SHRiMPS
Status of soft interactions in SHERPA

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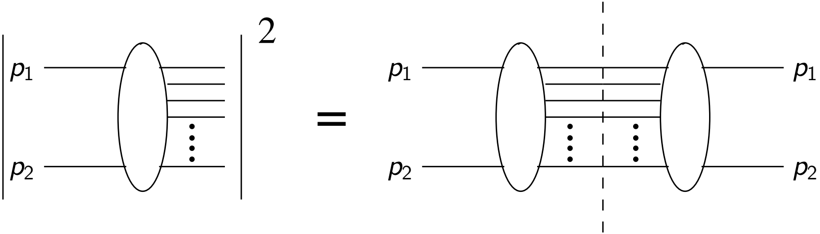
November 23, 2015

MPI@LHC 2015, Trieste

Introduction

- Unitarity of S-matrix $\rightarrow$ optical theorem
- Relates tree level to loop level diagram



$$\underbrace{\sigma_{\mathrm{tot}}(s)}_{\text{Eikonal ansatz}} = \frac{1}{s}\mathrm{Im}[\underbrace{A_{\mathrm{el}}(s, t=0)}_{\text{KMR model}}]$$

- $\rightarrow$ SHRiMPS model: MC event generation of elastic, inelastic and diffractive processes in SHERPA based on Khoze-Martin-Ryskin (KMR, `arXiv:0812.2407[hep-ph]`) through Multiple Pomeron Scattering

Eikonal ansatz

- $\sigma_{\mathrm{tot}}(s) = \frac{1}{s}\mathrm{Im}[A_{\mathrm{el}}(s, t = 0)]$
- Rewrite $A(s,t) \rightarrow A(s,b)$, b: impact parameter

<u>Ansatz:</u>

- $\sigma_{\mathrm{tot}}(s) = 2\int \mathrm{d}b^2 \mathrm{Im}[A(s,b)]$
- $\sigma_{\mathrm{el}}(s) = 2\int \mathrm{d}b^2 [A(s,b)]^2$
- $\sigma_{\mathrm{inel}}(s) = \sigma_{\mathrm{tot}}(s) - \sigma_{\mathrm{el}}(s)$

Eikonal ansatz

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- $\sigma_{\text{inel}}(s) = \sigma_{\text{tot}}(s) - \sigma_{\text{el}}(s)$
- $A(s, b) = i\left(1 - e^{\Omega(s,b)/2)}\right) \quad \rightarrow \quad \boxed{\sigma_{\text{tot}}(s) = 2 \int \text{d}b^2 \left(1 - e^{\Omega(s,b)/2)}\right)}$

Eikonal model

- $A(s,b) = i\left(1 - e^{\Omega(s,b)/2}\right)$
- Good-Walker (GW) states $|\phi_1\rangle$, $|\phi_2\rangle$ (diffractive eigenstates)
- $|p\rangle = \sum_{i=1}^{N_{\mathrm{GW}}} a_i |\phi_i\rangle$ SHRiMPS:$|p\rangle = \frac{1}{\sqrt{2}}|\phi_1\rangle + \frac{1}{\sqrt{2}}|\phi_2\rangle$
- $|N^*(1440)\rangle = \frac{1}{\sqrt{2}}|\phi_1\rangle - \frac{1}{\sqrt{2}}|\phi_2\rangle$

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- $\left(1 - e^{\Omega(s,b)/2)}\right) \to \sum_{i,k=1}^{N_{\mathrm{GW}}} |a_i|^2 \cdot |a_k|^2 \left(1 - e^{\Omega_{ik}(s,b)/2)}\right)$
- One single-channel Ω_{ik} eikonal per combination of GW states
- $\to$ e.g. $\sigma_{\mathrm{tot}} = 2\int \mathrm{d}b^2 \sum_{i,k=1}^{N_{\mathrm{GW}}} |a_i|^2 \cdot |a_k|^2 \left(1 - e^{\Omega_{ik}(s,b)/2)}\right)$

KMR modelling of Ω

Ω_{ik}: product of colliding (parton) densities $\omega_{i(k)}\ \omega_{(i)k}$

- $\omega_{i(k)}$: density of GW state i in the presence of k
- $\omega_{(i)k}$: density of GW state k in the presence of i
- Coupled evolution (in rapidity, y) equations

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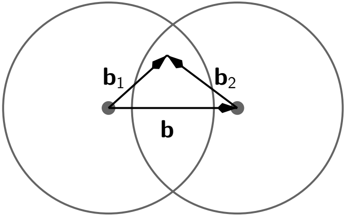
$$\Omega_{ik}(s,b) = \frac{1}{2\beta_0^2}\int \mathrm{d}b_1 \mathrm{d}b_2 \delta^2(b - b_1 + b_2)\omega_{i(k)}(y,b_1,b_2)\omega_{(i)k}(y,b_1,b_2)$$



KMR evolution

- $\frac{\mathrm{d}\omega_{i(k)}(y)}{\mathrm{d}y} = \Delta\omega_{i(k)} \cdot R(\lambda, \omega_{i(k)}, \omega_{(i)k})$
- $\frac{\mathrm{d}\omega_{(i)k}(y)}{\mathrm{d}y} = \Delta\omega_{(i)k} \cdot R(\lambda, \omega_{i(k)}, \omega_{(i)k})$
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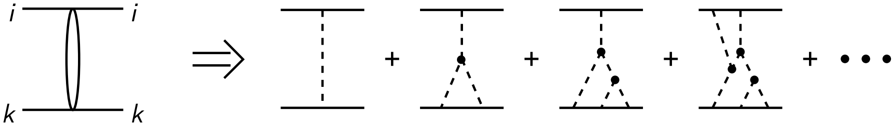
- $R(\lambda, \omega_{i(k)}, \omega_{(i)k})$: rescattering/absorption with free parameter λ
- Boundary conditions (form factors):
  - $Y = \log \frac{s}{m_p^2} - \delta Y$, parameter δY
  - $\omega_{i(k)}(-Y/2, b_1) = F_i(b_1, \quad \beta_0, \xi, \kappa, \Lambda)$
  - $\omega_{(i)k}(+Y/2, b_2) = F_k(b_2, \quad \beta_0, \xi, \kappa, \Lambda)$
  - with tuning parameters $\beta_0, \xi, \kappa, \Lambda$



Event generation

- Prob. for particular process p: $\frac{\sigma_p(Y)}{\sigma_{\text{tot}}(Y)}$, $p \in [\text{inel}, \text{el}, \text{SD}, \text{DD}]$
- Elastic scattering, single- and double diffractive easy
- Inelastic processes more involved (ladder-generation)

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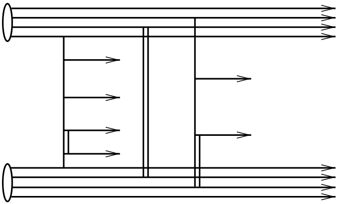
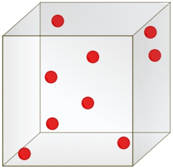
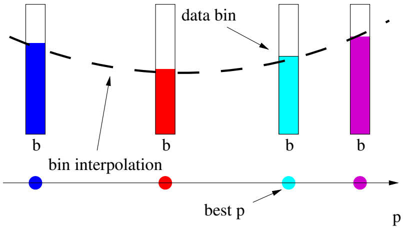


- 3 val. quarks + 1 val. gluon at $Q^2 = 0$
- Pick colliding GW states (i, k in σ_{inel})
- Choose impace parameter
- Pomeron exchanges independent $\rightarrow$ pick N according to Poisson ($\nu = \Omega_{ik}$)
- Generate N ladders similar to parton shower (gluon emissions)
- $\rightarrow$ correction of the tree-level t-channel
- t-channel propagators can be colour singlett $\rightarrow$ rapidity gaps
- $\oplus$ parton shower, hadronisation

Tuning with Professor

- Random sampling: N parameter points in n-dimensional space
- Run generator and fill histograms (e.g. Rivet)
- For each bin:
  - Don't care about actual dependence on parameters
  - Polynomial approximation
- Construct overall (now trivial) $\chi^2 \approx \sum_{bins} \frac{(parameterisation - data)^2}{error^2}$
- and Numerically *minimize* `Minuit`





Professor 2

- http://professor.hepforge.org, release 2.1.0
- Complete rewrite
- Parametrisation now in C++ (Eigen)
  - Usage in other codes (arXiv:1511.05170[hep-ph], arXiv:1506.08845[hep-ph])
- Python bindings (through cython) for flexibility:

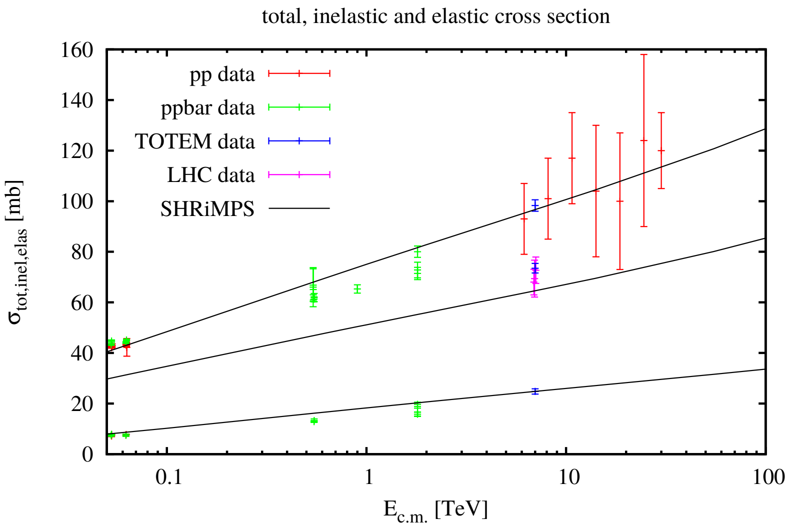
```
import professor2 as prof
# X ... parameter points, e.g. 3-dimensional
# Y ... corrsponding values
I=prof2.Ipol(X,Y, order=5)
print I.val([0, -.5, 13])
```

- HepMC to Rivet to YODA to Professor tool chain of course still supported with set of scripts
- Much improved command line
- Parametrisations stored in text files

Shrimps tuning

- Two stages:
  1. Tune parameters important for cross-sections to measured cross-sections at various $\sqrt{s}$
  2. Tune parameters of dynamic part of the model to variety of distributions measured at the LHC at 7 TeV (ATLAS, CMS, TOTEM)

Cross section tuning

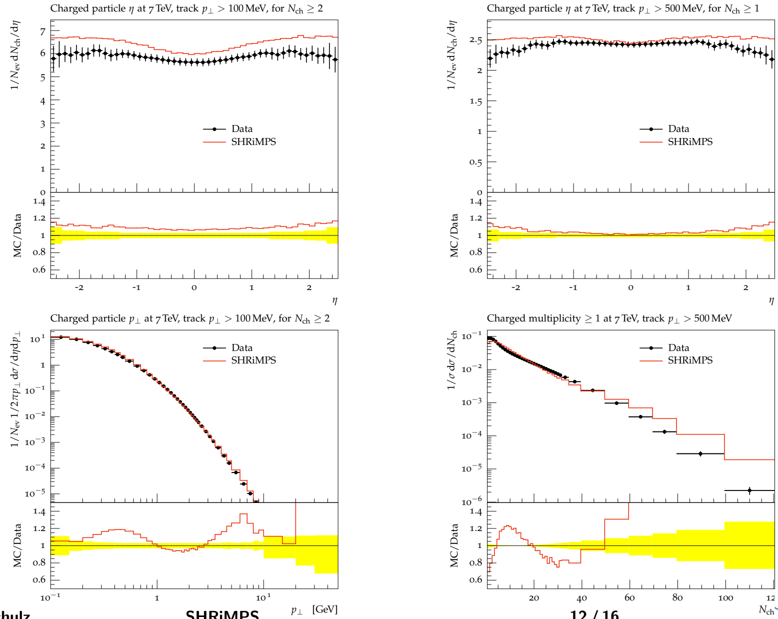


Tuning of dynamical part of SHRiMPS

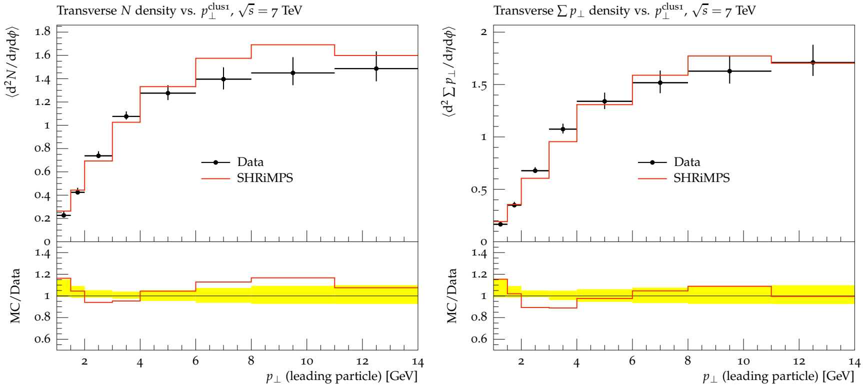
- Tuned 8 parameters to 7 TeV data
- Tuned parameters (below) not in latest release

Parameter	Tuned value
Q_0^2	3.02
Chi_S	0.65
Shower_Min_KT2	1.19
KT2_Factor	3.48
RescProb	1.01
RescProb1	0.18
Q_RC^2	0.50
ReconnProb	-15.30

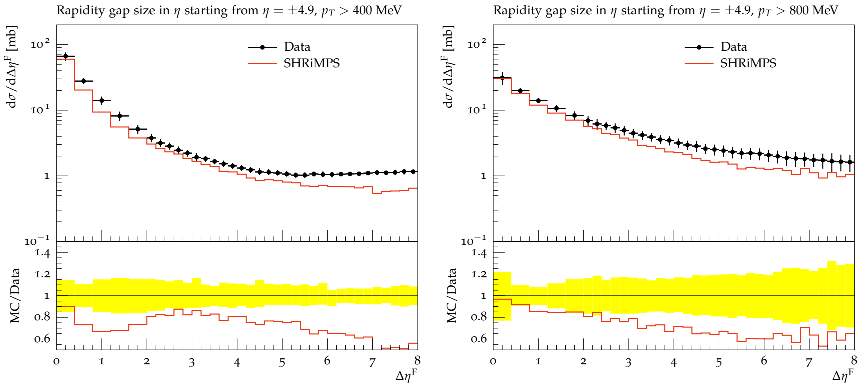
ATLAS 7TeV MinBias, arXiv:1012.5104



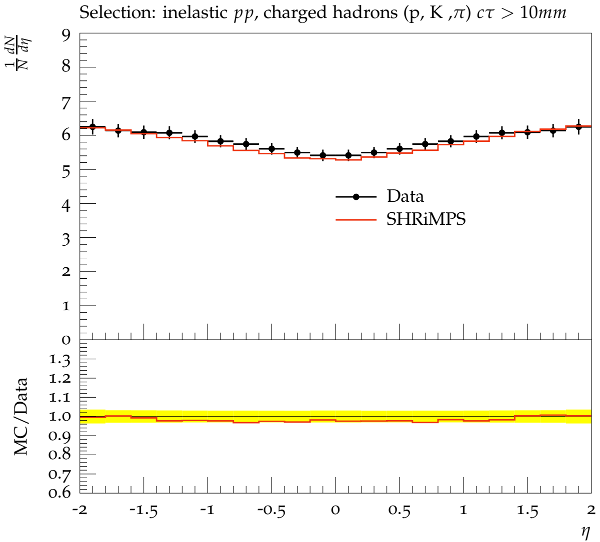
ATLAS 7 TeV UE arXiv:1103.1816



ATLAS rapidity gaps, arXiv:1201.2808[hep-ex]



CMS 13TeV arXiv:1507.05915[hep-ex]



- Encouraging prediction for 13 TeV

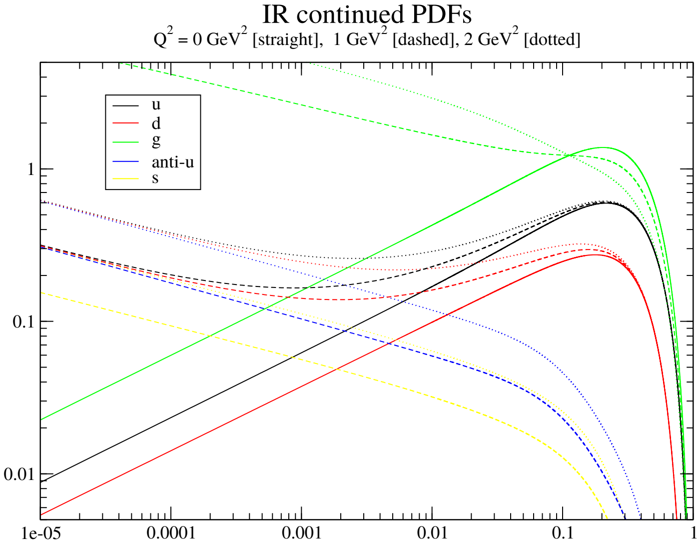
Summary

- MC generation of elastic, inelastic and diffractive processes with one model, based on KMR
- Satisfying prediction of cross-sections

- Unsatisfying prediction of minimum bias data at 7 TeV
- 13 TeV data comparison encouraging

- SHRiMPS had low priority in the last year within SHERPA
- Recently convinced ourselves that it's not tuning problem
- Currently code cleanup for improvements

Backup


IR continued PDFs
Q^2 = 0 GeV^2 [straight], 1 GeV^2 [dashed], 2 GeV^2 [dotted]
u
d
g
anti-u
s
1
0.1
0.01
1e-05
0.0001
0.001
0.01
0.1
1