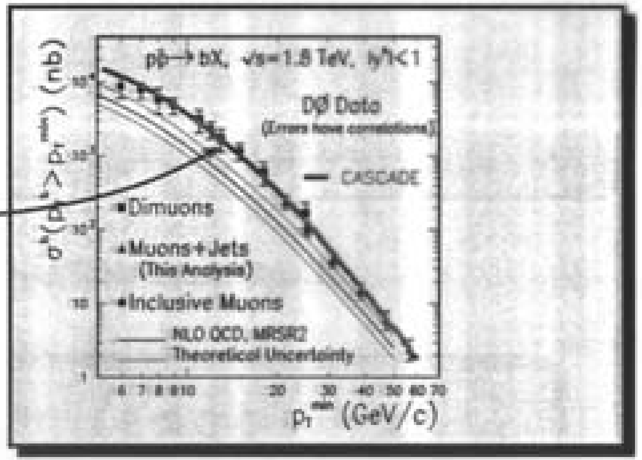
Solve CCFM equation
to fit F_2 data from HERA

- obtain CCFM un-integrated gluon
  CASCADE MC implements CCFM:
- predict fwd jet x-section at HERA ✔
- predict charm at HERA ✔
- predict bottom at HERA ✔

- test universality of un-integrated gluon density from HERA
- predict bottom at Tevatron ✔
- w/o additional free parameters

WOW !!!

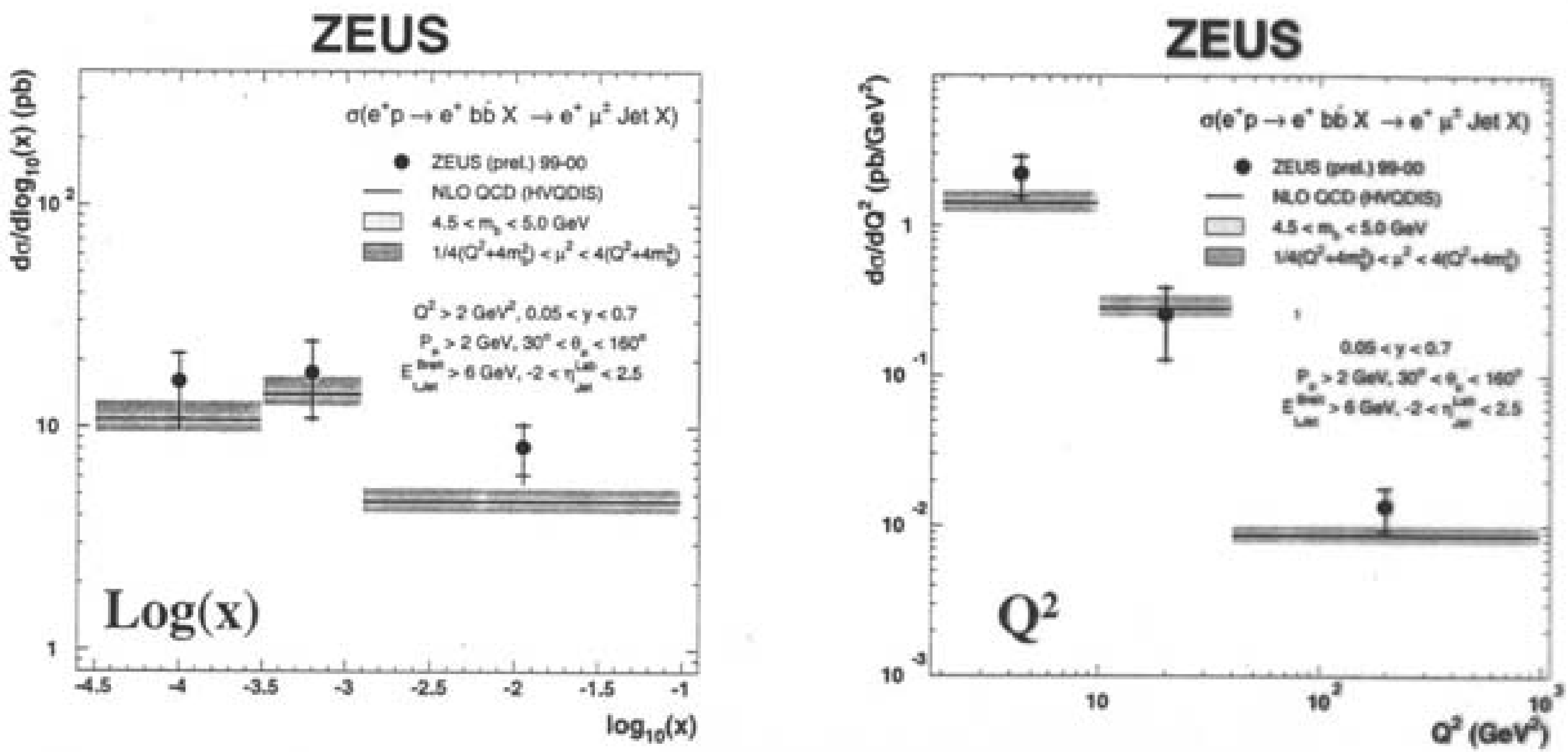




B. Olivier

Beauty in DIS

ZEUS: $Q^2 > 2\,\mathrm{GeV}^2$



- **Data and NLO in agreement within errors**

A. Staśto Saturation

Solution to Balitsky - Korchegov eq.

(Non-linear term important at high dencities.)

Result: Limited flow to very small $k_\perp$

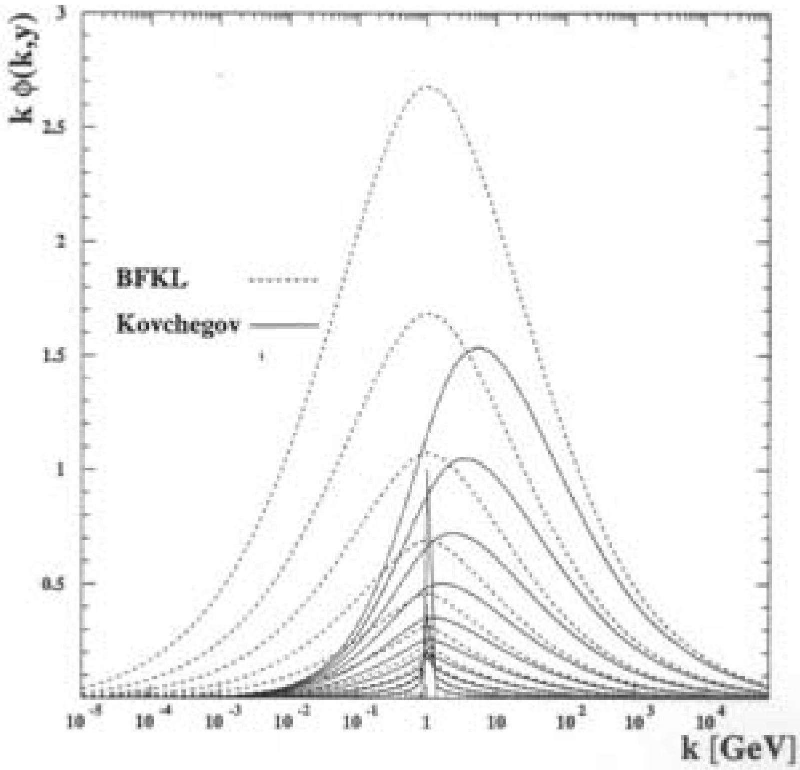
(fig)

Solution without b dependence

Balitsky- Kovchegov eq.

A. Staśto

K.Golec-Biernat, L.Motyka,A.S.



Momentum space.

$\phi(k,Y) = \int_0^\infty \frac{dr}{r} J_0(kr) N_Y(r)$

Rapidities from $Y = 1$ to $Y = 10$.

The maximum of the $k\phi$ distribution moves with the saturation scale $Q_s(Y)$.

Appl. to hh or AA

P. Steinberg : Saturation not seen at RHIC
dA coll (Fig)

A. Korytov Min. bias events at Tevatron
tuned Pythia MC OK

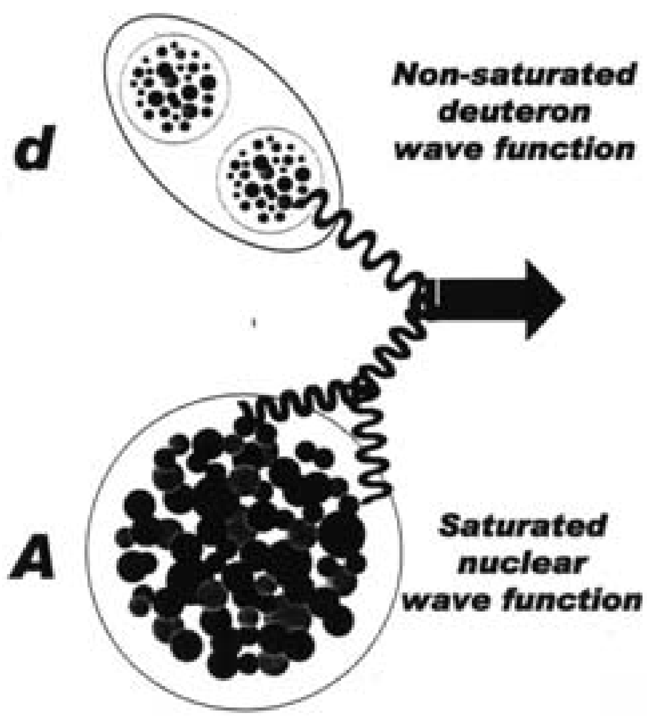
C. Butter Extrapolate to LHC ?

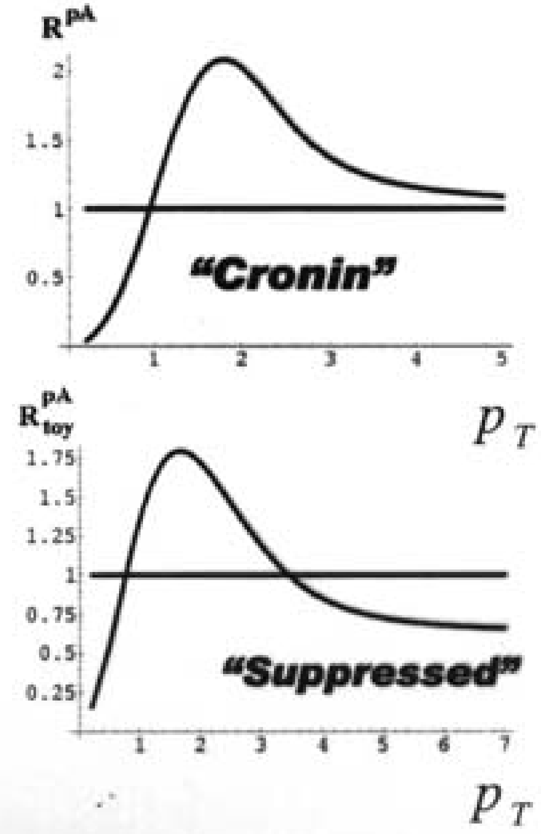
A. Szczurek Apply $k_\perp$ - factorization
formalism to hh coll.
Stabilizes low-$p_\perp$ minijets

H. Pirner New 2nd order phase trans.
dipole gas - dipole liquid
critical point determined
by Z_3 symm. in SU(3)

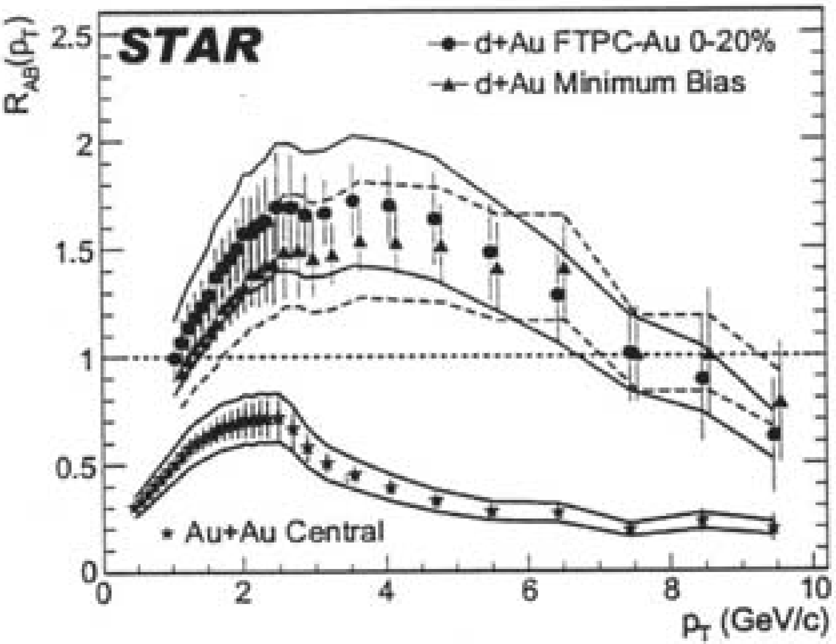
P. Steinberg

To rule out saturation scenario, RHIC devoted a large fraction of Run 3 to d+Au collisions

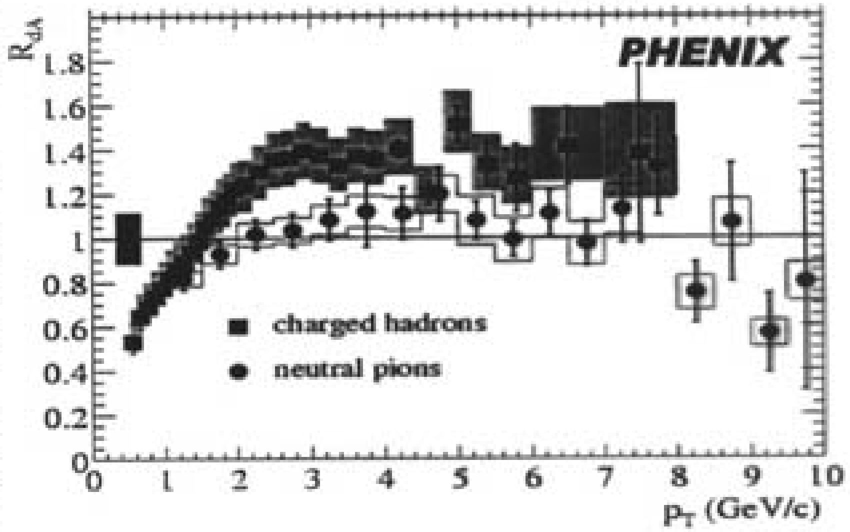




P. Steinberg



$$R_{dA} = \frac{1}{T(b)} \frac{dN/dp_T|_{d+A}}{d\sigma/dp_T|_{p+p}}$$



Striking absence of suppression claimed by all experiments, especially relative to central Au+Au

Dominant physics seems to be "Cronin Effect" (R>1)

D) Nuclear matter

- gluon radiation
- parton rescattering
- string loss
- hadron absorption

review H. Pirner

1) P. van der Nat

Hermes eA quark propagation

Large attenuation for small ν

Strong A-dep.

Not fully understood, but favours QCD-based models

(fig)

2) A. Rybicki hA vs AA

Leading particles: Valence quarks in nucleus propagate like – " – in hadron

(fig)

3) E. Gottschalk Doubly charmed baryons

Selex pA, $\Sigma^- A$

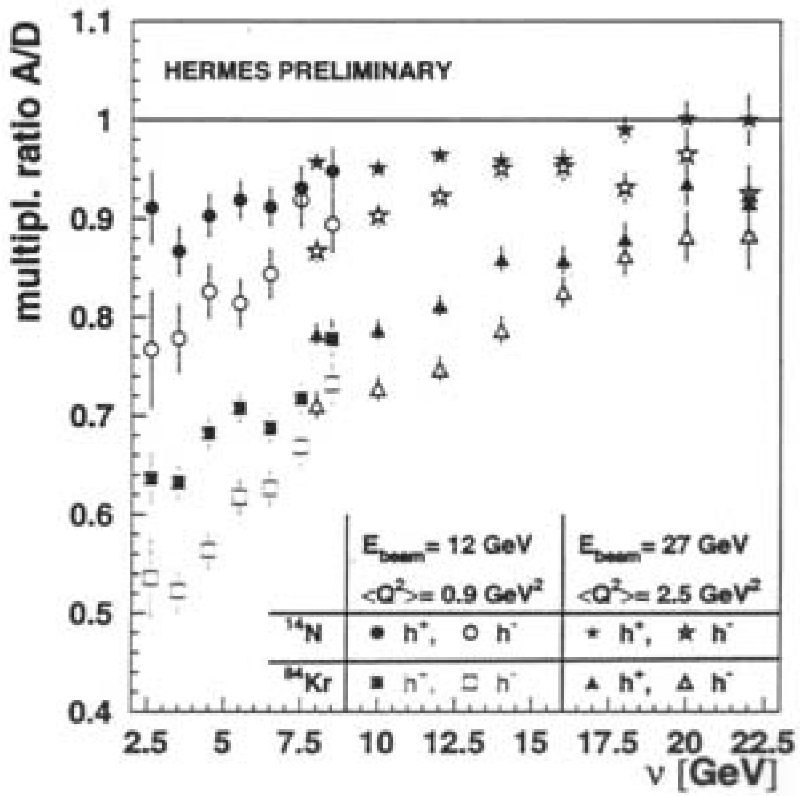
(fig)

(Not confirmed by other exp.)

P. van der Nat

New results at 12 GeV beam energy

New data extends existing data to lower ν: **Large Attenuation!**



qualitative behavior of 27 GeV data confirmed

P van der Nat

Model calculations for ^{84}Kr, ^{14}N vs. ν

strong A-dependence

I fragmentation function modification:

$$D_f^{h|A}(z,Q^2) = D_f^h(z,Q^2) + \Delta D_f^h(z,Q^2)$$

pQCD based model, with:

- multiple scattering
- induced gluon radiation

Wang et al. [PRL **89**(2002) 162301]

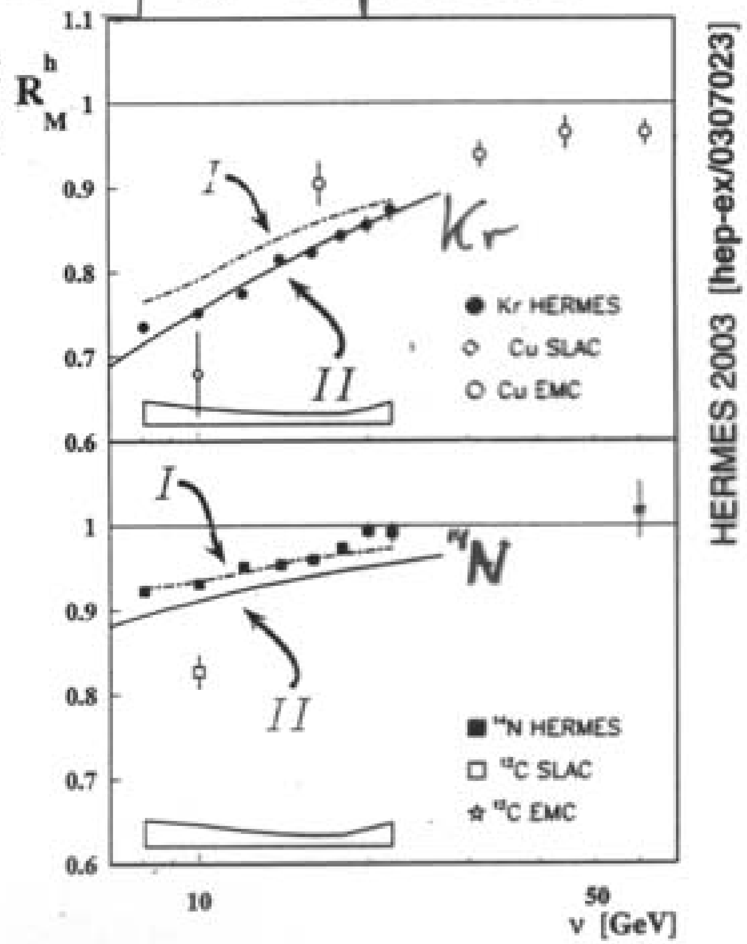
II Rescaling model:

$$q_f^A(x,Q^2) = q_f(x,\xi_A(Q)Q^2)$$

$$D_f^{h|A}(z,Q^2) = D_f^h(z,\xi_A(Q)Q^2)$$

comb. with (pre-)hadron absorption

A. Accardi et al. (2003)**[nucl-th/0211011]**



HERMES 2003 [hep-ex/0307023]

hermes

P. van der Nat

A dependence of the data, $R_{\mathrm{att}}(A)$

A dependence provides a way to distinguish between models:

- nuclear absorption models $\Longrightarrow$ $\alpha = 1/3$
- pQCD based models (Wang et al.) $\Longrightarrow$ $\alpha = 2/3$

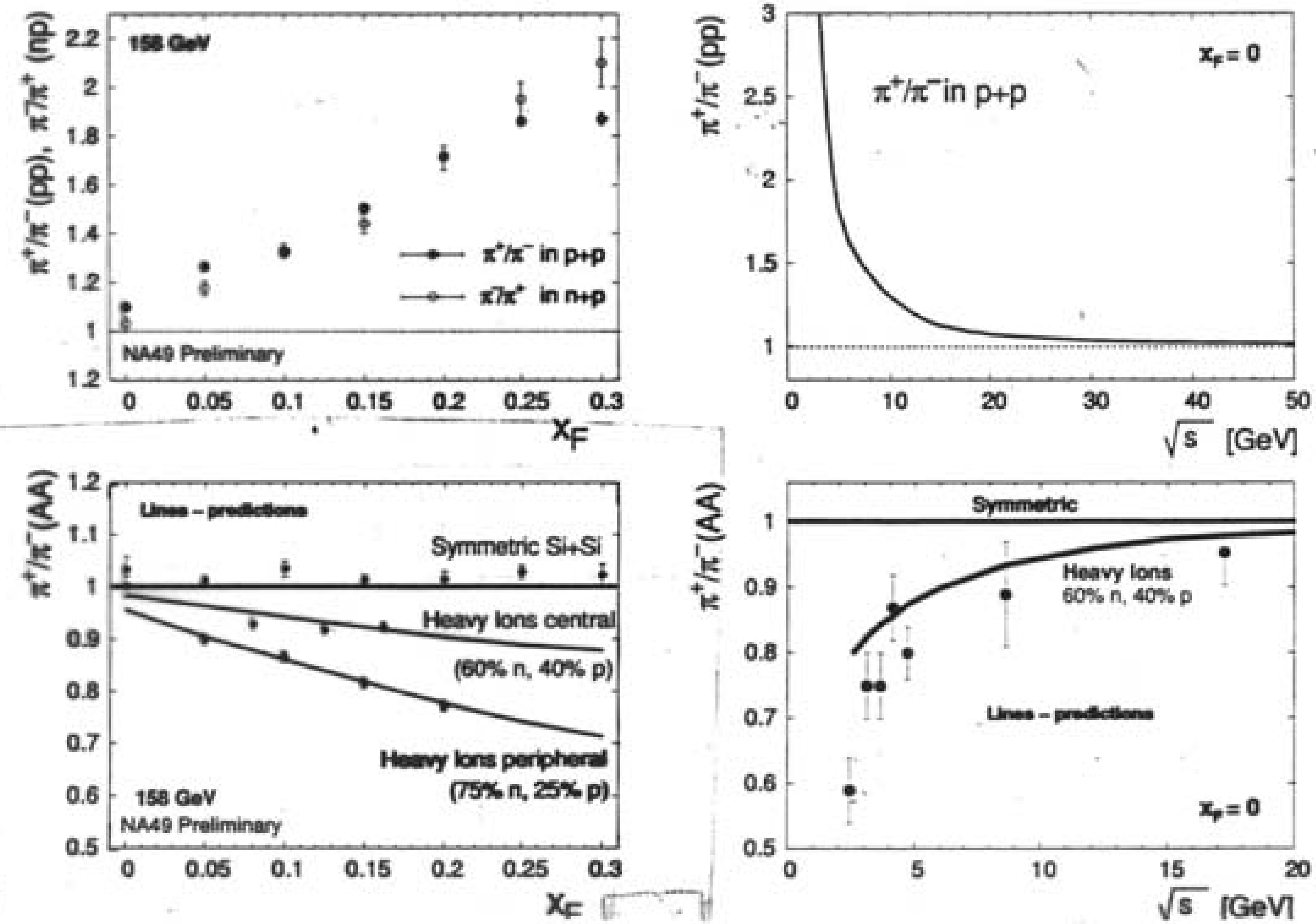
Extracted A dependence using: $1 - R_M \propto A^{\alpha}$

Combining ^{14}N and ^{84}Kr:

$$\alpha = \ln\left(\frac{1 - R_M^N}{1 - R_M^{Kr}}\right) / \ln\left(\frac{14}{84}\right)$$

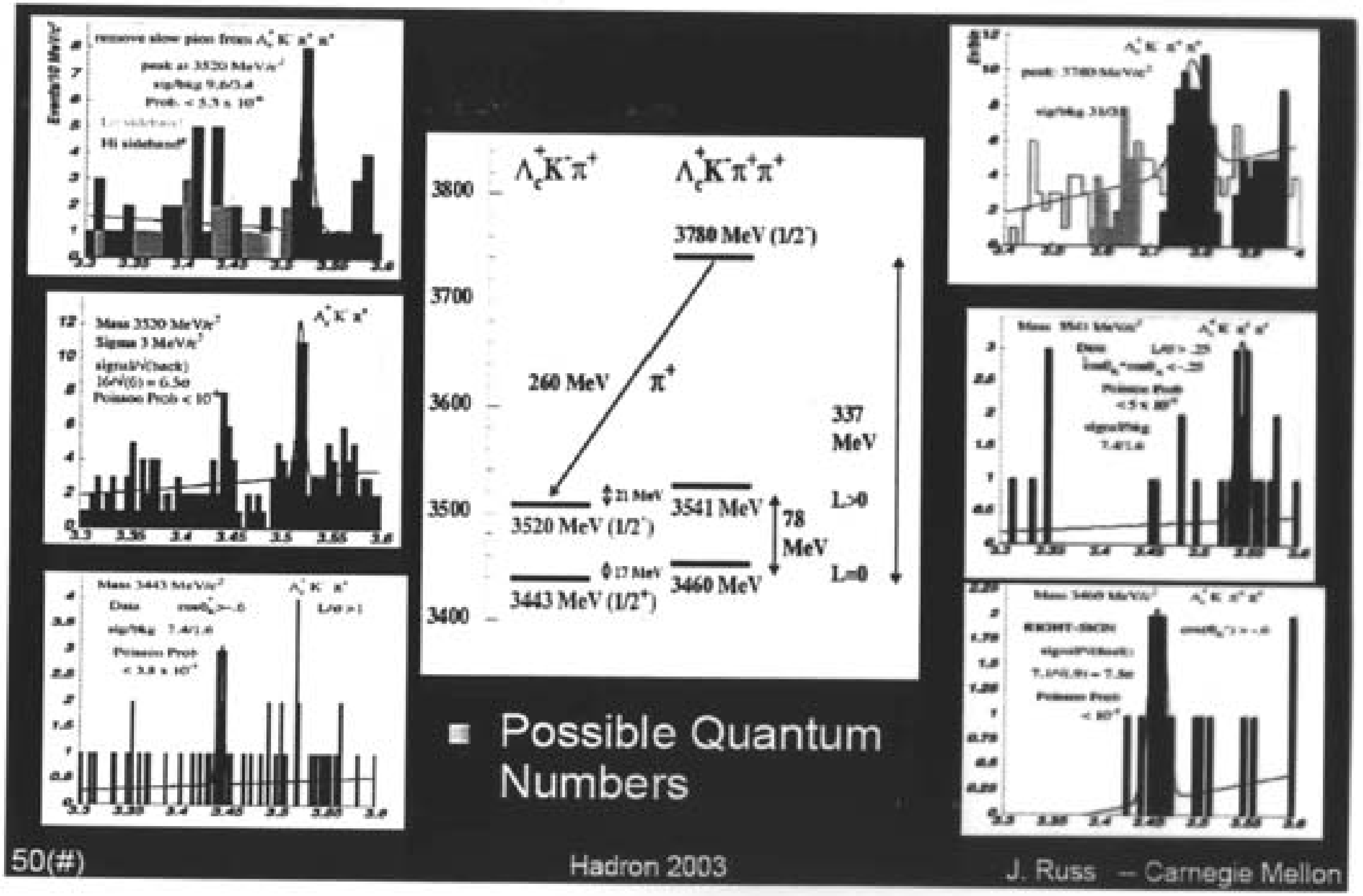
$\Longrightarrow$ data indicate $\alpha \simeq 2/3$, but further study is needed using all targets

A. Rybicki


158 GeV
NA49 Preliminary
π+/π− (pp), π−/π+ (np)
π+/π− in p+p
π−/π+ in n+p
xF
π+/π− (pp)
π+/π− in p+p
xF = 0
√s [GeV]
π+/π− (AA)
Lines – predictions
Symmetric Si+Si
Heavy Ions central
(60% n, 40% p)
Heavy Ions peripheral
(75% n, 25% p)
158 GeV
NA49 Preliminary
xF
π+/π− (AA)
Symmetric
Heavy Ions
60% n, 40% p
Lines – predictions
xF = 0
√s [GeV]

E. Gottschalk

SELEX reports possible signals for 5 doubly-charmed baryon states (Hadron 2003)



E) <u>Dense matter</u> (hot?)

<u>SPS</u> M. <u>Gaździcki</u>

Indications for phase trans. (fig)

<u>RHIC</u> Thermodynamical models with flow fit almost too well M. <u>Calderon</u>

W. <u>Broniowski</u>

Successful models: Blast-wave, Kraków, (fig)
Buda-Lund + ...

P. <u>Fachini</u> Resonances: Φ messenger from early times?

ϕ & K^* show no dependence on centrality.

Does not participate in flow?

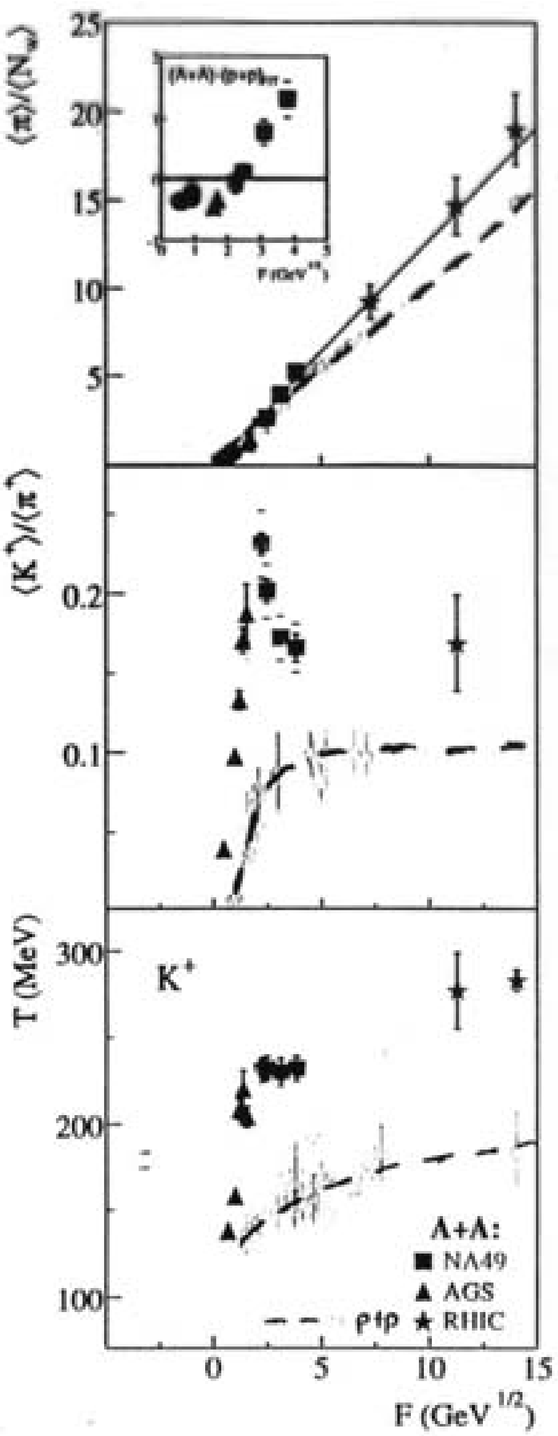
M. Gaździcki

SIGNALS OF DECONFINENENT

THE PION KINK:

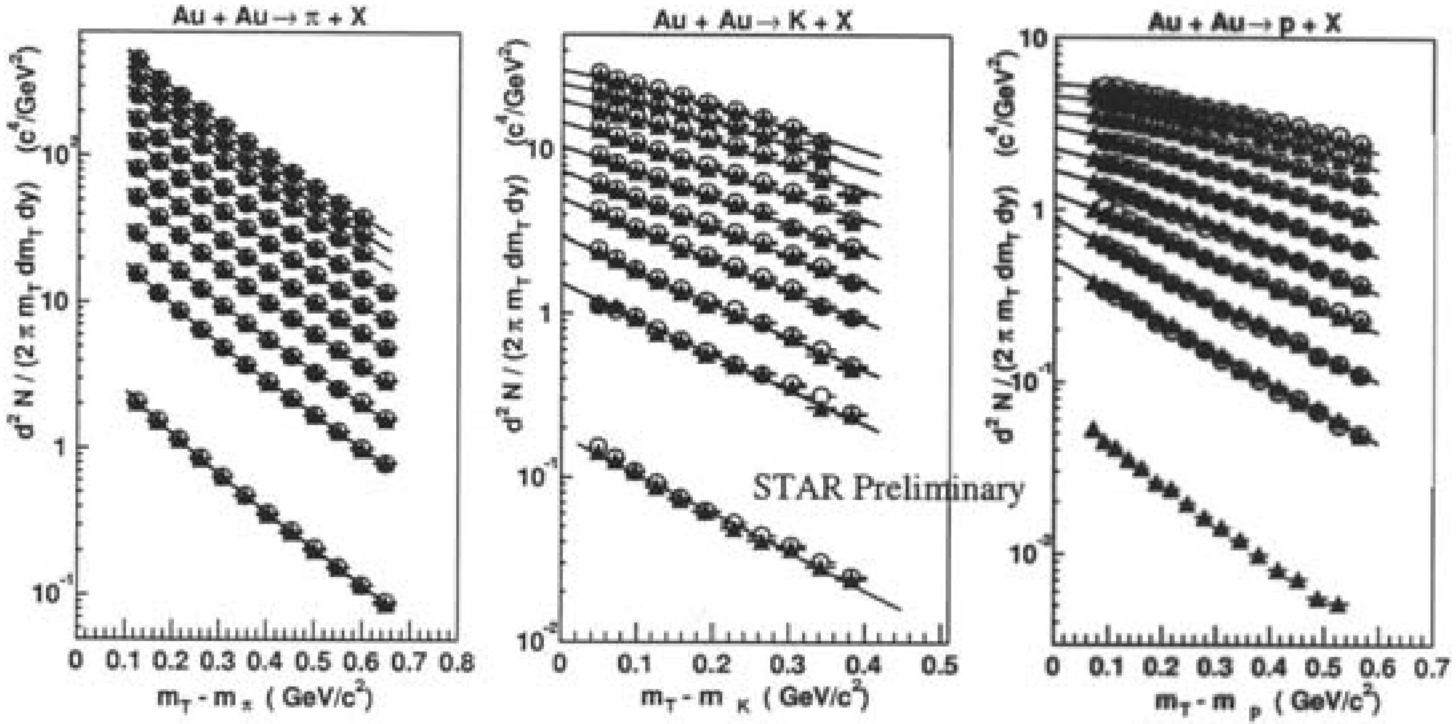
THE STRANGE HORN:

THE STEP IN SLOPES:



M. Calderón

Particle Spectra in Au+Au, STAR |y|<.5



- Hydro inspired "Thermal" Fits (input to Blast-Wave parameterization) (T, β_t) = (170 MeV, 0.6c) Large transverse flow component in central collisions.

Particle ratios @ 130 and 200 GeV →

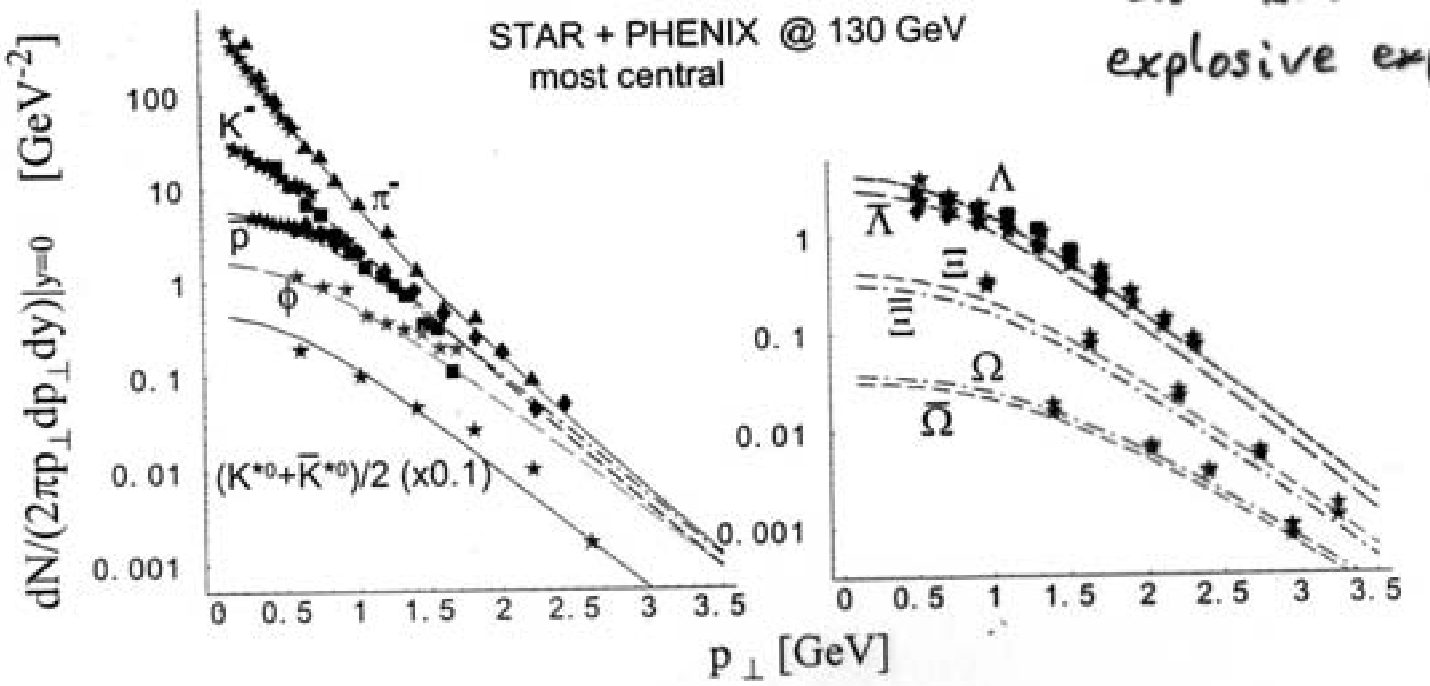
T [MeV]	165 ± 7	160±5
μ_B [MeV]	41 ± 5	26±4
μ_S [MeV]	9	5
μ_I [MeV]	-1	-1
χ^2/DOF	1.0	1.5

W. Broniowski

(Kraków model)

$T_{ch} = T_{kin}$

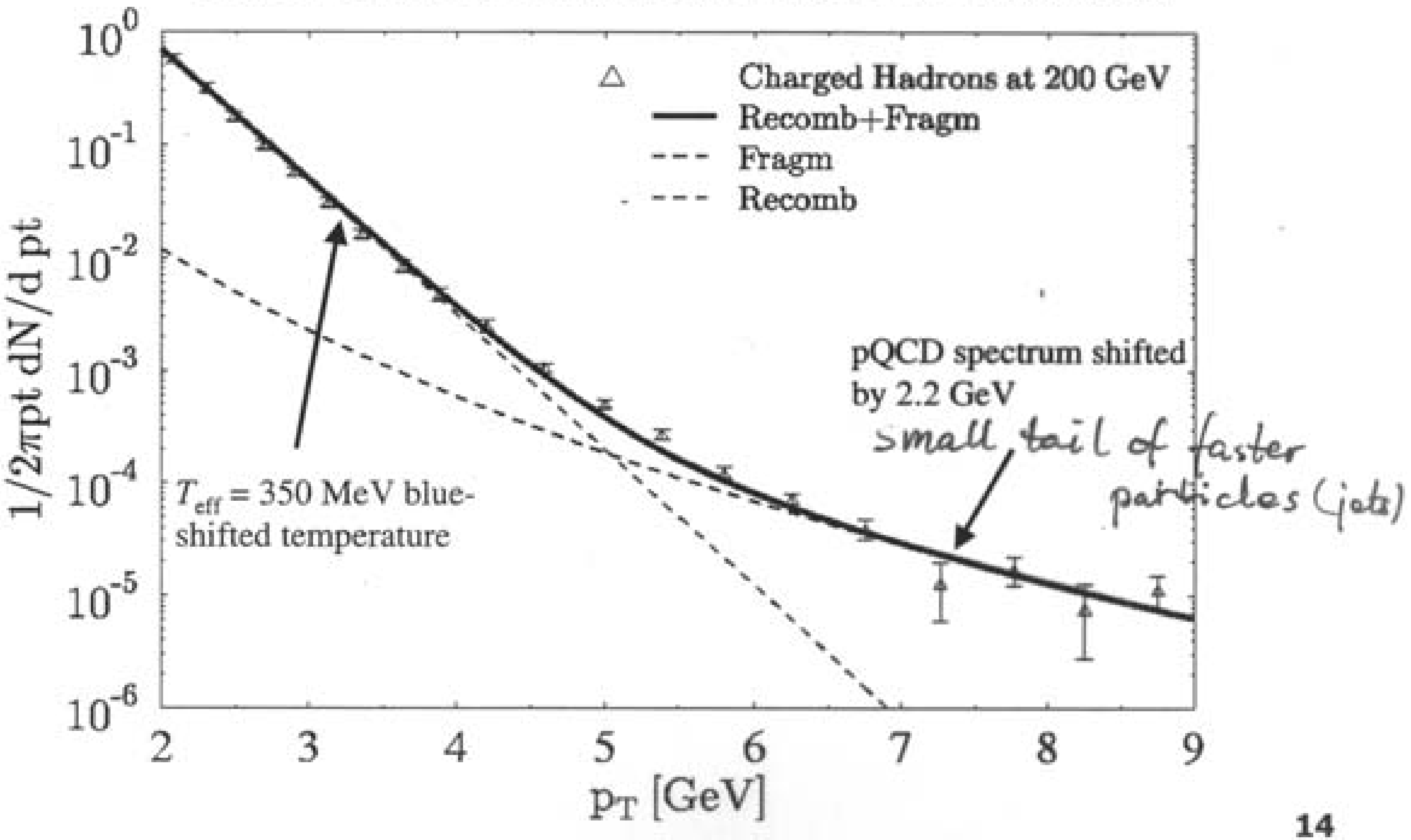
explosive expansion



M. Calderon

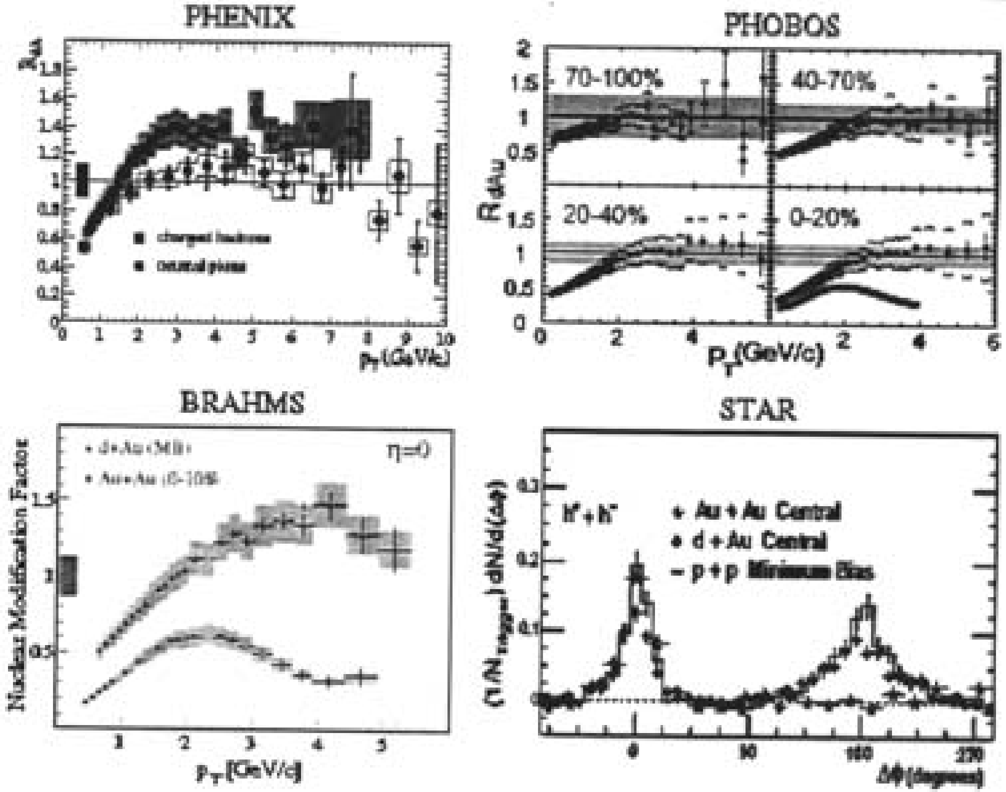
Does it fit the measured spectra?

R.J. Fries, B. Müller, C. Nonaka, S.A. Bass; PRL 90 202303 (2003)



M. Calderon

STAR High-p_t: Latest news from the d+Au run



From cover of
PRL 91 (2003)

072302 Phobos
072303 Phenix
072304 Star
072305 Brahms

- In Au+Au, suppression of high-pt hadrons and of away side jet, not seen in d+Au. Final state effect...consistent with the production of dense matter!!

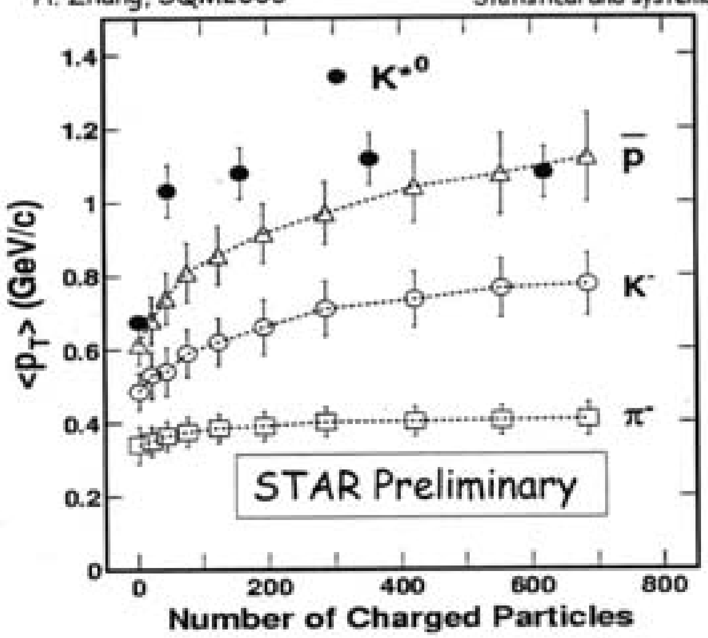
P. Fachini

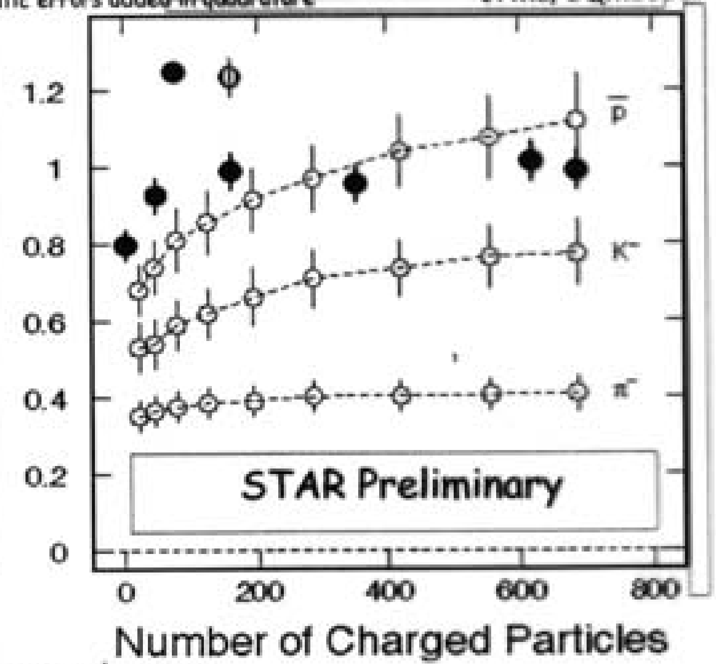
$\langle p_T \rangle$ Charged Particle Dependence

H. Zhang, SQM2003

Statistical and systematic errors added in quadrature

J. Ma, SQM2003





- Φ and $K^{*0} \Rightarrow$ No centrality dependence
- $\Phi \Rightarrow$ Flows differently ?
- $K^{*0} \Rightarrow$ Rescattering dominates at peripheral collisions and regeneration becomes significant for central collisions ?

BE essential to constrain models

G. Alexander: Large radii

Appears similar to classical HBT effect

(fig)

H. Appelshäuser

$$R_{long} = \tau_f \cdot \sqrt{\frac{T_f}{m_\perp}} \quad \text{(Sinyukov)}$$

→ Hubble expansion

(fig)

Angular anisotropy

U. Heinz, M. Lisa

Time-space separation.

(fig)

Asymmetry in unequal part. correl.

A. Kisiel shift 5fm in x or t

(fig)

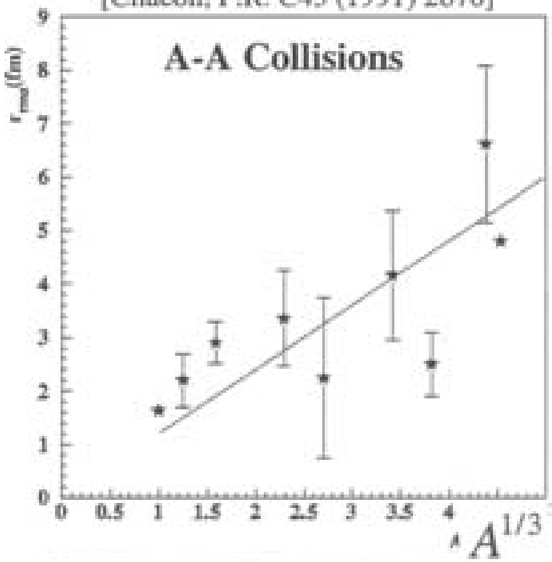
G. Alexander

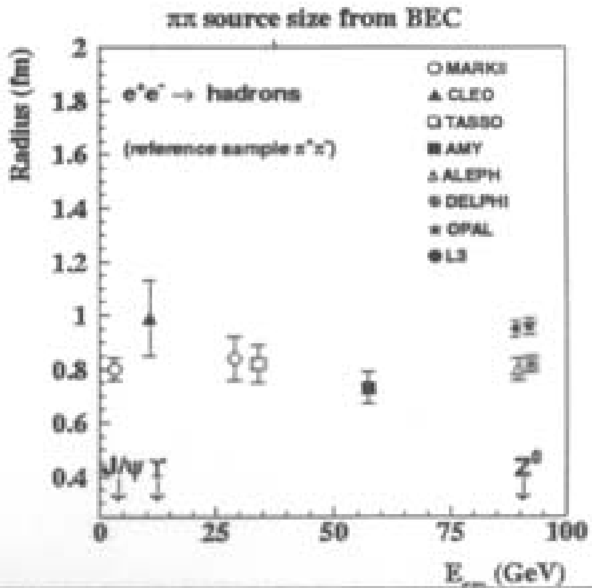
Hadron emitter radius in e^+e^- vs. E_{CM}

- HBT effect in the 50's measured stellar objects dimensions.

In heavy ions, an early compilation of *r* vs. the projectile A can be described by $\boxed{r = 1.2A^{1/3}\ fm}$

[Chacon, P.R. C43 (1991) 2670]



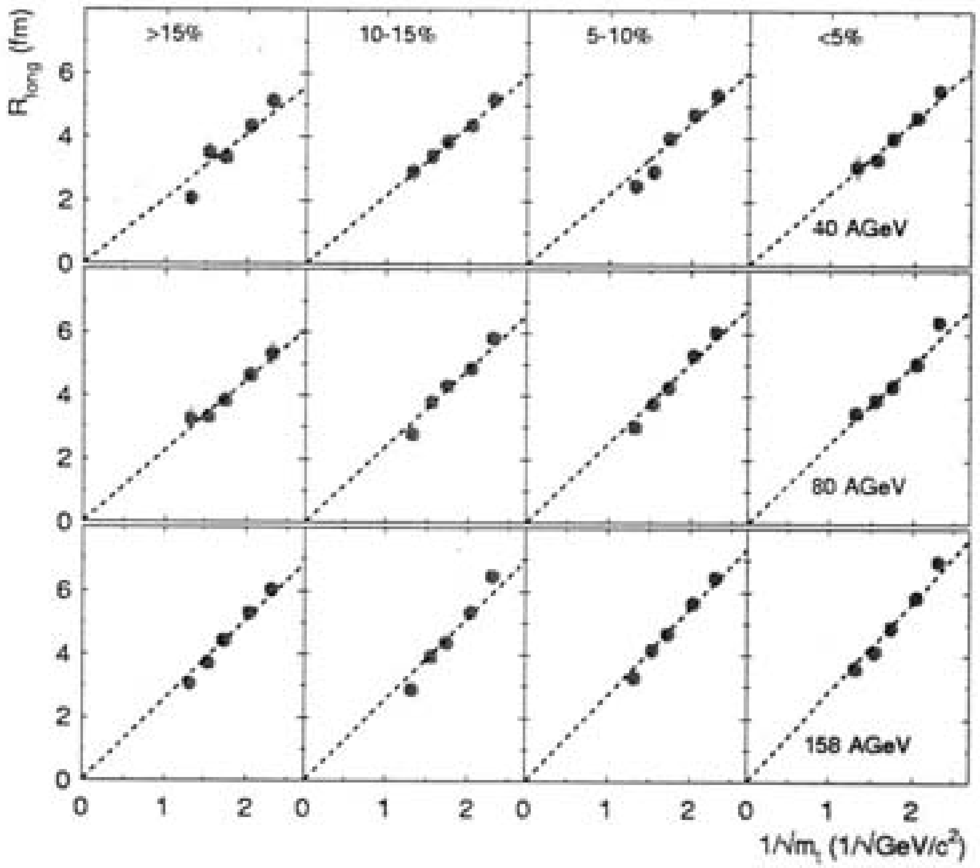


What about the $e^+e^- \rightarrow$ hadrons BEC dimension vs. E_{CM} ?

H. Appelshäuser

R_{long} - longitudinal expansion and lifetime

CERES Pb+Au, *Nucl. Phys. A714 (2003) 124*



Hubble-Expansion:

$$R_{\mathbf{long}} = \tau_f \cdot \sqrt{\frac{T_f}{m_t}}$$ (Y. Sinyukov)

lifetime (τ_f); $\approx$ thermal velocity ($\sqrt{T_f/m_t}$)

$$m_t = (m_\pi^2 + k_t^2)^{\frac{1}{2}}$$

At 158 AGeV:

$$\boxed{\tau_f \approx 7 - 8 \text{ fm/c}}$$

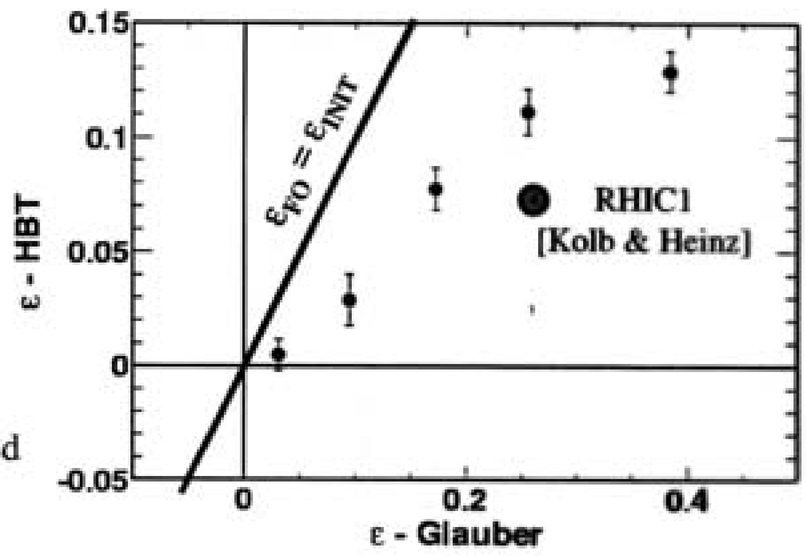
for $T_f = 160 - 120$ MeV

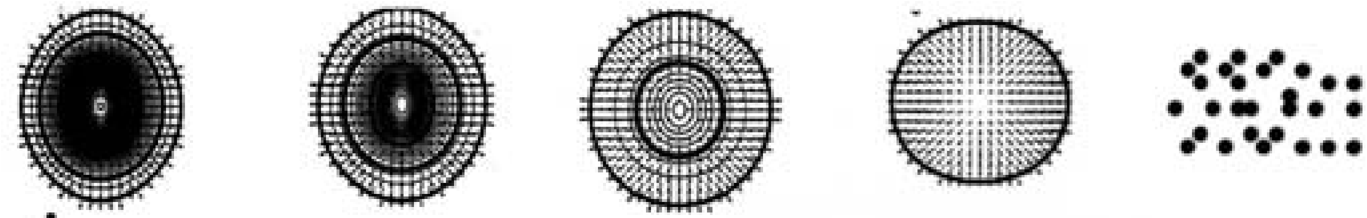
M. Lisa

Estimate of initial vs F.O. source shape

$$\varepsilon \equiv \frac{R_y^2 - R_x^2}{R_y^2 + R_x^2}$$

- estimate ε_{INIT} from Glauber
- from asHBT: $\varepsilon_{FO} \approx 2\frac{R_{S,2}^2}{R_{S,0}^2}$
- $\varepsilon_{FO} < \varepsilon_{INIT} \rightarrow$ dynamic expansion
- $\varepsilon_{FO} > 1 \rightarrow$ source always OOP-extended
  - constraint on evolution time



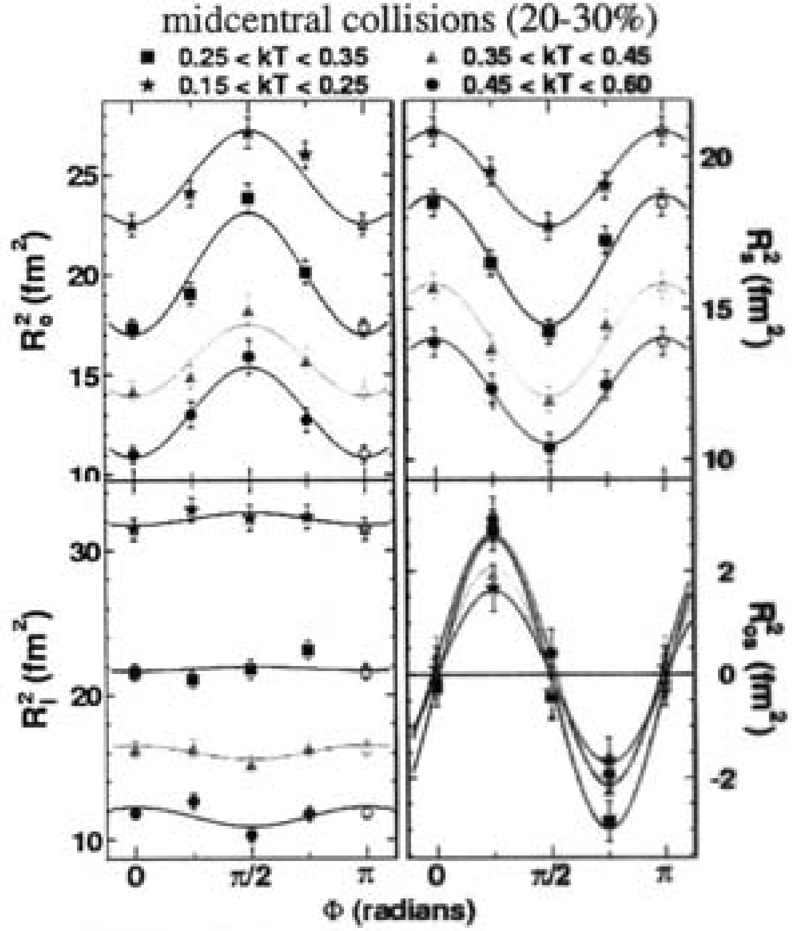


M Lisa

asHBT at 200 GeV in STAR - R(ϕ) vs k_T

- Clear oscillations observed at all k_T
- extract 7 radius Fourier Coefficients (shown by lines)

$$R^2_{\mu,n}(p_T) = \begin{cases} \langle R^2_\mu(p_T,\phi)\cdot\cos(n\phi)\rangle & (\mu = o,s,l) \\ \langle R^2_\mu(p_T,\phi)\cdot\sin(n\phi)\rangle & (\mu = os) \end{cases}$$



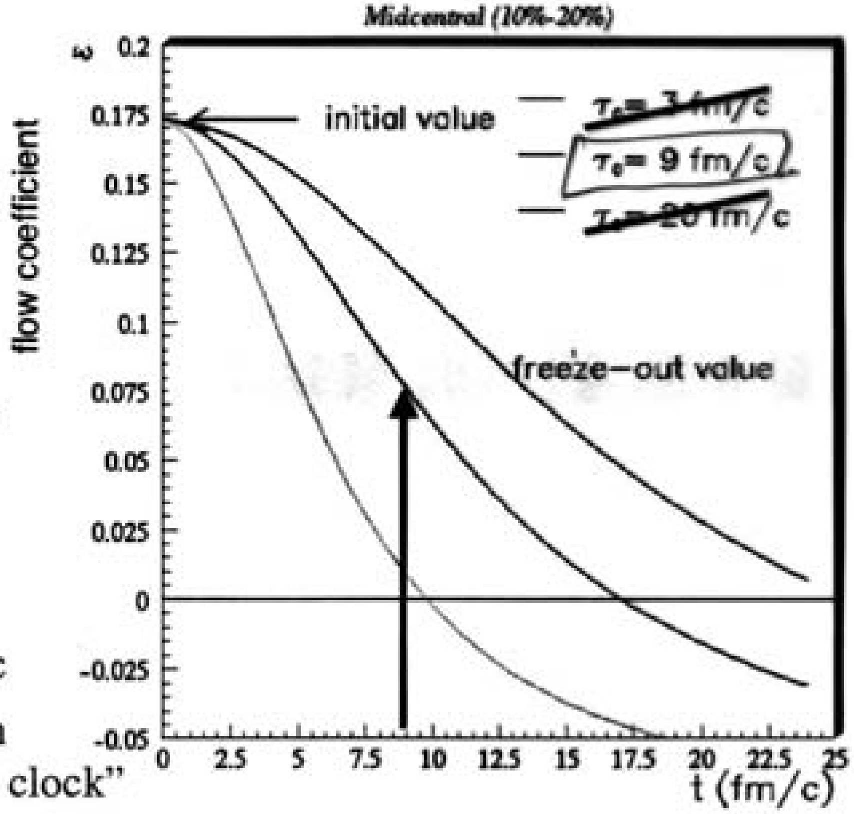
M. Lisa

A simple estimate - τ_0 from ε_{init} and ε_{final}

- BW → β_X, β_Y @ F.O. ($\beta_X > \beta_Y$)
- hydro: flow velocity grows ~ t

$$\rightarrow \beta_{X,Y}(t) = \beta_{X,Y}(F.O.) \cdot \frac{t}{\tau_0}$$

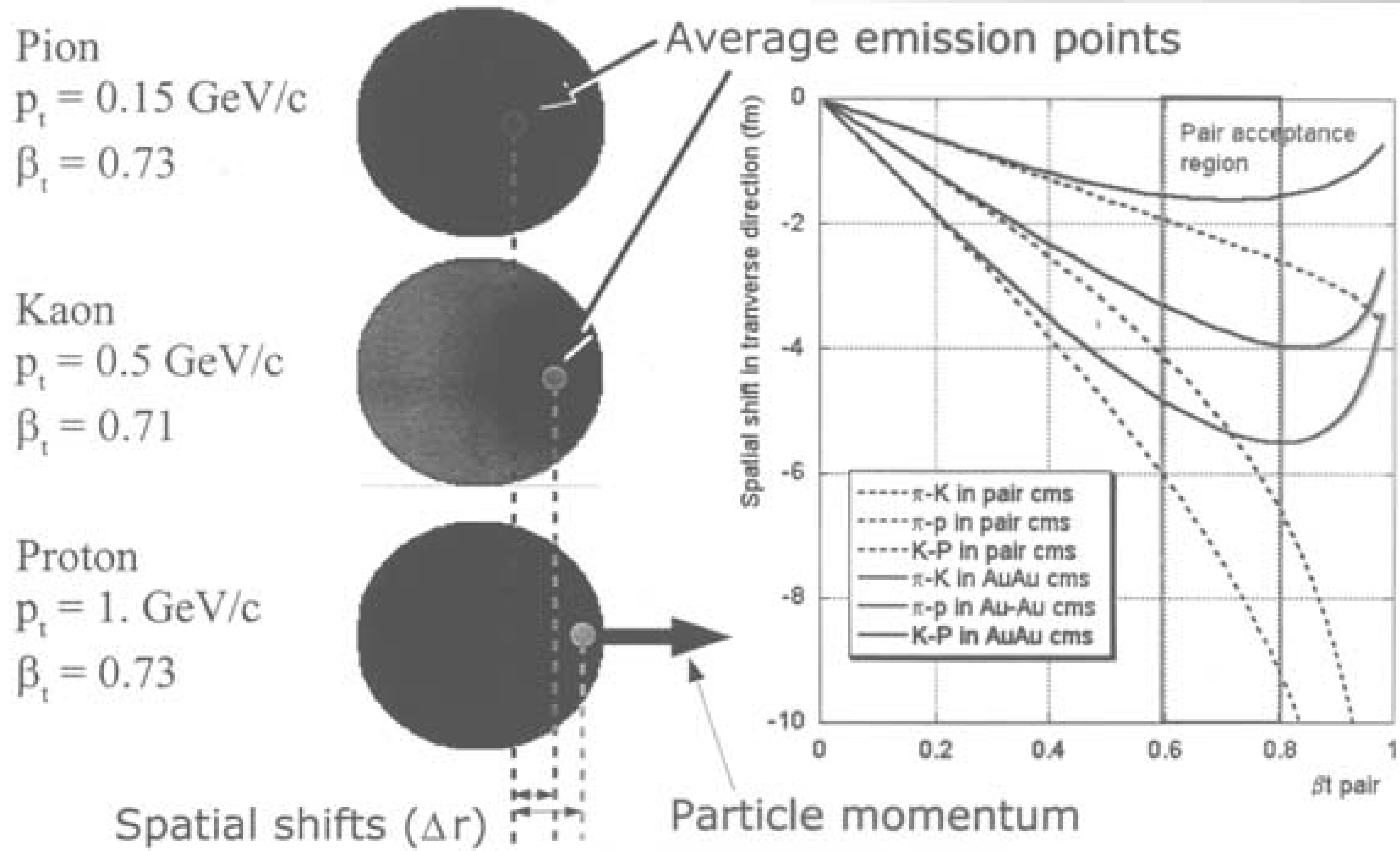
- From $R_L(m_T)$: τ_0 ~ 9 fm/c
  ✓consistent picture
- Longer or shorter evolution times
  X inconsistent



✓toy estimate: τ_0 ~ τ_0(BW)~ 9 fm/c
- But need a real model comparison
  → asHBT valuable "evolutionary clock" constraint for models

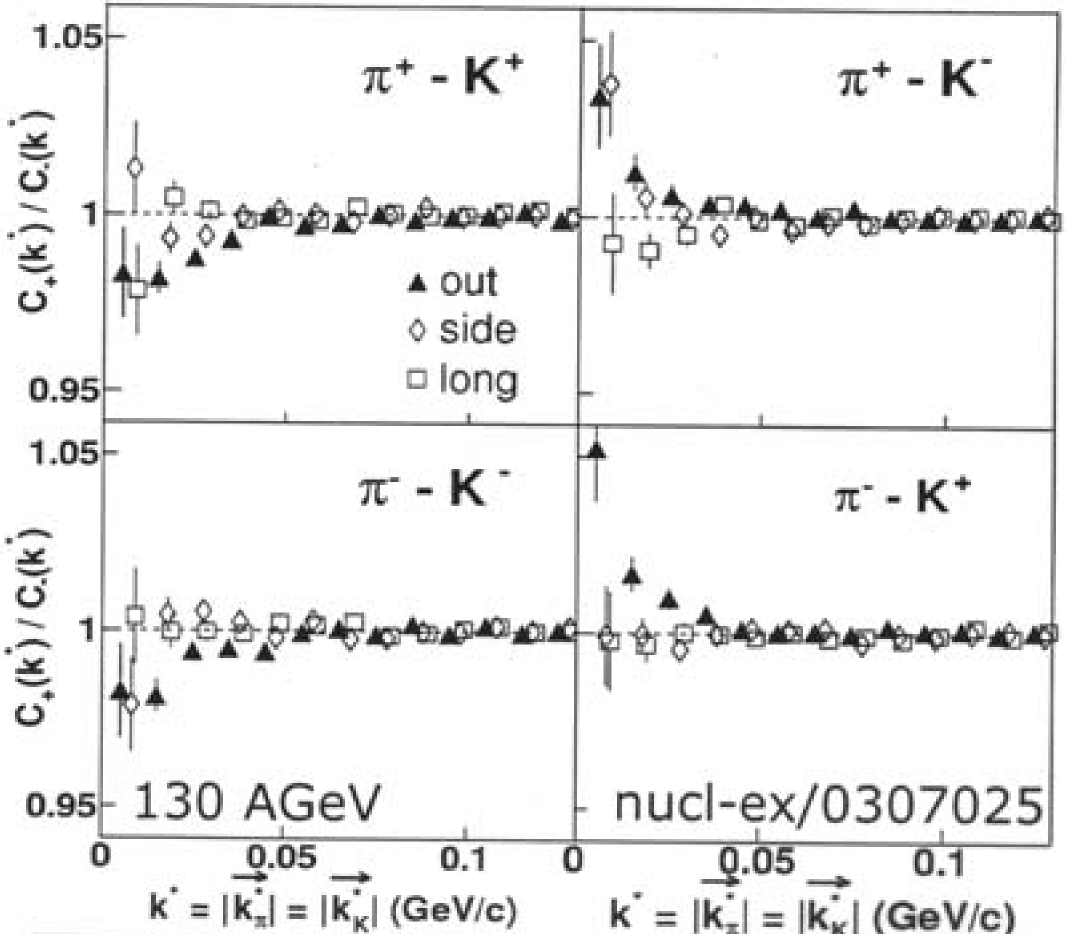
A Kisiel

Blast wave: a flow model



A. Kisiel

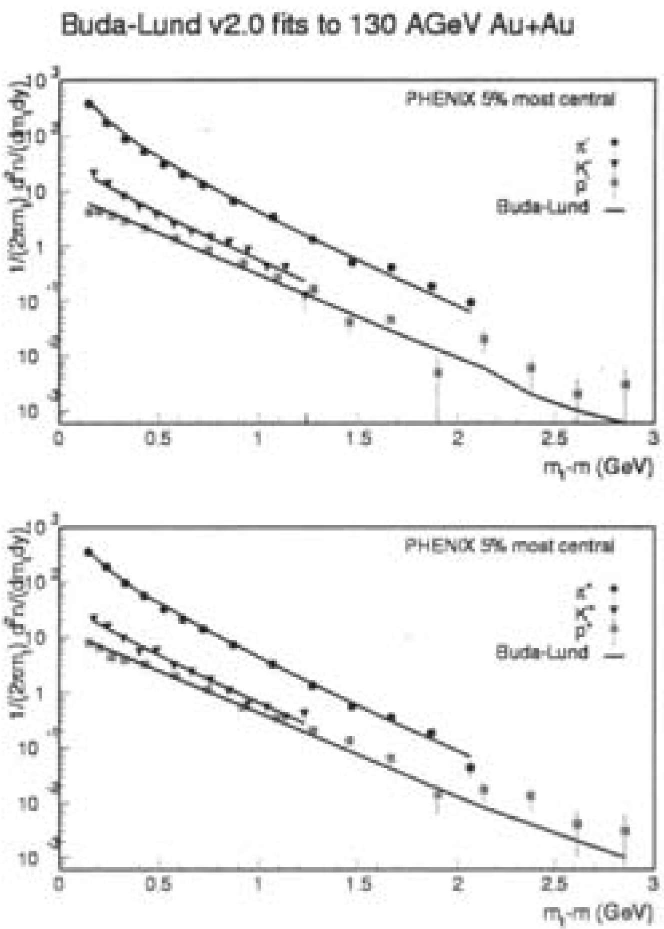
Double ratios

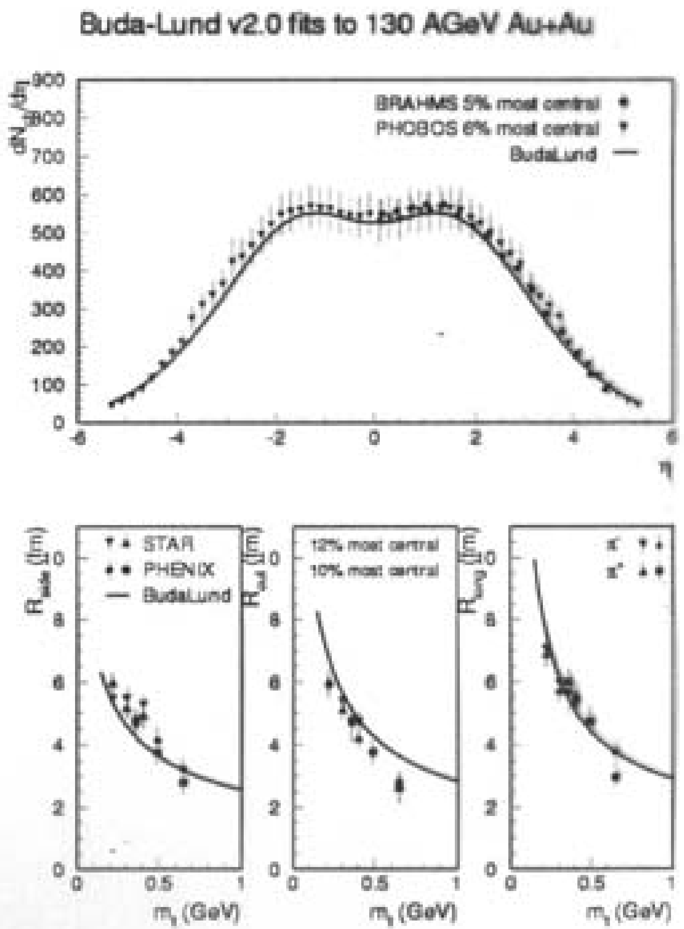


- Clear deviation from unity for Out – sign of asymmetry
- Side and Long – flat as expected (cross-check)

A Ster fit to part. distr. & BE

BudaLund fits to final run-1 RHIC data





Conclusions:

Hubble expansion

Fast freeze-out

Chemical freezeout - thermal f-o

Is a plasma formed?

Warning: W. Broniowski

Kraków model:

Full model with heavy resonances

at T = 165 MeV + cuts

≈ Simple model at 110 MeV

Diffraction

What is the Pomeron?

Pole in complex plane

cut

2 gluons

gluon ladder

many gluons

$q\bar{q}$ content

K. Golec-Biernat

Connection: Dipol picture ∞ Ingelman-Schlei

Special tools

Event-by-event correlations V. Koch

Application to πp, $K\pi$ YF Wu

(hy)

Special events : Very High Mult. events

A Sissakian, H Kokoulina

÷

Cosmic Rays

Kascade "knee"

AGASA Special rel. violated ?

M. Teshima

Massive relic particles in halo?

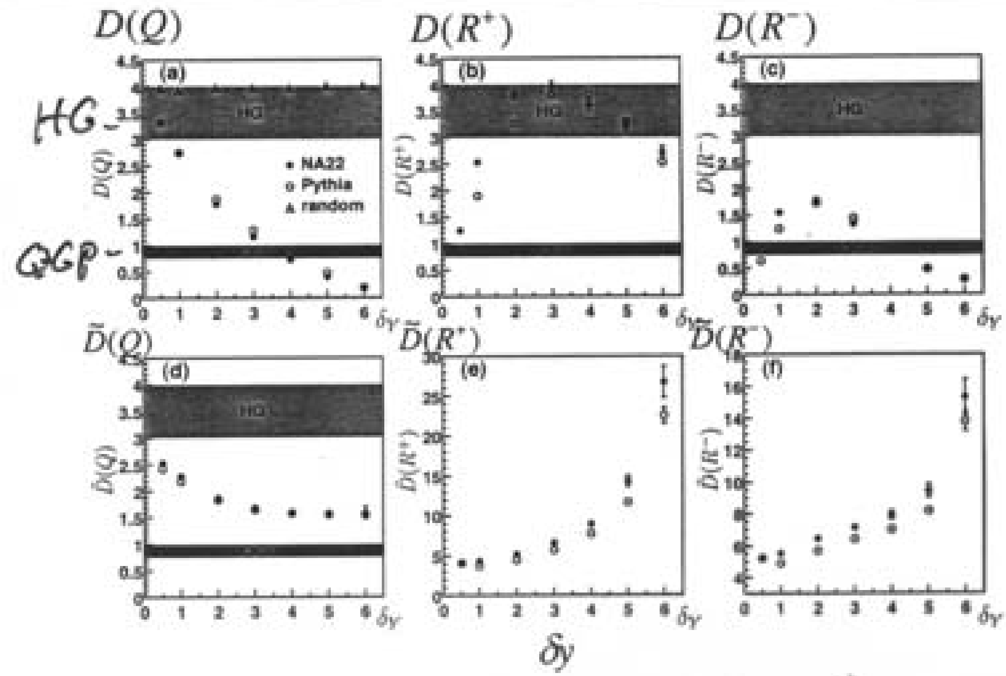
S. Sarkar

Tail of conventional events?

Y.F. Wu

2. Results

- The dependency of the fluc. on Y



1) $D(Q)$ & $\tilde{D}(Q)$

2) $D(R^+)$ & $\tilde{D}(R^+)$

3) $D(R^-)$ & $\tilde{D}(R^-)$

$$|y| < y_{cut} = \delta y / 2$$

$$R^+ = \frac{n^+}{n^-},\ R^- = \frac{n^-}{n^+}$$