Hannes and Siegen
31 eventful years of a fruitful collaboration

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On the occasion of Hannes 80th anniversary

How it started (3)?

Since we finished graduate school I often collaborated with Patrick Aurenche on soft multiparticle physics.

To describe our interest at this time, a short reminder on

- Dual Topological Unification,
- Planar Amplitudes as a building block, and
- the s-channel way to build the Pomeron of González-Mestres and Aurenche

How it started (2)?

The no longer interconnected strings allowed a simply model

The Dual Parton Model

A. Capella, Sukhatme, Chung-I Tan and Tran Than Van

Alfons explained us the crucial points.

1. take the fragmentation function from other processes
   like e+e- annihilation
2. use Reggeology structure function to distribute the energy

$\rightarrow$ obtain good fits to hadron-hadron spectra at pre-SPS energies
(above the resonance region)

Other authors developed more or less identical models.

How it started (1)?

Starting with SPS energies multiple Pomeron exchanges became important. Fits to the energy dependence of cross section required iteration of Pomerons. Essentially relying on Reggeon Calculus cross section fits of Capella, Kaidalov and others for the choice of the needed parameters, a definite description of multiparticle production could be obtained.

We participated in this. We produced nice program implementing Dual Parton Model using inclusive fragmentation functions.

Typical for the collaboration with Patrick at that time was that I came in the semester vacation for a month or two to CERN and Patrick split his time between Annecy and Geneva.

How it started ?

Our program with its inclusive fragmantation functions was quite successful. The main uncertainties came from kinematical effects which are just parameterized on a inclusive level. It was clear a exclusive model was the next step and planning had to be done.

Per chance there was a overlap with Hannes who also stayed at CERN helping with the development of **FLUKA**. He had written with his Leipzig group a Program

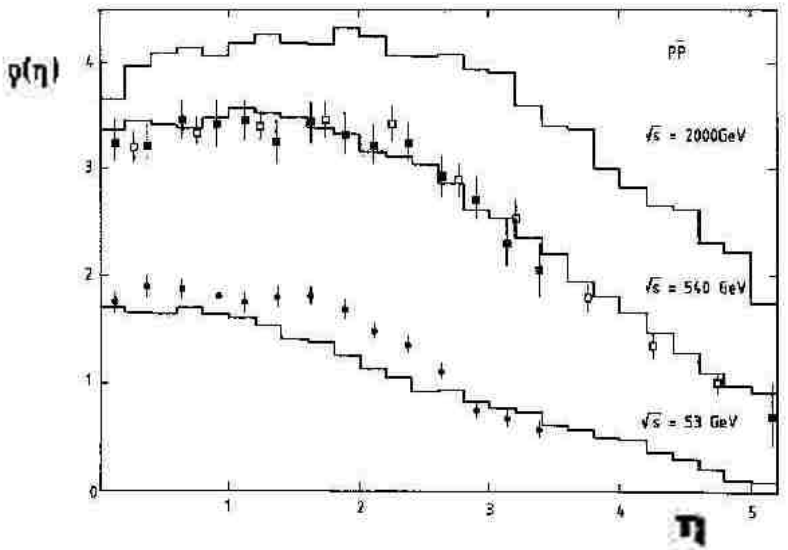
BAMJET & DECAY

for e^+e^- fragmentation and for a two string model. It was exactly what we needed for the multi-Pomeron version. So we decided to join both programs.

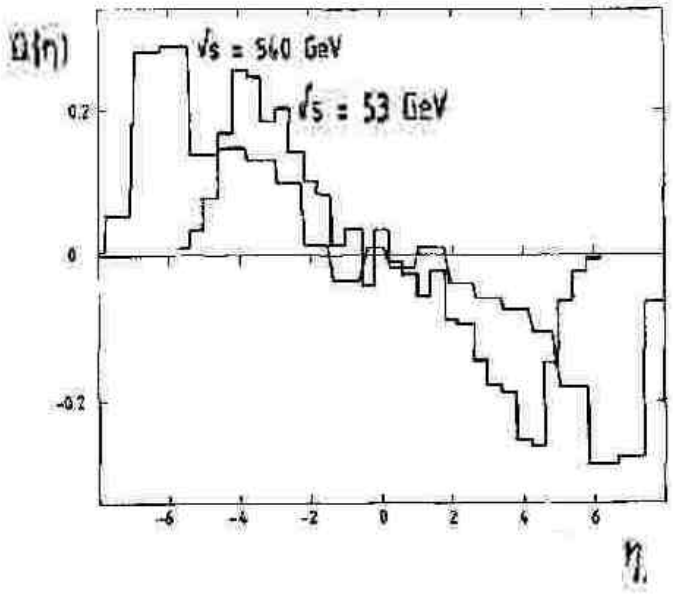
At the time German-German collaborations were very rare.

Early results 1

After the program worked, a number of questioned could be investigated. It started with the general features



Charged particle pseudorapidity spectrum for $\bar{p}p$ scattering



The charge distribution $Q(\eta) = \rho^{+}(\eta) - \rho^{-}(\eta)$

(From "Particle Production In Hadron Hadron Collisions At Collider Energies In An Exclusive Multistring Fragmentation Model, Z. Phys. C **23** *(1984) 67.)*

Early results 2

It was done with very little computing power. Part of the work was on a IBM type personal computer somehow existing in Leipzig and skillfully fragmented Monte Carlo code to make it work. Few people other than Hannes would have the discipline to do this.

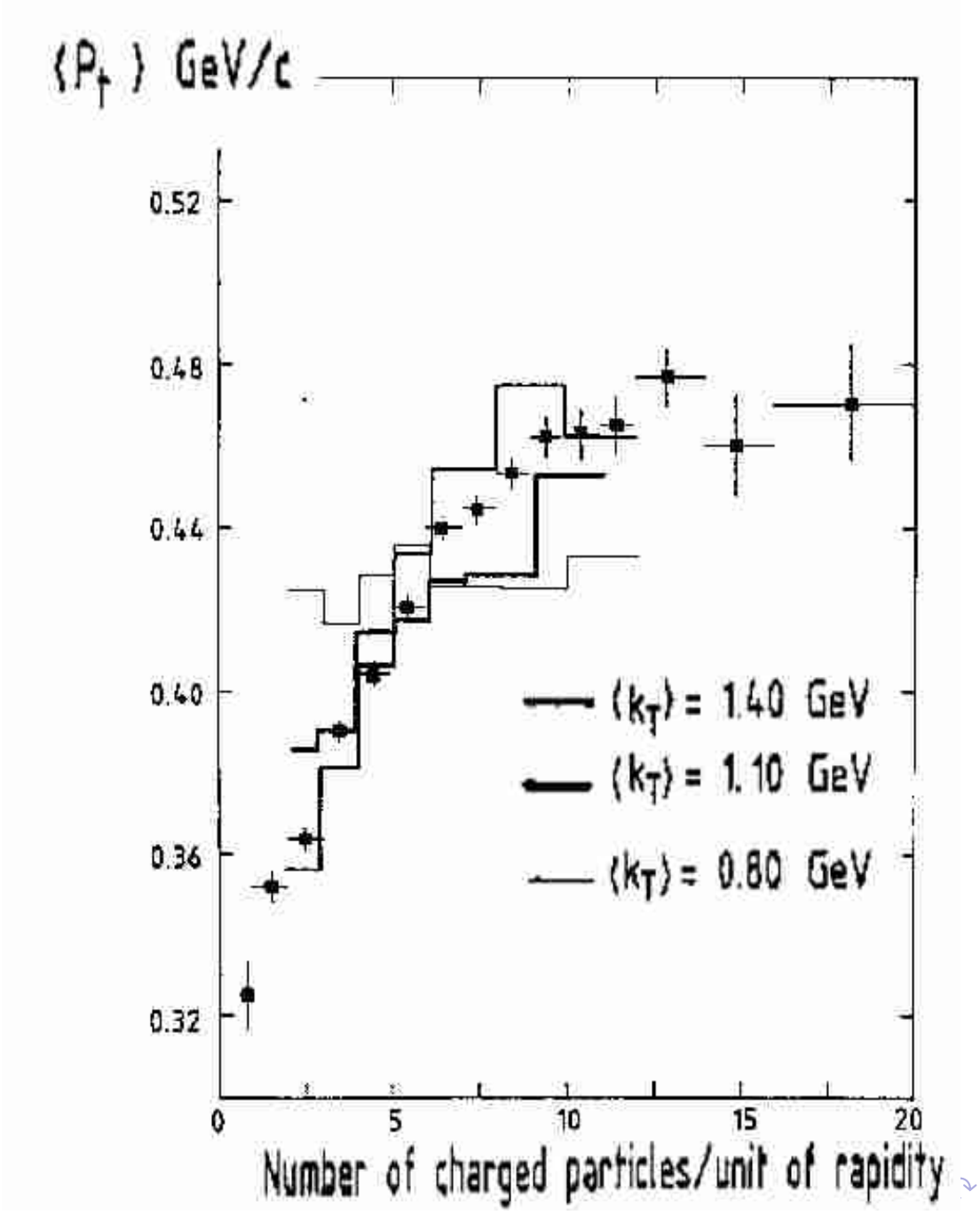
It was important to understand the multiplicity distribution
(see „The Multistring Fragmentation Model And Violation Of KNO Scaling,"Z. Phys. C **26** *(1984) 279.)*
We got a good agreement with the data and a widening.
To point out that there is a definite prediction of a strong KNO scaling violation was the merit of Kaidalov.

Early results 3

An important prediction of fragmentation models - which is not commonly appreciated - is the **multiplicity dependence of the average transverse momentum.**

The relative weight of particles originating in the harder string ends inceases if the choosen multiplicity selects more and shorter strings.

(From:"The Multiplicity Dependence Of The Transverse Momentum Distribution At The SPS Collider Energy And The Multistring Fragmentation Model"; Phys. Lett. B **147** (1984) 212.*)* and*: The Transverse Momenta In Minimum Bias Events At Collider Energies";* Phys. Rev. D **33** (1986) 1867.*)*



Early results 4

The SSC collider was soon to be build and predictions were important:

- *"Extrapolation Of Multistring Production Mechanism To Super Collider Energies,"* SI-84-6
- *'A Consistent Approach To Large Cross-sections,"* SI-87-08.

More predictions followed later.

But now there was a new observation
which required an major adjustment of the model.

The Mini-Jet Contribution 1

SPS observed an abundance of Minijets.

Minijets are a Jet like contribution extrapolated in a semi-hard region where perturbative consideration where considered unreliable.

Jan Kwiecinski advised us that with some modifications like Reggeized t-channel gluon perturbative QCD could be extended up to values of $p_\perp \sim 1\,\mathrm{GeV}$.

It meant they had to be accounted for in the program.

The Mini-Jet Contribution 2

The Dual Parton Model is essentially a longitudinal model. The obvious transverse momenta of the partons on the string ends were parametrized to fit the data. At SPS energies their value reached the semi-hard region. To consider soft and hard physics as disjoint made no longer sense.

As a first step in this direction

- we added a hard contribution to the bar scattering entering the eikonal iteration with a suitable soft/hard cut off and
- adjusted the soft $p_\perp$ ad the string ends to obtain a continuous contribution around this cut off.

For the first step we followed a 1987 letter of Capella, Tran Than Van and Kwiecinski

The Two Component Dual Parton Model

A new DTUJET program was a huge project and huge projects require big collaborations. So we joined
with

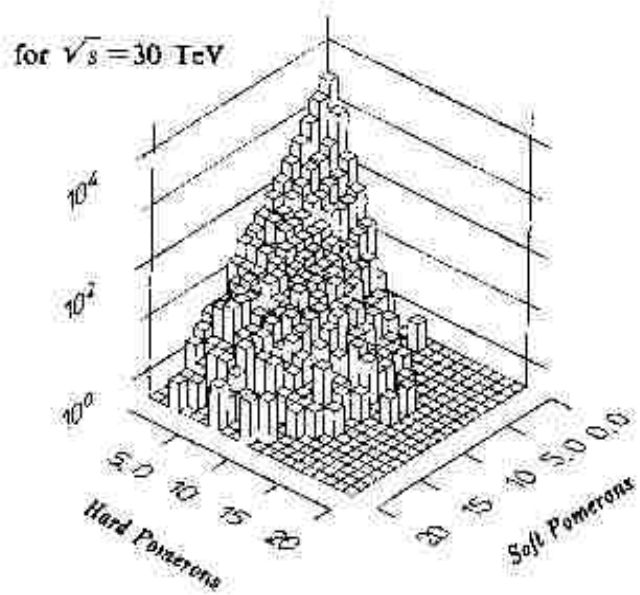
- A. Capella and J. TranThan Van
- J. Kwiecinski (authors of the Letter)
- P. Maire (experimentalist for MC questions)
- K. Hahn (from Hannes group)

In spite of the man power the actual work developed slowly. It changed abruptly when until Hannes and Hahn could spend a month or two in Berkeley working for the SSC Central Design Group.

The Two Component Dual Parton Model

The charged particle spectrum for 40 TeV reached 7.5.
Let me except one central figure of the resulting papers:

- *"Dual Topological Unitarization Of Hard And Soft Hadronic Cross-sections, A New Approach To Multiparticle Production At Hadron Colliders In The TeV Energy Range," SSC-149*
- *Multiparticle production in a two component dual parton model,"Phys. Rev. D* **45** *(1992) 92.*



Even at super high energy the soft contribution remains significant.

The Collaps of the GDR

The immediate effect for us was that usual travelling was possible. I could drive to Leipzig for discussion in the somewhat desolate high rise with an dated paternoster elevator. Many members of Hannes group could be invited to travel to Siegen to give seminars.

Physicswise a collaboration with Dieter Pertermann who was Postdoc in Hannes group started. Together with Hannes we investigated the influence of different structure functions in: "Hadron production at supercolliders in the two component dual parton model and the small x behavior of the structure functions," Z. Phys. C **54** (1992) 68 and similar papers.

The Break Up of Hannes Group

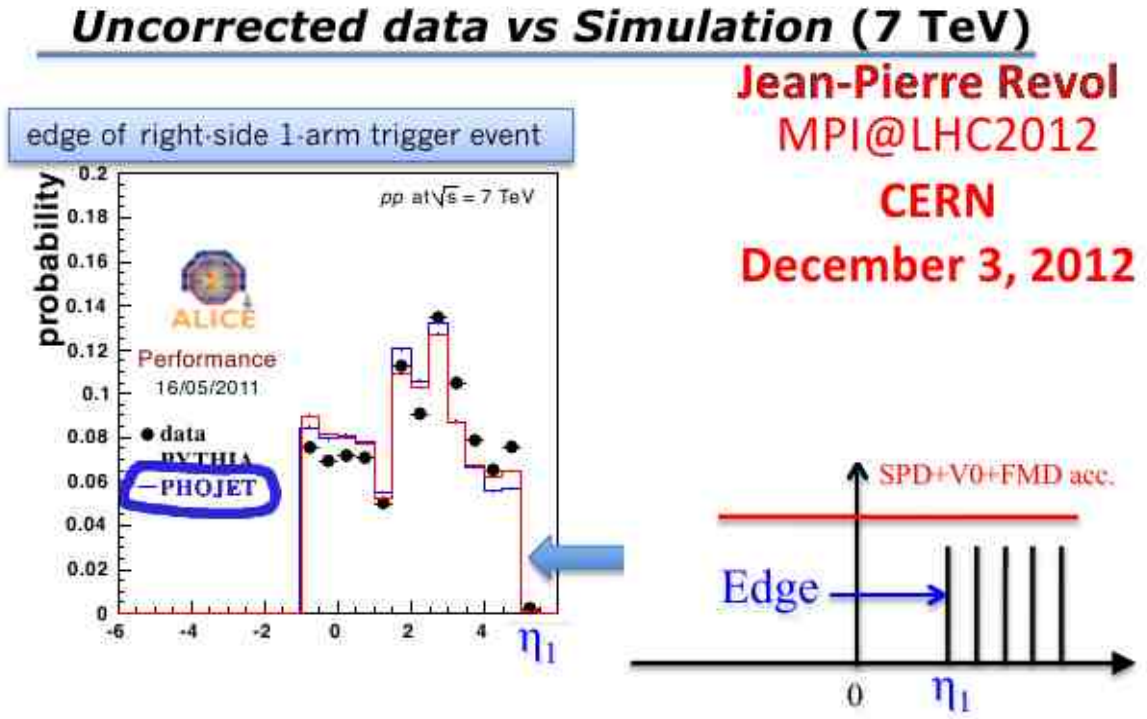
Hannes Position in Leipzig was taken after a few uncertain years by an embarrassing „Kanzler“.

Hannes choose devote his time to physics and - as you know - he managed to do this with the help of influential friends at various places in Europe.

Siegen benefited from this by having the honor of two exceptionally gifted doctoral students, Ralph Engel and Stefan Roesler.

Ralph's PHD

Ralph wrote a new cleaner version of the program named „PHOJET“ which could also handle photons as needed in HERA. It was extremely successful and it was until recently still used by LHC collaborations. Almost twenty years is an unusual „date of expiry“ for a physics program. As a recent example a diffractive gap distribution:

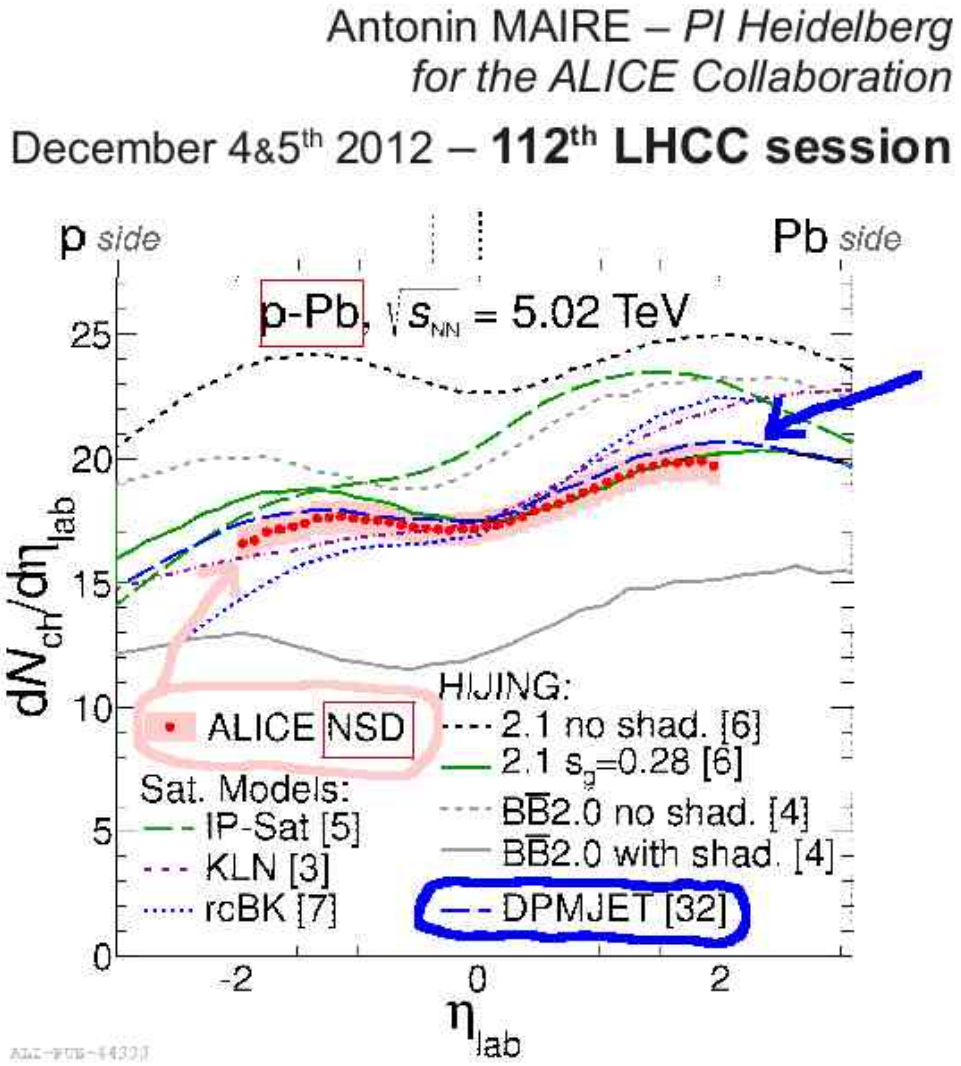


Stefans's PHD

Stefan wrote a program for nucleus-nucleus scattering containing many nuclear physics aspects. It was named „DPMJET“.

It was also extremely successful and time resisting. As a recent example the $p + Pb$ spectrum:

As it is somewhat crowded I put in arrows. DPMJET was by far the best fit.



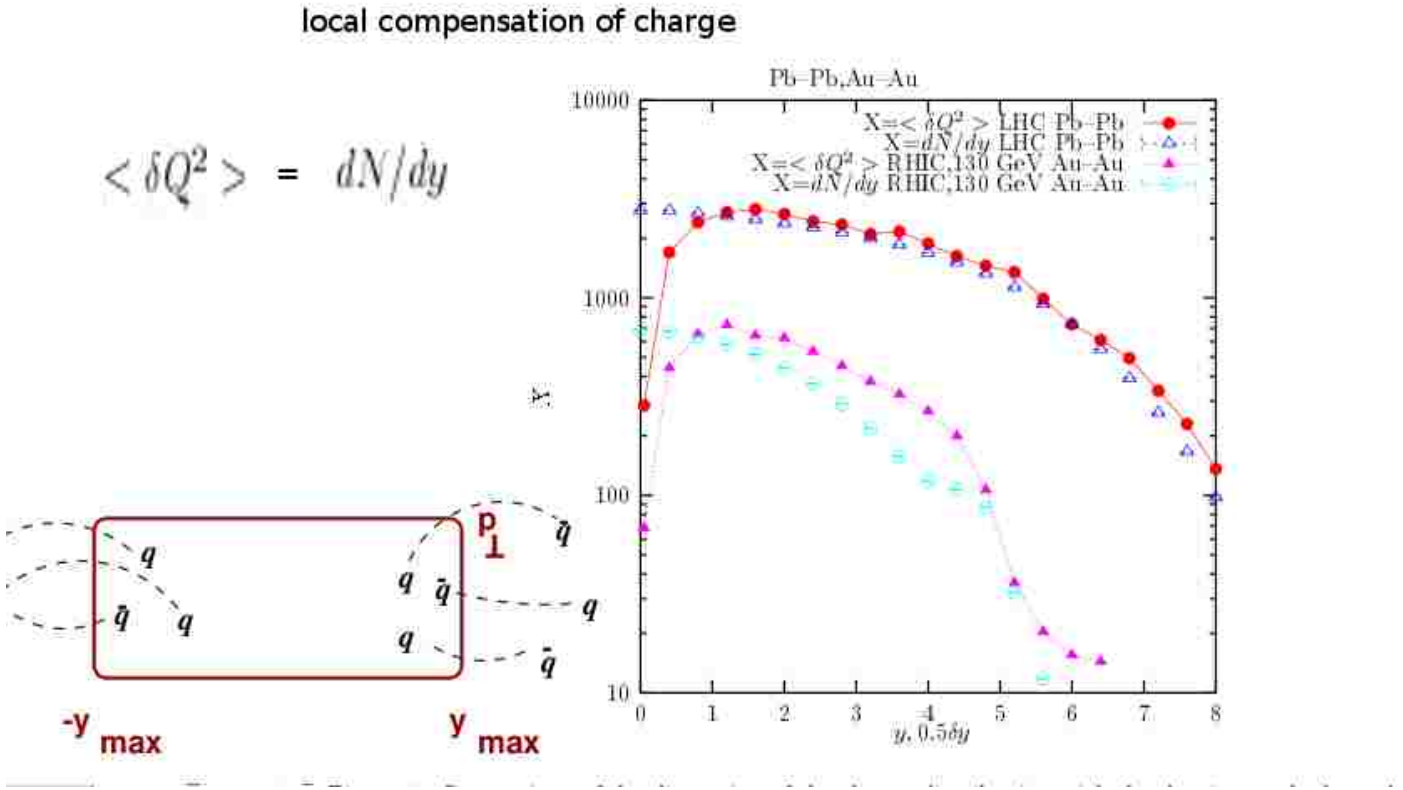
Gastprofessor at the University of Siegen

The role of the University of Siegen became more important. Hannes worked at home and came once every month or two for few days to „his“ office in Siegen to keep up with the literature and proceed with the new projects.

Part of the work involved looking for new aspects of the data and explain them within the frame work of the model.

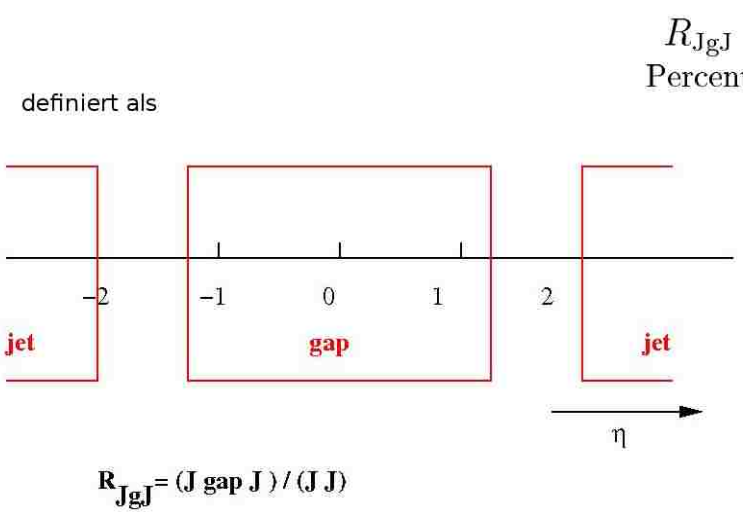
Here two examples:

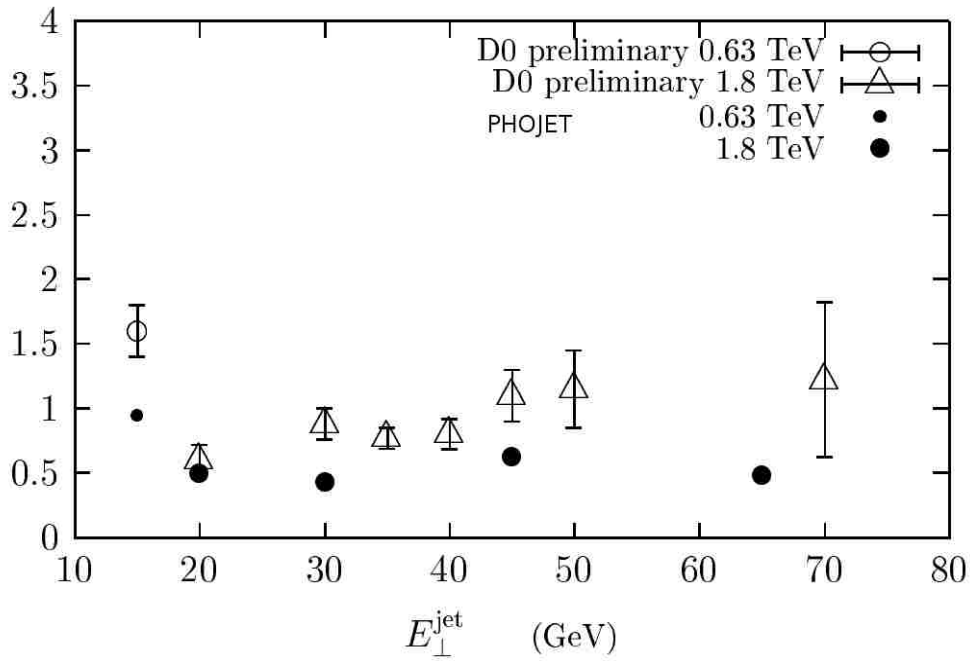
'Charged particle fluctuation as signal of the dynamics in heavy ion processes,"Eur. Phys. J. C **22** (2001) 171



"Rapidity gaps and the PHOJET Monte Carlo"

With a continous soft / hard transition the Pomeron has a hard component. This allows to understand Fermilab jet-gap-jet Data:





The main part of the work now involved looking for corners where the program did not represent the data

and where it was necessary to introduce slight modifications.

What was learnt from RHIC

It was necessary to introduce :

(i) Percolation and fusion of chains - the data from RHIC allow to determine the amount of percolation to be implemented into DPMJET–III.

(ii) Collision scaling of large $p_\perp$ hadron production in d–Au collisions.

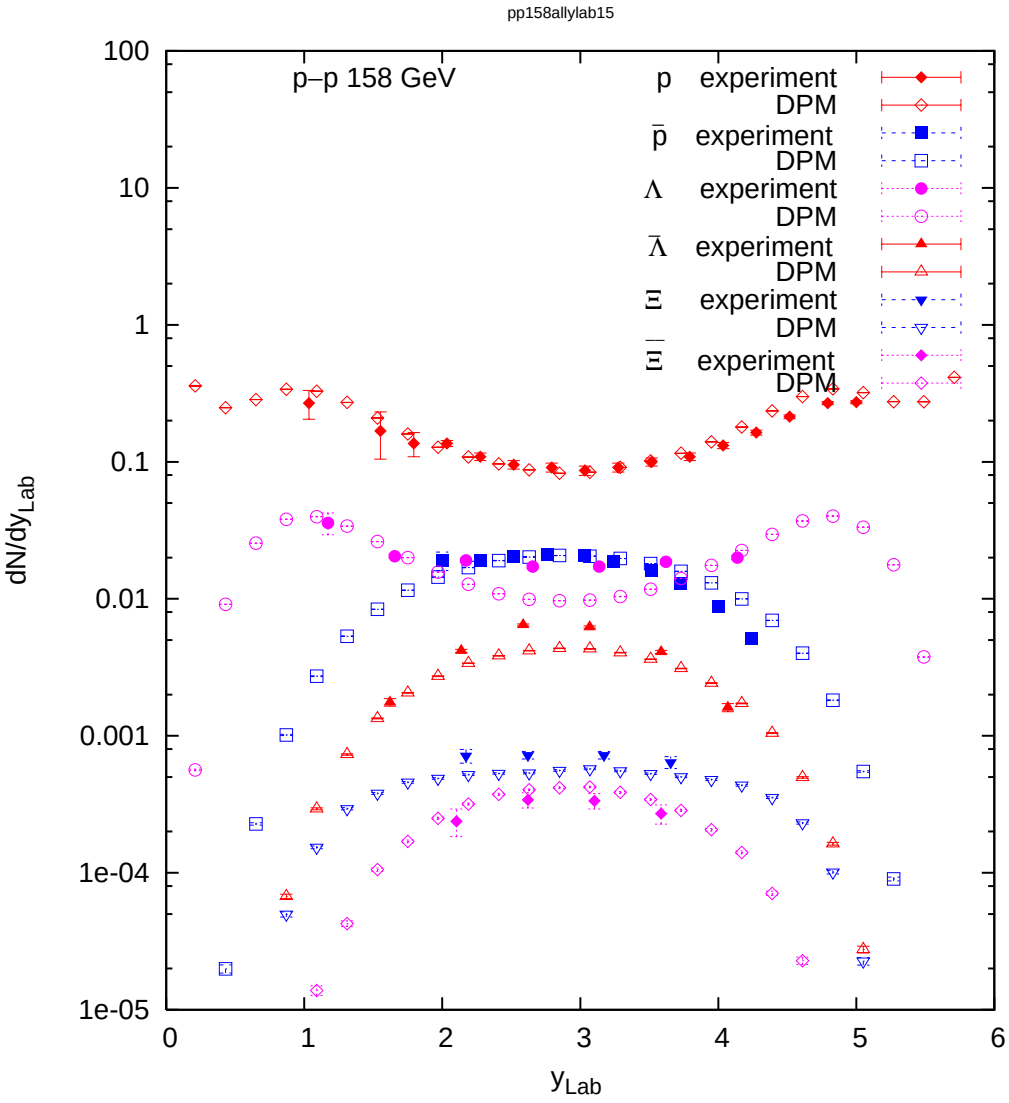
(iii) Replacing the Gaussian transverse momentum distribution contained in the Jetset/Pythia code by an exponential distribution in soft hadronic collisions.

(iv) Implementation of new diagrams for an improved description of baryon stopping.

(v) Addition of a baryonium like di-meson to the fragmentation of diquark chains to decouple flavor

These corrections are somewhat technical, they do not involve the basic structure of the string model.

To illustrate the result a picture from:
"Antiparticle to Particle Production Ratios in Hadron-Hadron and d-Au Collisions in the DPMJET-III Monte Carlo,"Phys. Rev. C **77** (2008) 014904



Expecting LHC

With these adjustment a new round of LHC predictions where made. The were published in:

'Inclusive distributions at the LHC as predicted from the DPMJET-III model with chain fusion,"
F. W. Bopp, R. Engel, J. Ranft and S. Roesler, arXiv:0706.3875 [hep-ph].

Heavy Ion Collisions at the LHC - Last Call for Predictions
N. Armesto, N. Borghini, S. Jeon, U. A. Wiedemann, S. Abreu, V. Akkelin, J. Alam and J. L. Albacete *et al.*, J. Phys. G **35** (2008) 054001

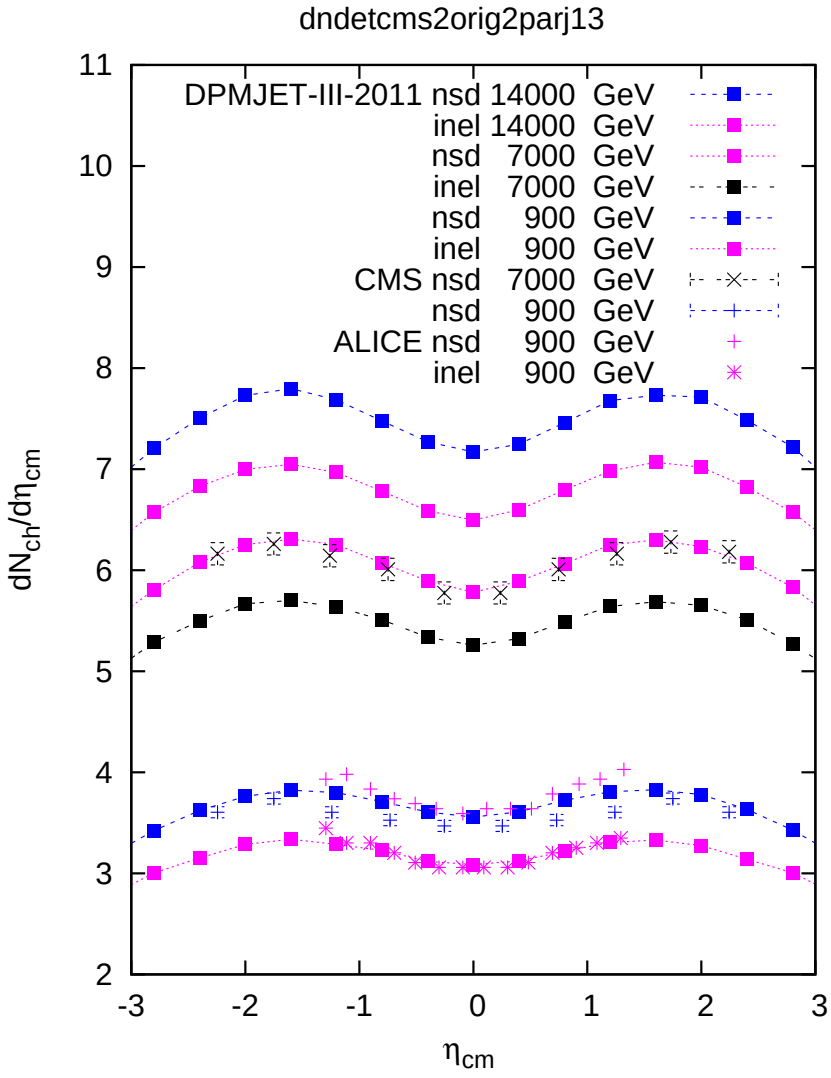
What do LHC results tell us?

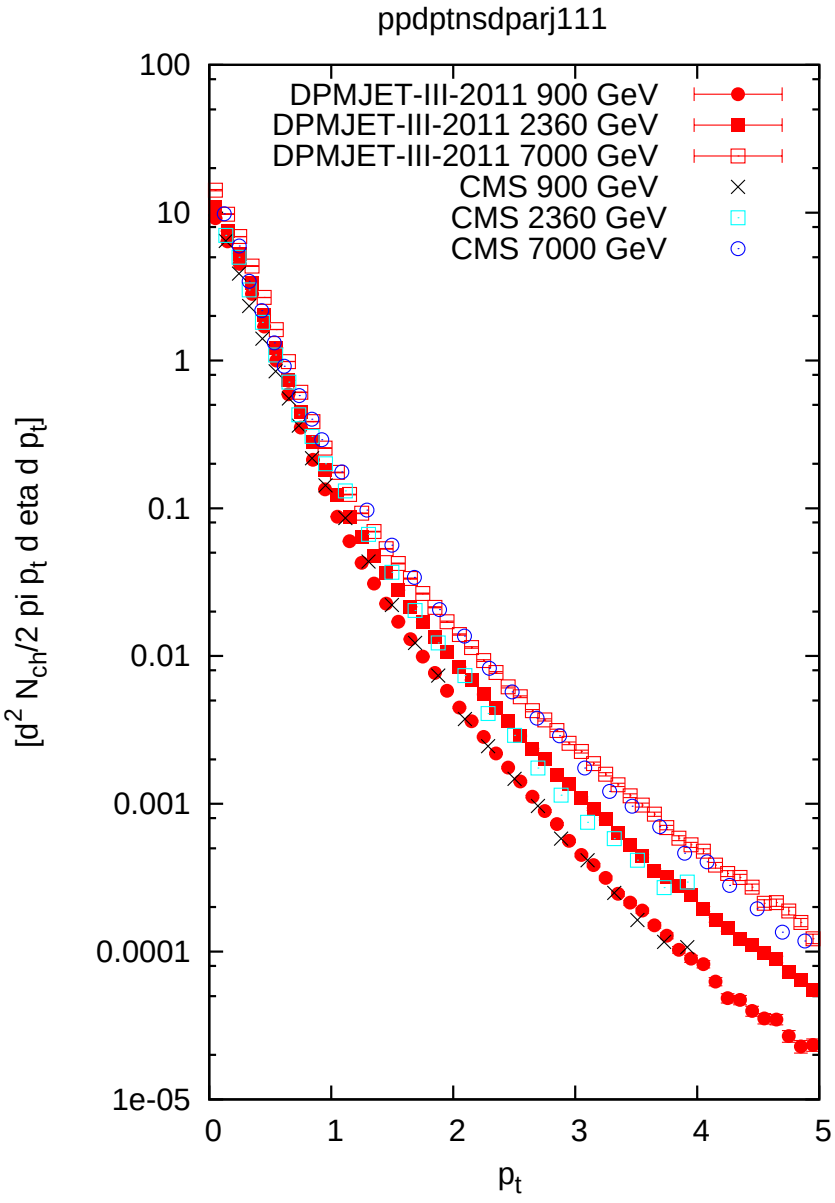
In plots where various predictions are compared with the new results PHOJET and DPMJET usually ranked quite well.

However there are problems. To solve them we made in DPMJET-III the PYTHIA-parameters energy dependent.

We consider the introduction of energy-dependent parameters only as a temporary solution. A more permanent solution will require deeper changes in the program.

Two plots from "Inclusive distributions in p-p collisions at LHC energies compared with an adjusted DPMJET-III model with chain fusion," (2012) to show that this temporary solution works:


dndetcms2orig2parj13
DPMJET-III-2011 nsd 14000 GeV
inel 14000 GeV
nsd 7000 GeV
inel 7000 GeV
nsd 900 GeV
inel 900 GeV
CMS nsd 7000 GeV
nsd 900 GeV
ALICE nsd 900 GeV
inel 900 GeV
dN_ch/dη_cm
η_cm


ppdptnsdparj111
DPMJET-III-2011 900 GeV
DPMJET-III-2011 2360 GeV
DPMJET-III-2011 7000 GeV
CMS 900 GeV
CMS 2360 GeV
CMS 7000 GeV
[d^2 N_ch/2 pi p_t d eta d p_t]
p_t

to the end

If one talks about our collaboration, one should not ignore the the evenings with interesting and lively discussion about many things.

Not to forget something important

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Not to forget something important
I included a picture

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and I hope such discussion will continue at dinner tonight.