Miklós++ version 70th

(subversion 13th)

G.G. Barnaföldi

Wigner RCP of the Hungarian Academy of Sciences

Collaborations with Miklós

A brief history from my side..

- 1996-1997 BSc: I made a “national student research” with Peter Lévai on finding “tetraquarks” in high-energy heavy ion collisions at SPS & RHIC
- 1998-2000 MSc: with P. Lévai & G. Papp & G. Fai, to build a 1+2 D parton model based pQCD code, the later “kTpQCD” code
- 2000- PhD: Investigation of initial & final state nuclear effects in the framework of the NLO version of the kTpQCD_v2.0 → works with Miklós
- 2015- HIJING++ in collaboration with the Miklós++ & Xin-Nian

1998- my first steps in pA & AA → jet

- 1998-2000 Development of a high-precision (NLO) pQCD code including all high-energy nuclear effects to see the ‘room for jet-quenching’.
- My first paper: J. Phys G27 (2001) 1767.

KSUCNR-103-00

Jets and produced particles in *pp* collisions from SPS to RHIC energies for nuclear applications

G.G. Barnaföldi[1], G. Fai[2], P. Lévai[1,2], G. Papp[2,3], Y. Zhang[2]

[1] *KFKI Research Institute for Particle and Nuclear Physics, P. O. Box 49, Budapest 1525, Hungary*
[2] *Physics Department, Kent State University, Kent OH 44242, USA*
[3] *HAS Research Group for Theoretical Physics, Eötvös University, Pázmány P. 1/A, Budapest 1117, Hungary*

(October 31, 2018)

Higher-order pQCD corrections play an important role in the reproduction of data at high transverse momenta in the energy range 20 GeV $\leq \sqrt{s} \leq$ 200 GeV. Recent calculations of photon and pion production in *pp* collisions yield detailed information on the next-to-leading order contributions. However, the application of these results in proton-nucleus and nucleus-nucleus collisions is not straightforward. The study of nuclear effects requires a simplified understanding of the output of these computations. Here we summarize our analysis of recent calculations, aimed at handling the NLO results by introducing process and energy-dependent K factors.

$$\frac{d\sigma^{NLO}}{d^3p} = \frac{d\sigma^{Born}}{d^3p} + \frac{d\sigma^{corr}}{d^3p} = K(s, p_T)\frac{d\sigma^{Born}}{d^3p}$$

$$K_{jet}(s, p_T) = 1. + \frac{65.}{\sqrt{s} + 160.} + \frac{2.}{\sqrt{s} - 6.}\; p_T$$

$$K_{jet}(s, p_T) = 1.6 + \frac{20.}{\sqrt{s}} - \frac{24.}{(\sqrt{s} - 10.)^2}\; p_T + \frac{6.}{(\sqrt{s} - 10.)^2}\; p_T^2$$

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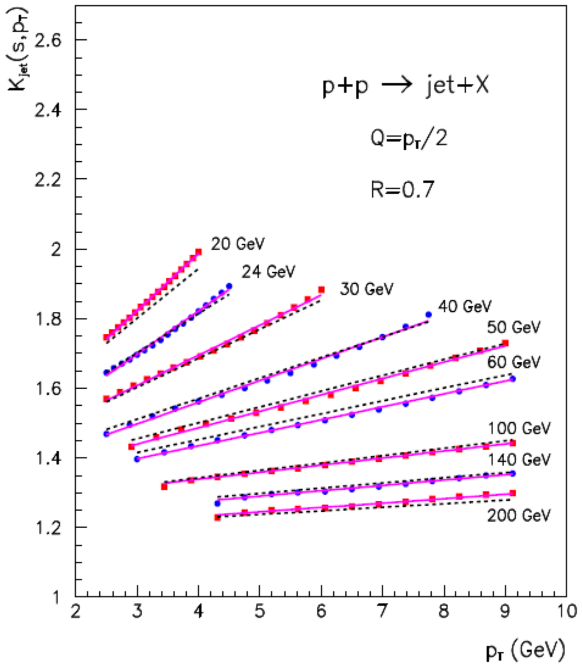

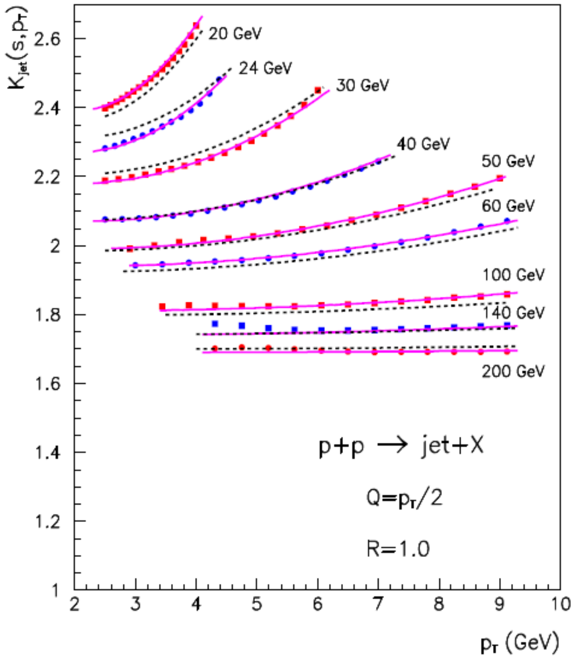

→ The first time I met Miklós at Tihany (Hungary) ISMD 2000

1998- my first steps in pA & AA → jet

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- A reaction….

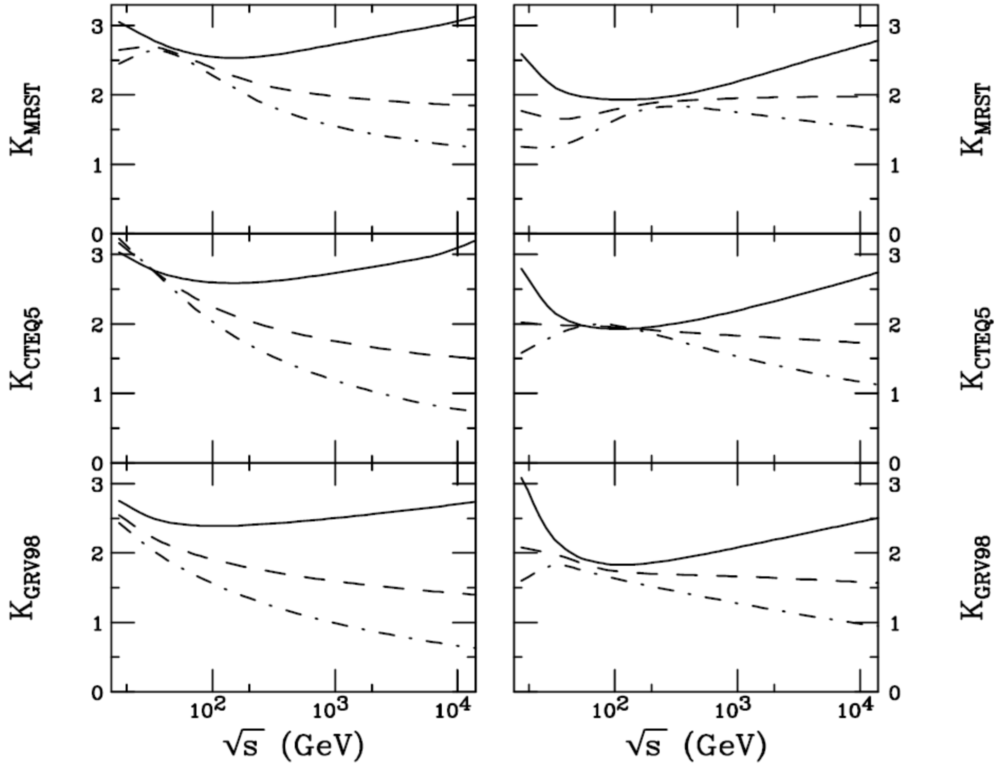
What is the Real K Factor?

R. Vogt

Nuclear Science Division, Lawrence Berkeley National Laboratory, University of California, Berkeley, California 94720, USA
and
Physics Department, University of California, Davis, CA 95616, USA

Received August 5, 2002

Abstract. The theoretical K factor, describing the difference between the leading and higher order cross sections, has no precise definition. The definition is sensitive to the order of the fit to the parton densities and the number of loops at which α_s is evaluated. We describe alternate ways to define the K factor and show how the definition affects its magnitude and shape for examples of hadroproduction of W^+ bosons, Drell-Yan lepton pairs, and heavy quarks. We discuss which definition is appropriate under certain circumstances.



2000- Initial & final state effects in pA & AA

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- kTpQCD: Phys. Rev C65 (2001) 034903.

KSUCNR-102-01

High-p_T pion and kaon production in relativistic nuclear collisions

Yi Zhang* and George Fai†

Center for Nuclear Research, Department of Physics

Kent State University, Kent, OH 44242

Gábor Papp‡

HAS Research Group for Theoretical Physics

Eötvös University, Pázmány P. 1/A, Budapest 1117, Hungary

Gergely G. Barnaföldi§ and Péter Lévai**

KFKI Research Institute for Particle and Nuclear Physics, P.O. Box 49, Budapest 1525, Hungary

(September 4, 2018)

High-p_T pion and kaon production is studied in relativistic proton-proton, proton-nucleus, and nucleus-nucleus collisions in a wide energy range. Cross sections are calculated based on perturbative QCD, augmented by a phenomenological transverse momentum distribution of partons ("intrinsic k_T"). An energy dependent width of the transverse momentum distribution is extracted from pion and charged hadron production data in proton-proton/proton-antiproton collisions. Effects of multiscattering and shadowing in the strongly interacting medium are taken into account. Enhancement of the transverse momentum width is introduced and parameterized to explain the Cronin effect. In collisions between heavy nuclei, the model over-predicts central pion production cross sections (more significantly at higher energies), hinting at the presence of jet quenching. Predictions are made for proton-nucleus and nucleus-nucleus collisions at RHIC energies.

$$E_h \frac{d\sigma_h^{pp}}{d^3p} = \sum_{abcd} \int dx_a dx_b dz_c \, f_{a/p}(x_a, Q^2) \, f_{b/p}(x_b, Q^2) \frac{d\sigma}{d\hat{t}}(ab \to cd) \frac{D_{h/c}(z_c, Q'^2)}{\pi z_c^2} \hat{s}\, \delta(\hat{s} + \hat{t} + \hat{u})$$

$$dx \; f_{a/p}(x, Q^2) \to dx \; d^2k_T \; g(\vec{k}_T) \; f_{a/p}(x, Q^2)$$

$$g(\vec{k}_T) = \frac{1}{\pi \langle k_T^2 \rangle} e^{-k_T^2/\langle k_T^2 \rangle}$$

$$\langle k_T^2 \rangle_{pA} = \langle k_T^2 \rangle_{pp} + C \cdot h_{pA}(b)$$

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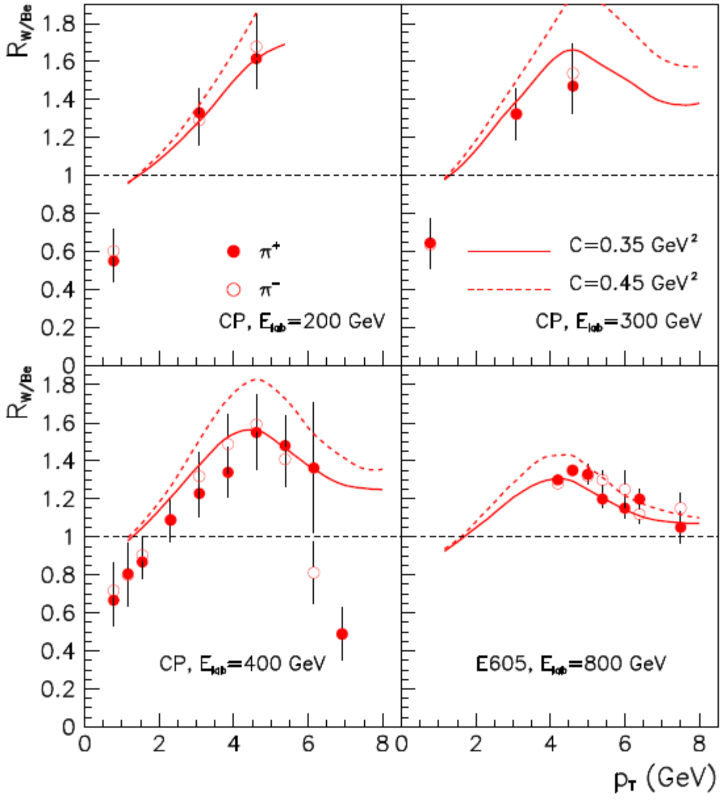

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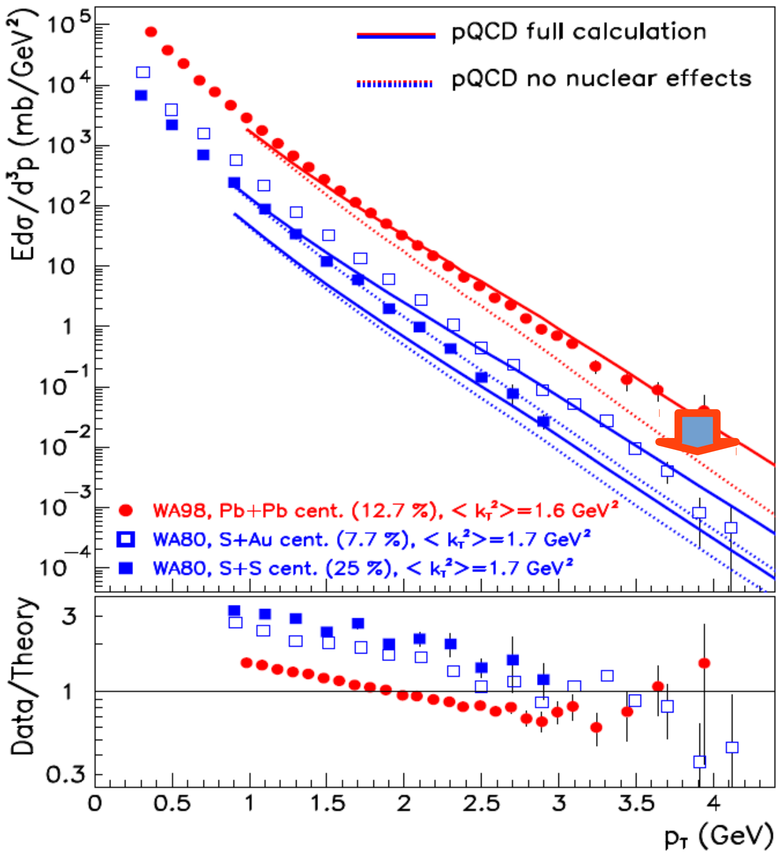

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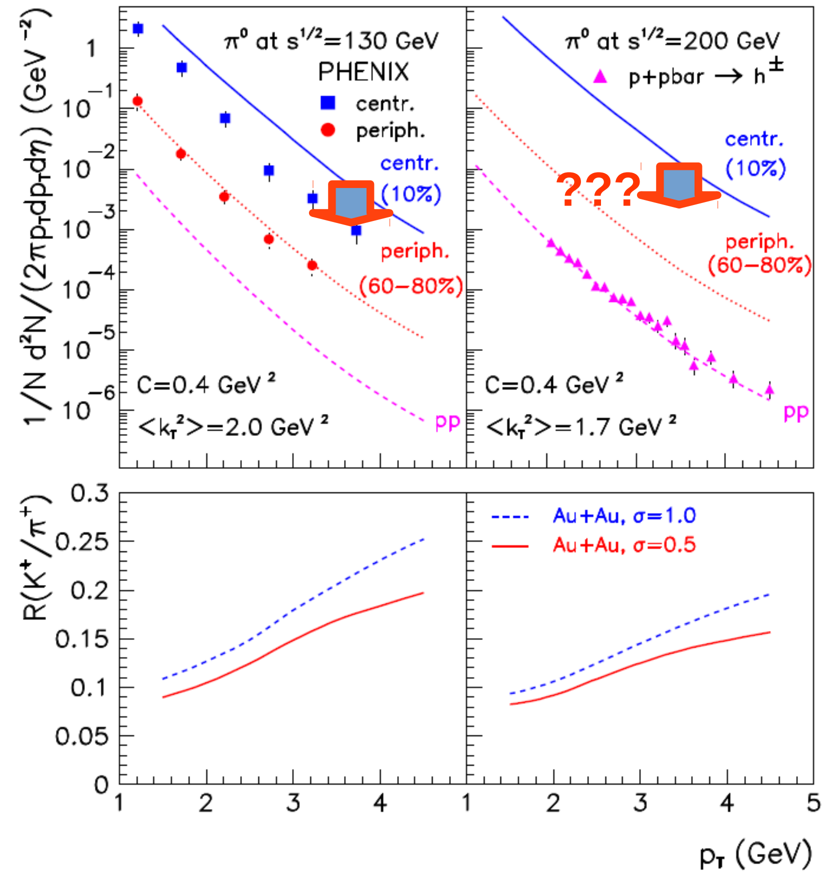

I was super-flustrated...

...we were working on the “most perfect” theoretical description for years and failed on the latest RHIC data.

BUT: Miklós & Péter were super-excited…

This is how my collaborations started with Miklós.

2000- The GLV bomb…

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- The pocket formula and the one hard night @ CERN: kTpQCD + GLV

nucl-th/0104035v1 10 Apr 2001

Discovery of Jet Quenching at RHIC and the Opacity of the Produced Gluon Plasma

P. Lévai[a], G. Papp[b], G. Fai[c], M. Gyulassy[d], G.G. Barnaföldi[a], I. Vitev[d] and Y. Zhang[c,a]

[a] HAS KFKI Research Institute for Particle and Nuclear Physics, PO Box 49, Budapest 1525, Hungary
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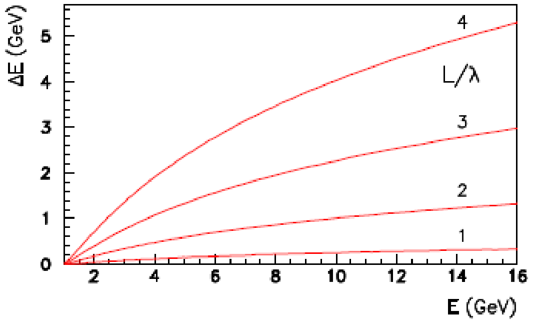
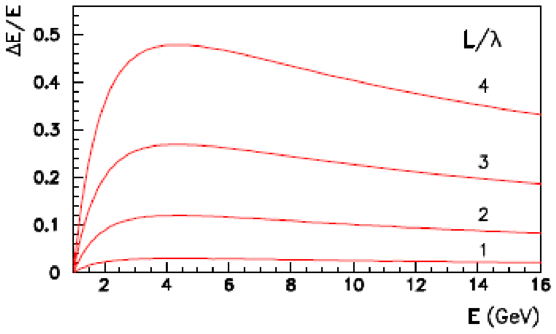
[d] Physics Department, Columbia University, 538 West 120th Street, New York, NY 10027, USA

The predicted quenching of jets in $A+A$ at RHIC energies has been discovered by STAR and PHENIX in preliminary data reported at this conference. We apply the GLV theory [1] of QCD radiative energy loss to estimate the opacity, L/λ_g, of the gluon plasma produced in $Au+Au$ collisions at 130 AGeV. We show that (in contrast to the factor of two Cronin enhancement of π^0 found at the SPS by WA98) the factor of 5-8 suppression of $p_T \sim 2-4$ GeV π^0 reported by PHENIX [2] can be accounted for with an effective static plasma opacity $L/\lambda_g \approx 3-4$.

$$\Delta E^{(1)}_{\rm GLV} = \frac{2C_{\rm R}\alpha_{\rm s}}{\pi}\frac{EL}{\lambda_{\rm g}}\int_0^1 {\rm d}x \int_0^{{\rm k}^2_{\rm max}} \frac{{\rm dk}^2_\perp}{{\rm k}^2_\perp}\int_0^{{\rm q}^2_{\rm max}} \frac{{\rm d}^2{\rm q}_\perp\,\mu^2_{\rm eff}}{\pi({\rm q}^2_\perp+\mu^2)^2}\cdot\frac{2\,{\bf k}_\perp\cdot{\bf q}_\perp({\bf k}-{\bf q})^2_\perp L^2}{16x^2E^2 + ({\bf k}-{\bf q})^4_\perp L^2}$$

$$= \frac{C_{\rm R}\alpha_{\rm s}}{N(E)}\frac{L^2\mu^2}{\lambda_{\rm g}}\log\frac{E}{\mu}, \qquad (1)$$





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$$z_c^* = z_c/\left(1-\Delta E/p_c\right) \rightarrow \frac{D_{h/c}(z_c,Q'^2)}{\pi z_c^2} \longrightarrow \frac{z_c^*}{z_c}\frac{D_{h/c}(z_c^*,Q'^2)}{\pi z_c^2}$$

$$E_{\rm h}\frac{{\rm d}\sigma_{\rm h}^{AA}}{{\rm d}^3p} = \int {\rm d}^2b\,{\rm d}^2r\; t_{\rm A}(\vec b)t_{\rm B}(\vec b-\vec r)\sum_{\rm abcd}\int {\rm d}x_{\rm a}{\rm d}x_{\rm b}{\rm d}z_{\rm c}{\rm d}^2k_{\perp,{\rm a}}{\rm d}^2k_{\perp,{\rm b}}\,\cdot$$

$$f_{\rm a/A}(x_{\rm a},k_{\perp,{\rm a}}(\vec b),Q^2)f_{\rm b/A}(x_{\rm b},k_{\perp,{\rm b}}(\vec b-\vec r),Q^2)\;\frac{{\rm d}\sigma}{{\rm d}\hat t}\frac{z_{\rm c}^*}{z_{\rm c}}\frac{D_{\rm h/c}(z_{\rm c}^*,\widehat{Q}^2)}{\pi z_{\rm c}^2}\;\hat s\delta(\hat s+\hat t+\hat u)$$

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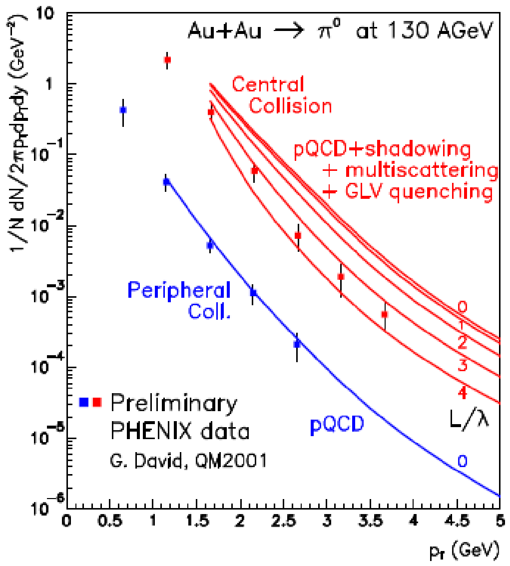

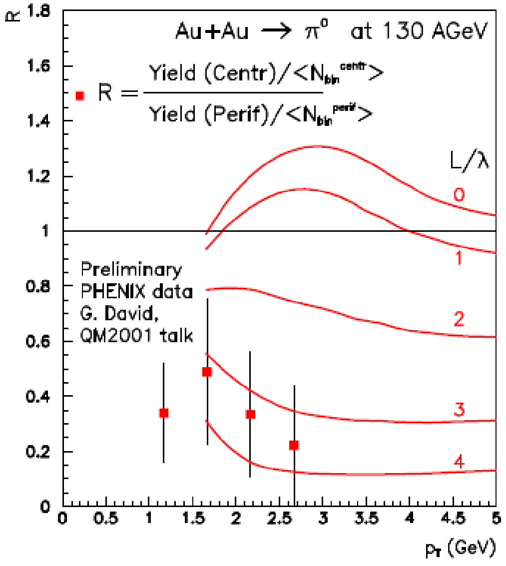

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Jet quenching as a probe of gluon plasma formation

G. Fai[1]*, G.G. Barnaföldi[2], M. Gyulassy[3], P. Lévai[2],
G. Papp[4], I. Vitev[3], and Y. Zhang[1]

[1] CNR, Dept. of Physics, Kent State Univ., Kent, OH 44242, USA
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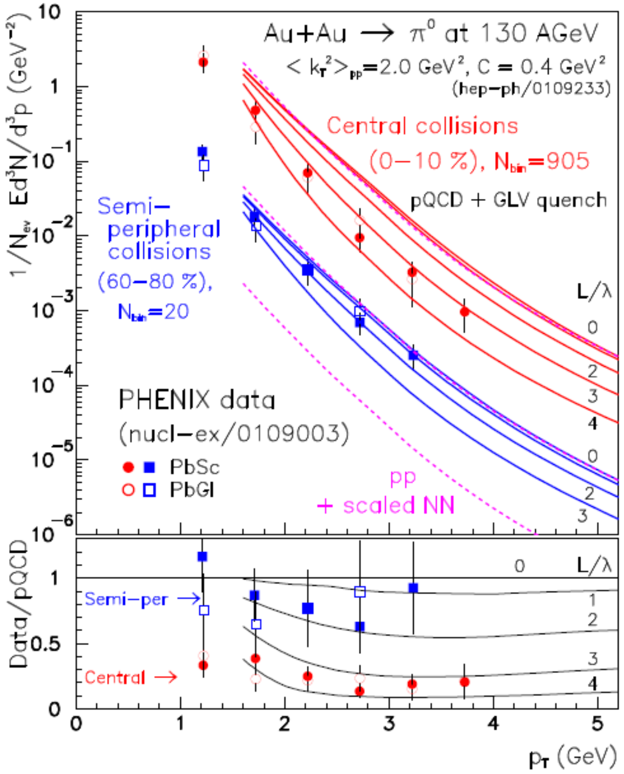
[3] Physics Department, Columbia Univ.,
538 W. 120-th Street, New York, NY 10027, USA
[4] HAS Research Group for Theoretical Physics,
P.O. Box 32, Budapest 1518, Hungary
E-mail: fai@cnrred.kent.edu

November 16, 2001

Abstract

We study, in a pQCD calculation augmented by nuclear effects, the jet energy loss needed to reproduce the π^0 spectra in Au+Au collisions at large p_T, measured by PHENIX at RHIC. The transverse width of the parton momentum distributions (*intrinsic* k_T) is used phenomenologically to obtain a reliable baseline *pp* result. Jet quenching is applied to the nuclear spectra (including shadowing and multiscattering) to fit the data.



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Jet Tomography Studies in $AuAu$ Collisions at RHIC Energies

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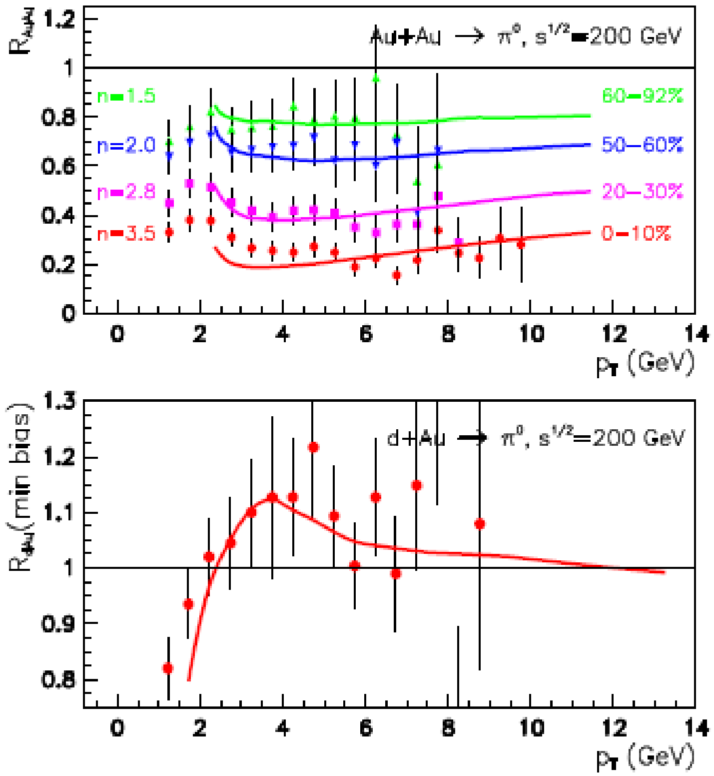
the date of receipt and acceptance should be inserted later

Abstract. Recent RHIC results on pion production in $AuAu$ collision at $\sqrt{s} = 130$ and 200 AGeV display a strong suppression effect at high p_T. This suppression can be connected to final state effects, namely jet energy loss induced by the produced dense colored matter. Applying our pQCD-based parton model we perform a quantitative analysis of the measured suppression pattern and determine the opacity of the produced deconfined matter.



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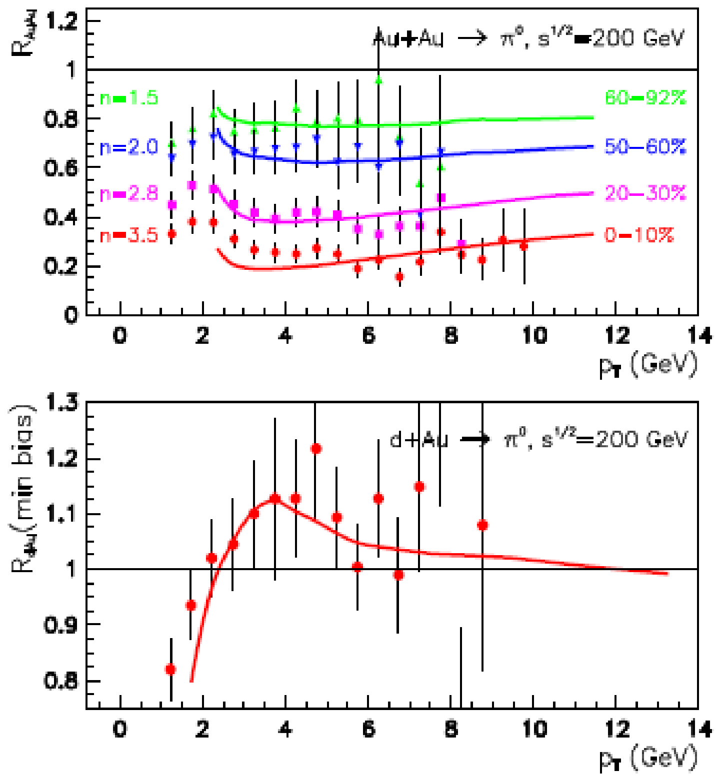

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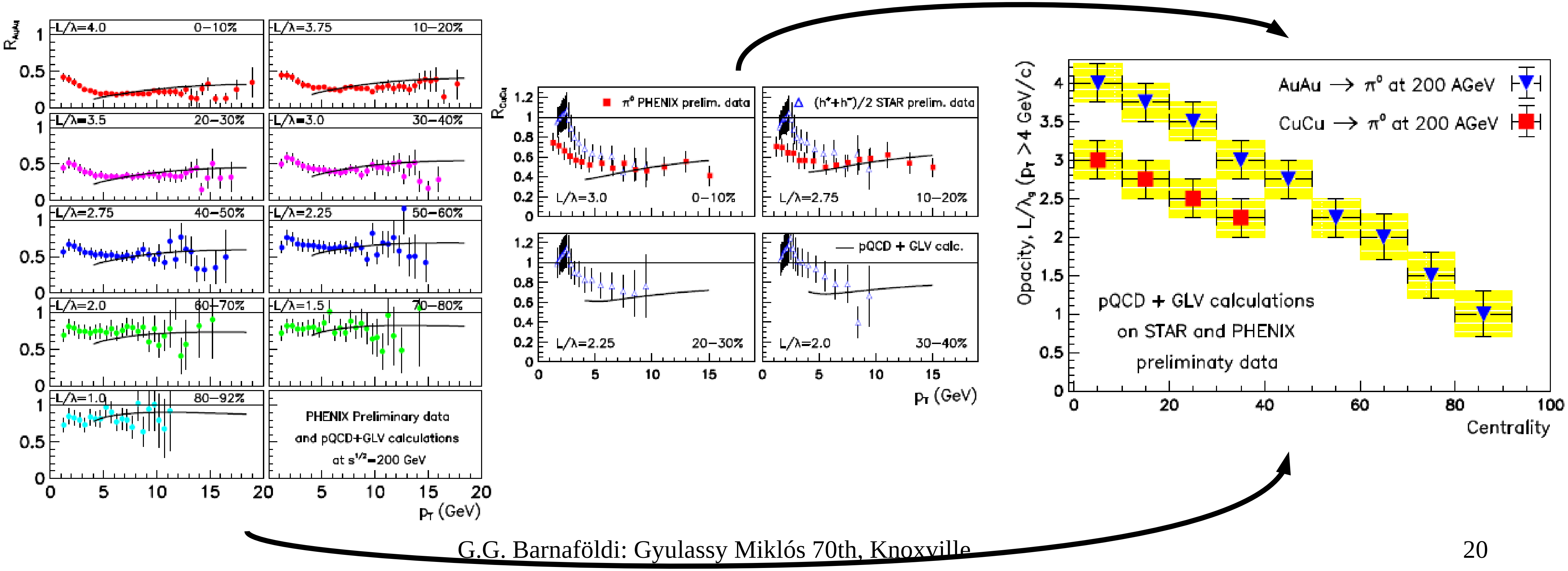

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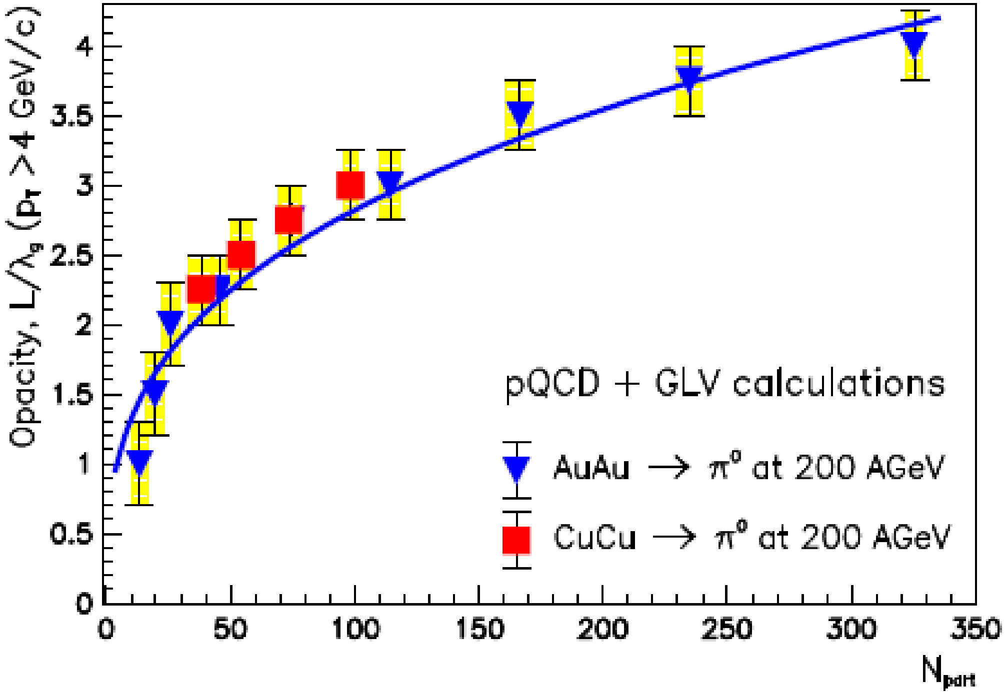
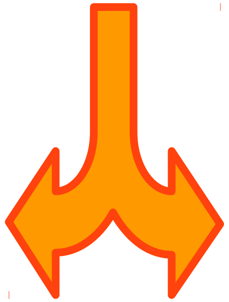
- Rapidity & Multiplicity study: EPJ C49 (2007) 333



$$L/\lambda = (0.62 \pm 0.09) \cdot \langle N_{part} \rangle^{0.33 \pm 0.03}$$

$$L \propto A^{1/3} \propto N_{part}^{1/3}$$



$$\epsilon = \Delta E / E \propto N_{part}^{2/3}$$

2000- The GLV bomb…

- From 2000 we had the NLO pQCD code including all high-energy nuclear effects, but not the jet suppression.
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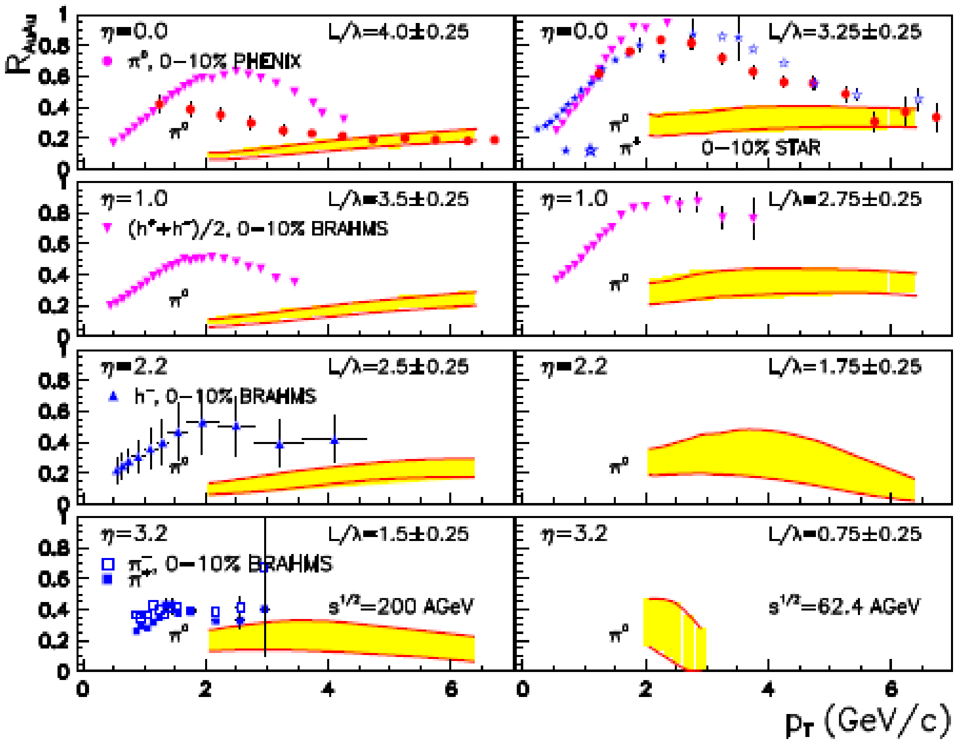
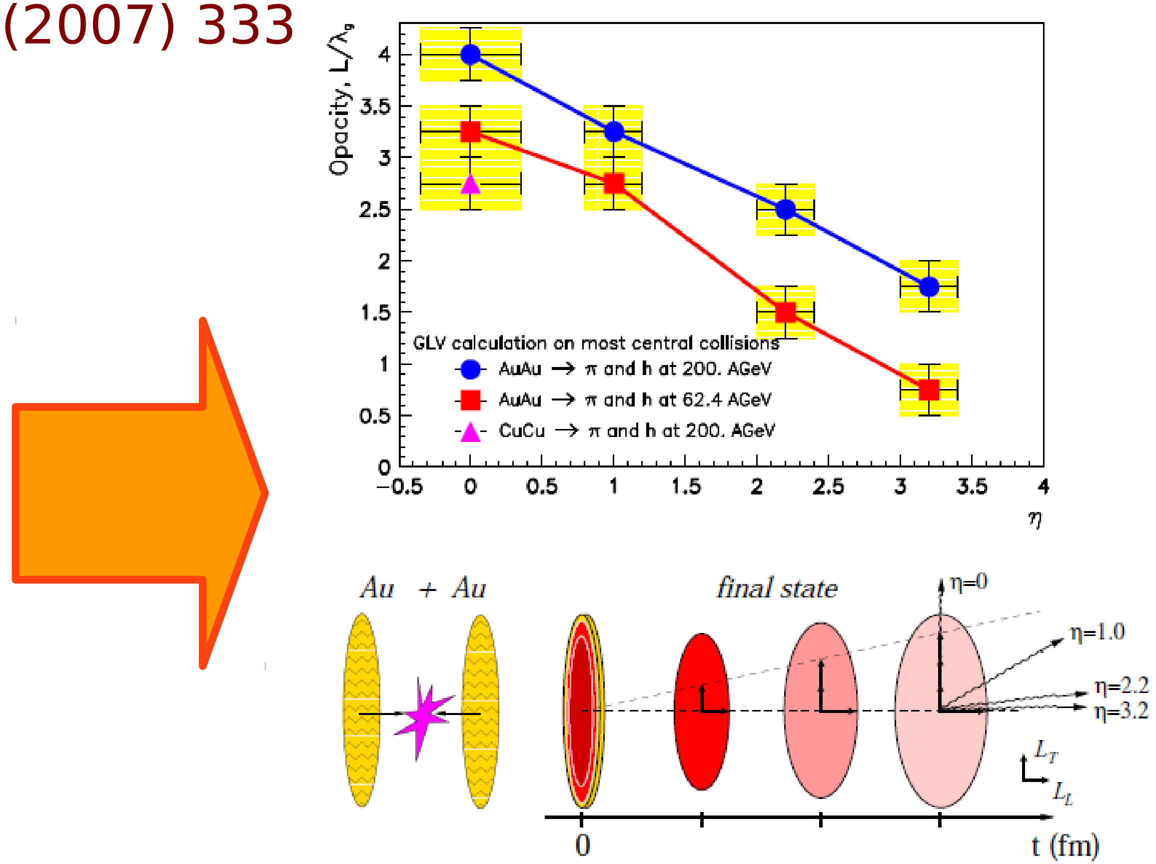


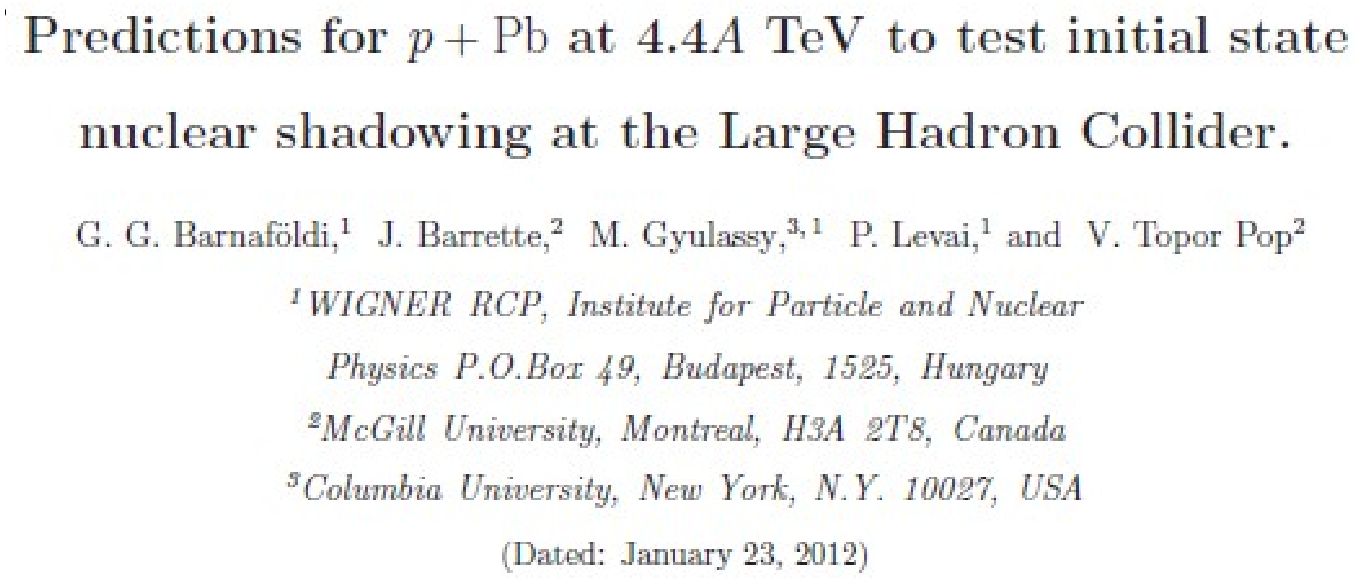


...then they were super-happy...

Prediction for the pA @ LHC after the re-birth

2010 - preparing for the LHC pA era

- We used both kTpQCD and HIJINGBB for prediction for the LHC pA era at cm energies 4.4, 5.02, and 8.16 ATeV
- HIJING/BBv20 & kTpQCD: PRC85 (2012) 024903, arXiv 1211.2256



Predictions for $p+\text{Pb}$ at $4.4A$ TeV to test initial state nuclear shadowing at the Large Hadron Collider.

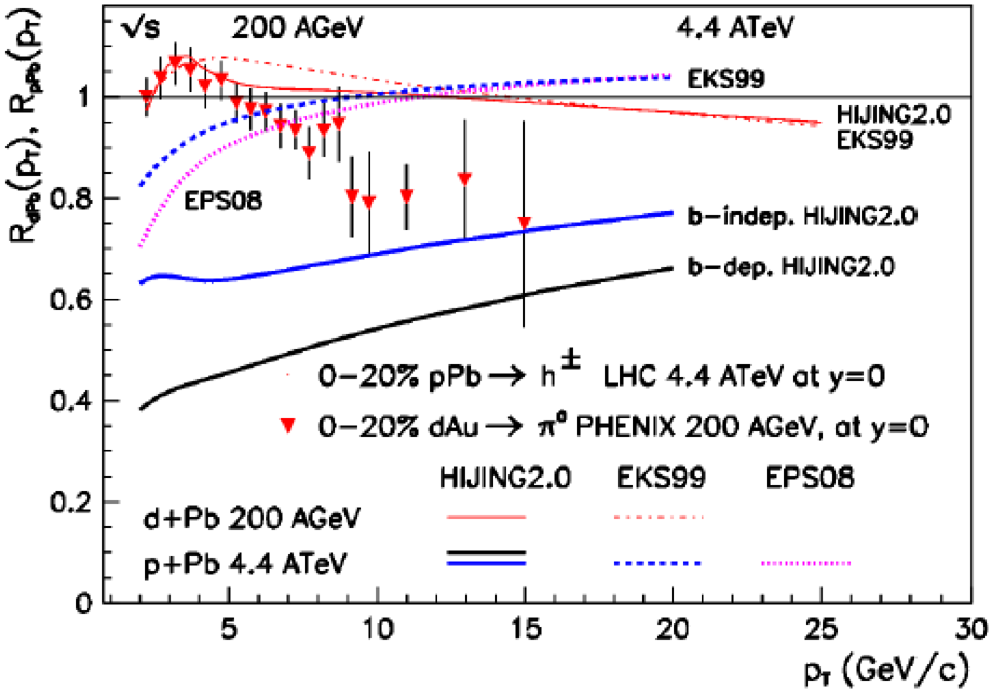
G. G. Barnaföldi,[1] J. Barrette,[2] M. Gyulassy,[3,1] P. Levai,[1] and V. Topor Pop[2]

[1] *WIGNER RCP, Institute for Particle and Nuclear Physics P.O.Box 49, Budapest, 1525, Hungary*

[2] *McGill University, Montreal, H3A 2T8, Canada*

[3] *Columbia University, New York, N.Y. 10027, USA*

(Dated: January 23, 2012)



2010 - preparing for the LHC pA era

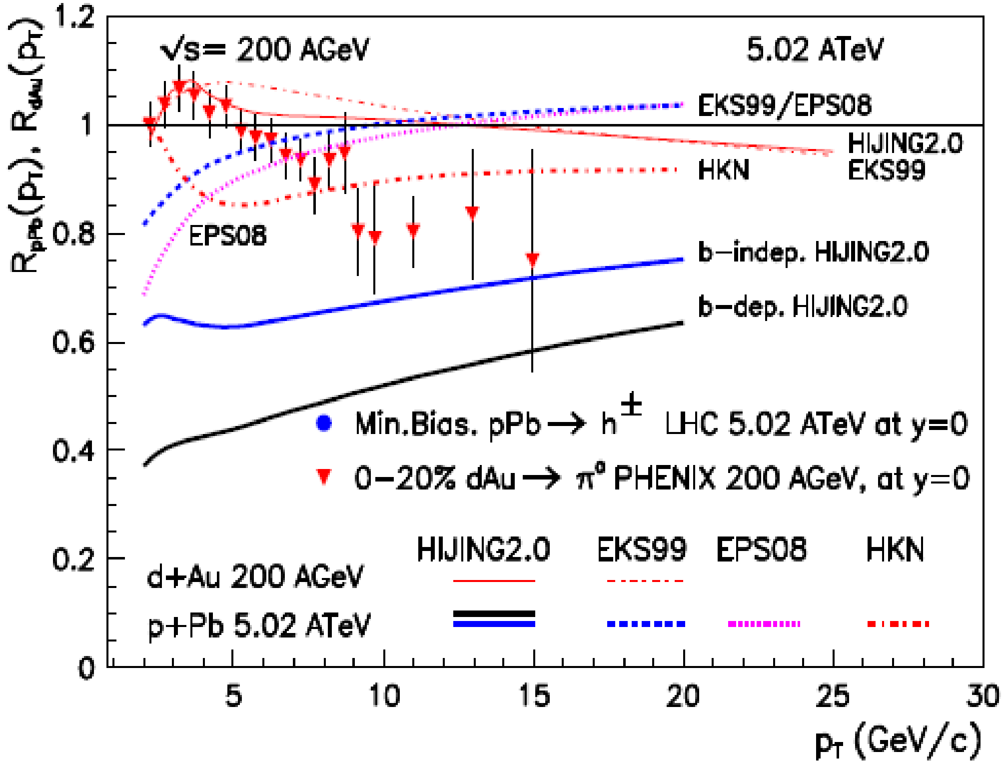
- We used both kTpQCD and HIJINGBB for prediction for the LHC pA era at cm energies 4.4, 5.02, and 8.16 ATeV
- HIJING/BBv20 & kTpQCD: PRC85 (2012) 024903, arXiv 1211.2256

Predictions for $p+\mathrm{Pb}$ at $5.02A$ TeV to test initial state nuclear shadowing at the Large Hadron Collider.

G. G. Barnaföldi,[1] J. Barrette,[2] M. Gyulassy,[3,1]
P. Levai,[1] G. Papp,[4] M. Petrovici,[5] and V. Topor Pop[2]

[1]*WIGNER RCP, Institute for Particle and Nuclear Physics P.O.Box 49, Budapest, 1525, Hungary*
[2]*McGill University, Montreal, H3A 2T8, Canada*
[3]*Columbia University, New York, N.Y. 10027, USA*
[4]*Eötvös Loránd University, Pźmány Péter Sétány 1/A, H-1117 Budapest, Hungary*
[5]*National Institute for Physics and Nuclear Engineering- Horia Hulubei, R-077125, Bucharest, Romania*

(Dated: December 11, 2012)



The era of “++”

2015- from HIJING to HIJING++

- We could see the limitation of the HIJING during these studies. So I tried to convince Xin-Nian & Miklós to start a new project with updating HIJING
- They all supported the idea, but noted this will be a long journey in a big mess…

→ Certainly we are equipped with all the features for this


The old HIJING


The old HIJING
Solid hardware basis at Wigner

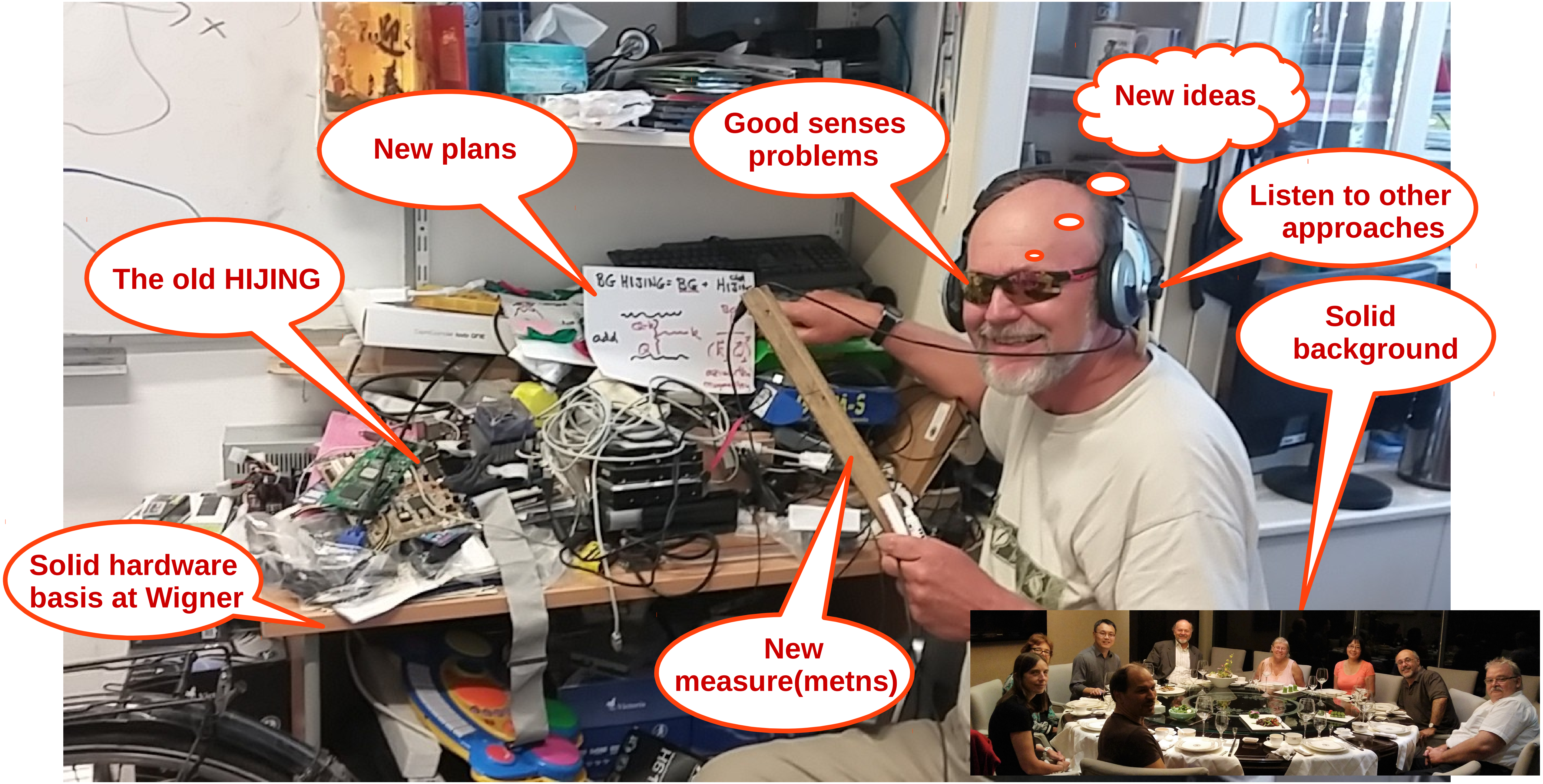

New plans
The old HIJING
Solid hardware
basis at Wigner


New plans
The old HIJING
Solid hardware basis at Wigner
New measure(metns)


New plans
Good senses problems
The old HIJING
Solid hardware basis at Wigner
New measure(metns)


New plans
Good senses problems
New ideas
The old HIJING
Solid hardware basis at Wigner
New measure(metns)
BG HIJING = BG + HIJING


New plans
Good senses problems
New ideas
Listen to other approaches
The old HIJING
Solid hardware basis at Wigner
New measure(metns)


New ideas
Good senses problems
New plans
Listen to other approaches
The old HIJING
Solid background
Solid hardware basis at Wigner
New measure(metns)

2015- from HIJING to HIJING++

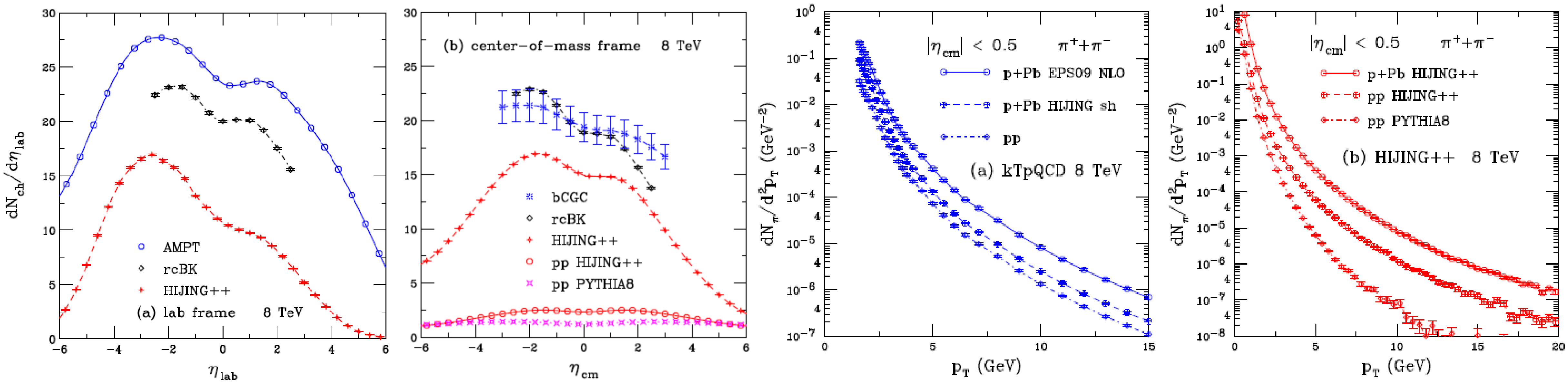
- We could see the limitation of the HIJING during these studies. So I tried to convince Xin-Nian & Miklós to start a new project with updating HIJING
- They all supported the idea, but noted this will be a long journey…

- In January 2015 three of us, G. Papp, Sz. Harangozó & me, were at Berkeley with Xin-Nian and Miklós for a week. We made the update plan and in a week we had a 2x faster FORTRAN version → both of them were convinced
- By this time, we have a working semi-parallel, modular C++ version of HIJING, called HIJING++ → soon to be published and make publicly available for the future.

→ Stay tuned on this, the live part of the story to be continued tomorrow….

2018 – Frirst HIJING++ data for LHC pA

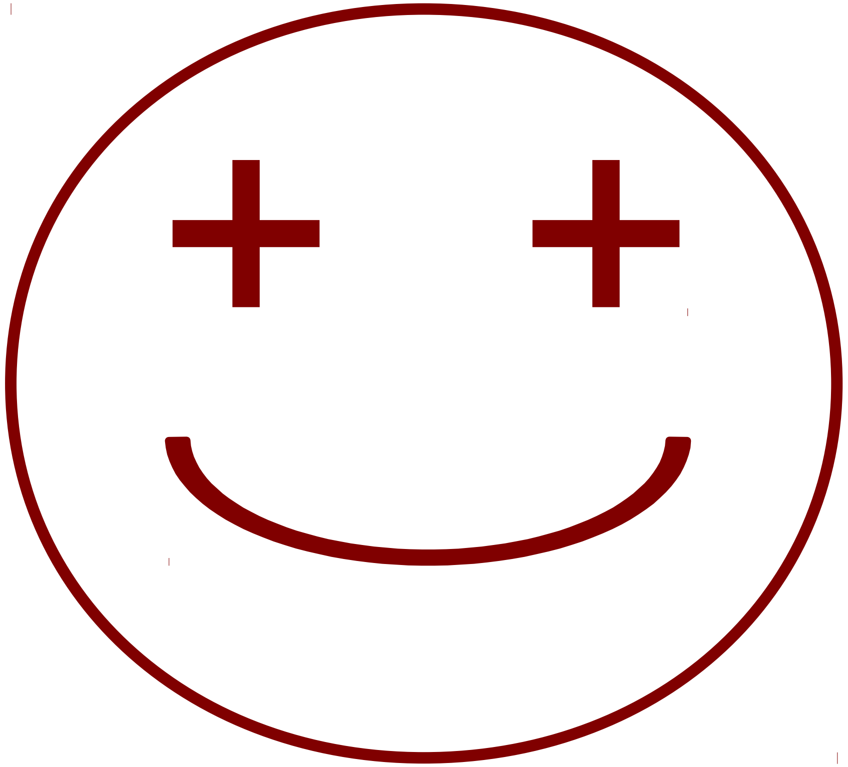
- Apetizer: LHC pA predictions: 8.16 ATeV: NPA 972 (2018) 18



So…, Miklós, finally I wish a lot of

+ +

So…, Miklós, finally I wish a lot of



...and Happy 70th or 13th Birthday!