GenEx - Exclusive Light Meson Generator

Paula Erland (IFJ PAN)

supervisor:
Maciej Trzebiński (IFJ PAN)

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GenEx Generator

- Generator for the soft exclusive processes in high energy collisions.
- Based on calculations by P. Lebiedowicz, A. Szczurek, O. Nachtmann.
- Processes implemented so far:
  - $p + p \to p + \pi^- + \pi^+ + p$,
  - $p + p \to p + K^- + K^+ + p$,
  - $p + p \to p + \gamma + p$,
  - and many more.
- Plans to include:
  - resonant production of: $f_0(500)$, $f_0(980)$, $f_0(1370)$, $f_0(1500)$, $f_2(1270)$, $f_2(1520)$, ρ^0,
  - vector and tensor Pomeron exchange,
  - absorption effects.
- the description can be found in:

GenEx: A simple generator structure for exclusive processes in high energy collisions

R. A. Kycia, J. Chwastowski, R. Staszewski, J. Turnau

arXiv:1411.6035

Exclusive Production: Elastic Scattering

Exclusivity: hard or soft diffractive process in which all stable particles can be measured.

Elastic scattering:

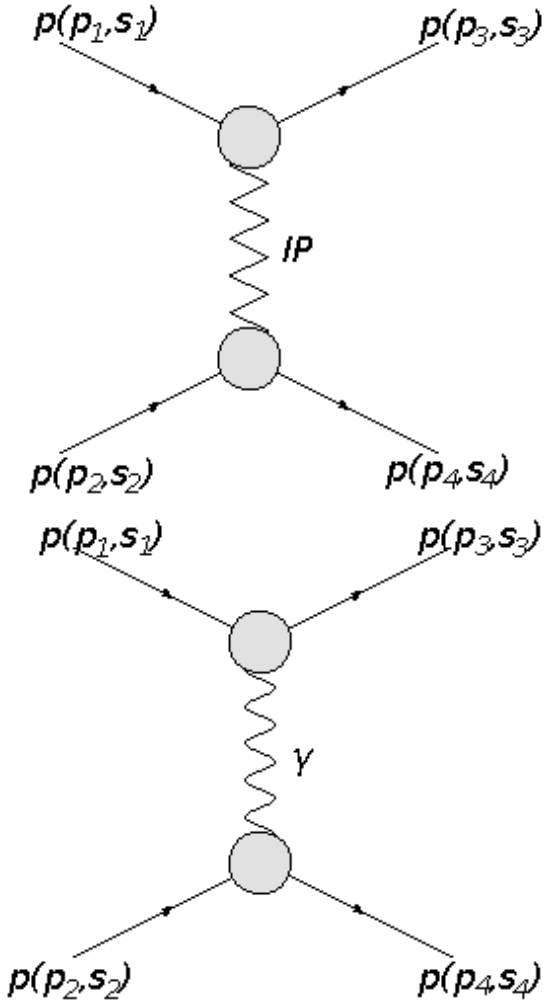
- the simplest process one can imagine p + p → p + p,
- exchanged object is a colour singlet: **photon** or **Pomeron**,
- very common (around 30% of all collisions in the LHC),

and

- essential for the total cross section measurement.

BUT:

- not very well known.



Tensor Pomeron

- High-energy small-angle hadron-hadron scattering is dominated by the exchange of the soft Pomeron.
- The nature of the soft Pomeron is not very well known.
- For example: what is the spin structure of the soft Pomeron?
- Usual approach – Pomeron as a vector.
- New approach – Pomeron as a tensor:

Exclusive central diffractive production of scalar and pseudoscalar mesons; tensorial vs. vectorial pomeron

Piotr Lebiedowicz, Otto Nachtmann, Antoni Szczurek

Annals Phys. **344** (2014) 301

Implementaion of Elastic Scattering

Elastic scattering: $pp \to pp$

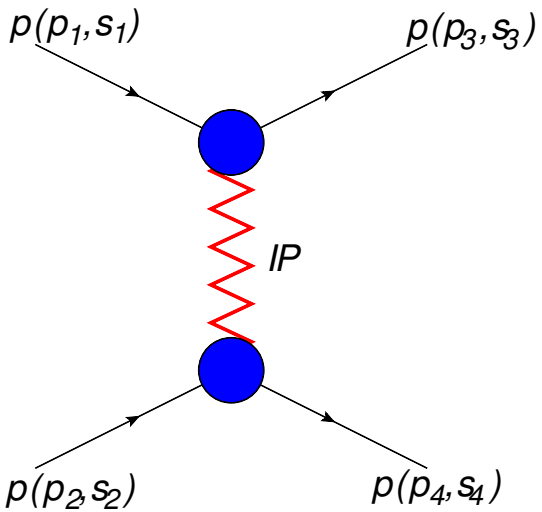
$$i < s_3, s_4|\mathcal{T}|s_1, s_2 >= i\bar{u}(p_3, s_3)\mathbf{\Gamma(p_3, p_1)}u(p_1, s_1)i\mathbf{\Delta(s, t)} \times i\bar{u}(p_4, s_4)\mathbf{\Gamma(p_4, p_2)}u(p_2, s_2),$$

vertex:

$$i\Gamma^{I\!P_T\,pp}_{\mu\nu}(p', p) = -i3\beta_{I\!P NN}F_1[(p'-p)^2]\{\tfrac{1}{2}[\gamma_\mu(p'+p)_\mu + \gamma_\nu(p'+p)_\nu] - \tfrac{1}{4}g_{\mu\nu}(\not{p}' + \not{p})\}$$

propagator:

$$i\Delta^{(I\!P_T)}_{\mu\nu\kappa\lambda}(s, t) = \tfrac{1}{4s}(g_{\mu\kappa}g_{\nu\lambda} - \tfrac{1}{2}g_{\mu\nu}g_{\kappa\lambda})(-i\alpha'_{I\!P})^{\alpha_{I\!P}(t)-1}$$



Where:

- $\beta_{I\!PNN}$ – standard coupling constant,
- $F_1[(p'-p)^2]$ – form factor,
- γ_ν – gamma matrices,
- $g_{\mu\nu}$ – matrix
- $\not{p}$ – Feynman slash notation,
- $\alpha'_{I\!P}$ – Pomeron slope.

Model was described in: Phys. Lett. B **763** (2016) 382

Helicity in Proton-Proton Elastic Scattering and the Spin Structure of the Pomeron

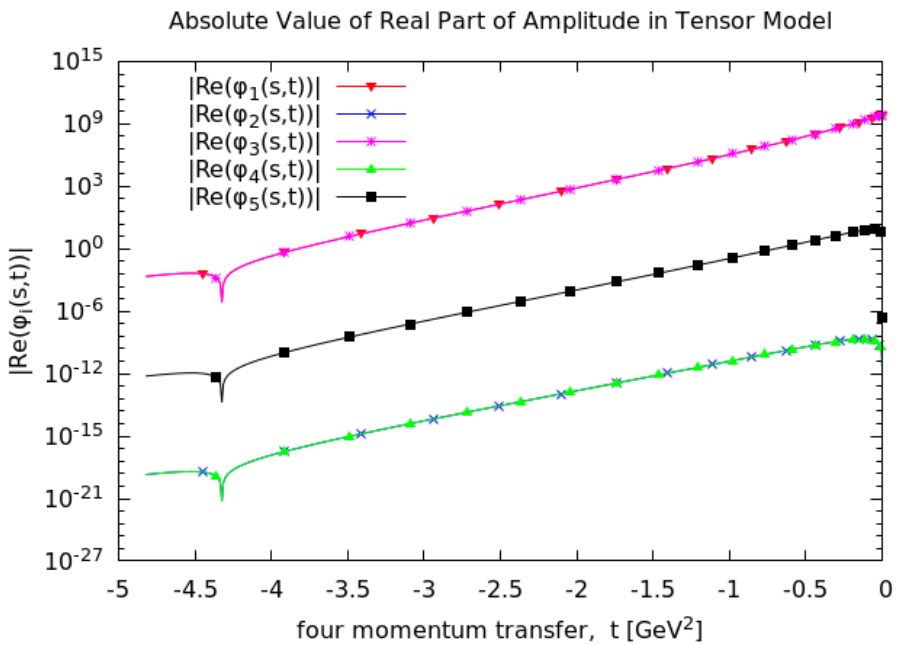
Carlo Ewerz, Piotr Lebiedowicz, Otto Nachtmann, Antoni Szczurek

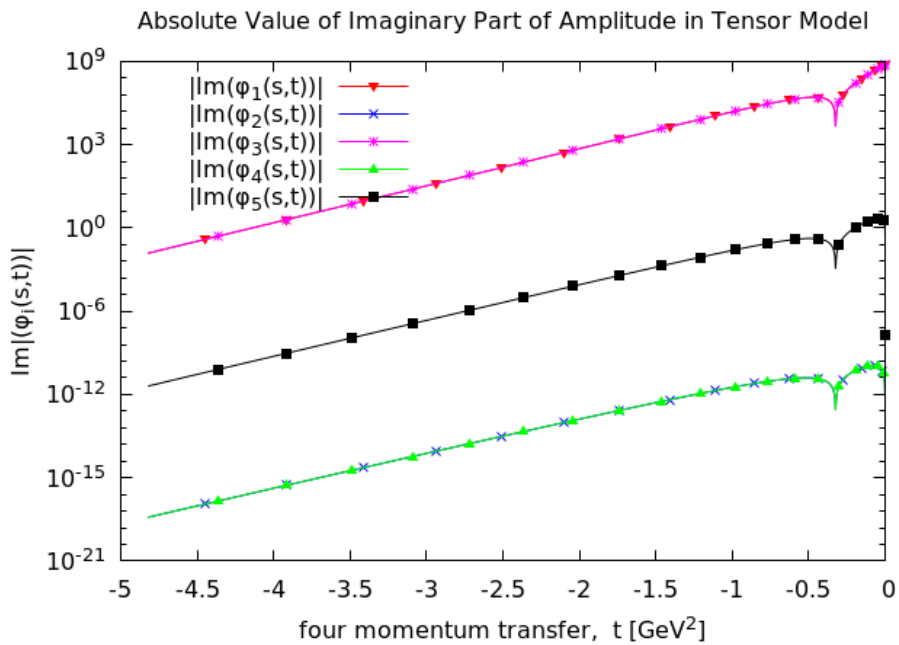
Helicity Amplitudes for Tensor Pomeron

Only five out of the sixteen possible helicity amplitudes are independent:

$\phi_1(s,t) = \langle ++|\mathcal{T}|++\rangle \quad \phi_2(s,t) = \langle ++|\mathcal{T}|--\rangle \quad \phi_3(s,t) = \langle +-|\mathcal{T}|+-\rangle$

$\phi_4(s,t) = \langle +-|\mathcal{T}|-+\rangle \quad \phi_5(s,t) = \langle ++|\mathcal{T}|+-\rangle$

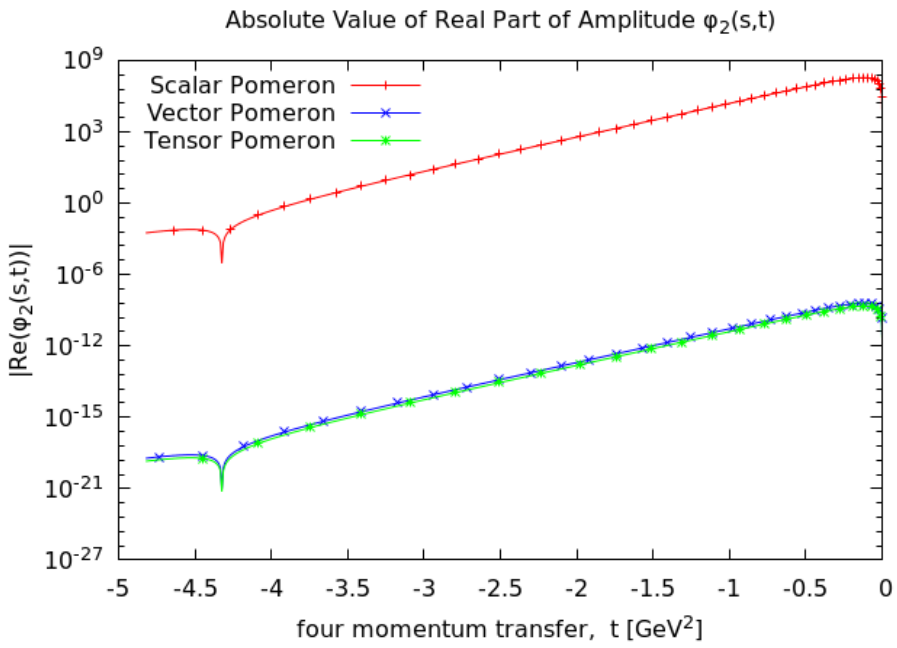


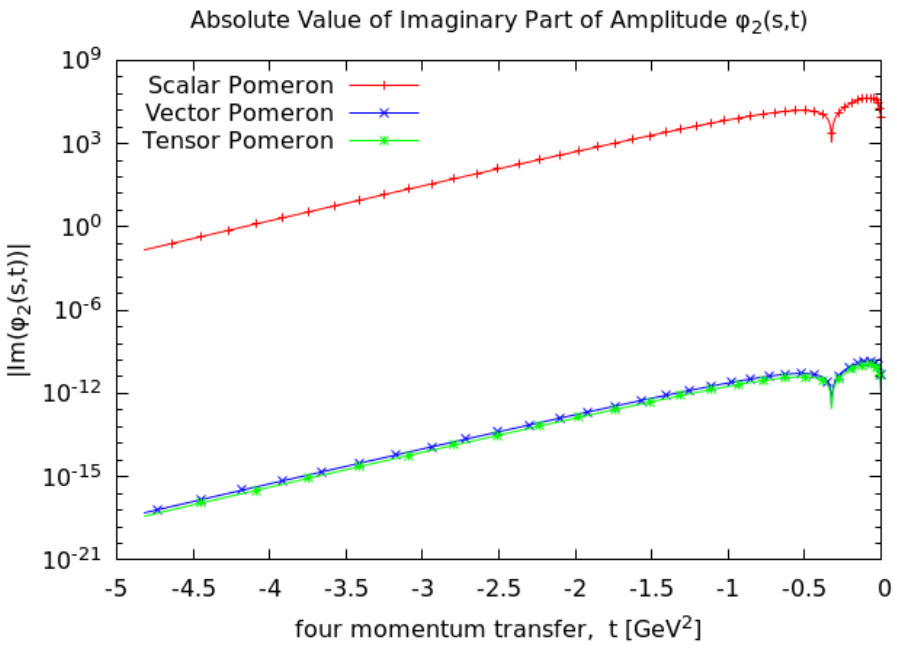


Real and imaginary part of elastic scattering amplitudes as a function of the four-momentum transfer. Predictions were done using the tensor Pomeron model.

Helicity Amplitudes for Various Models

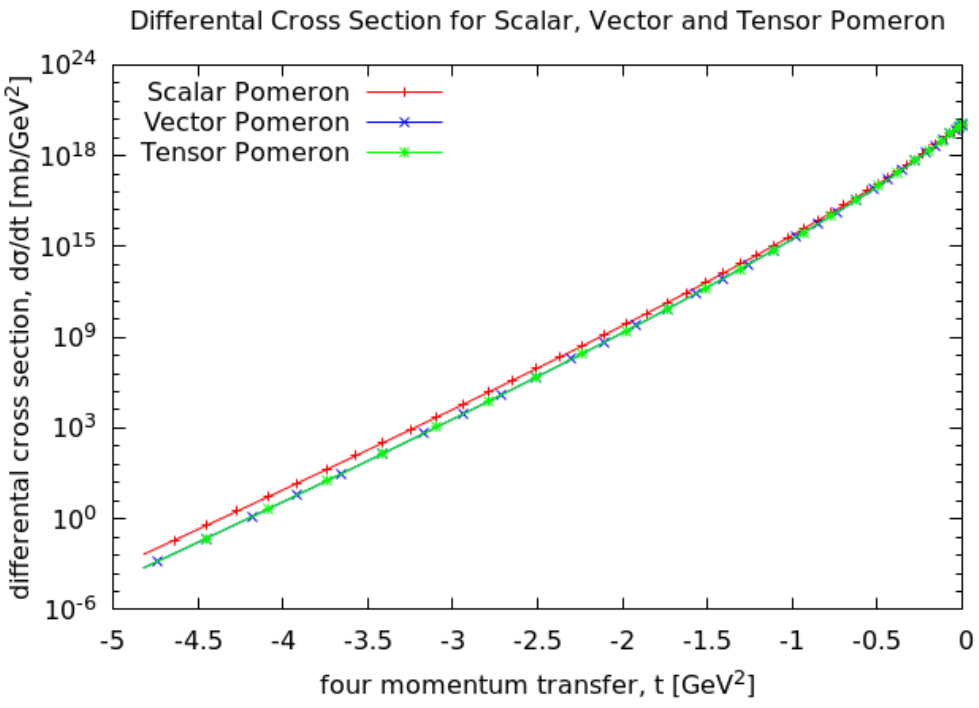
Example: ϕ_2 amplitude as a function of the four-momentum transfer





Tensor and vector models give the same results. Predictions of scalar model are much higher.

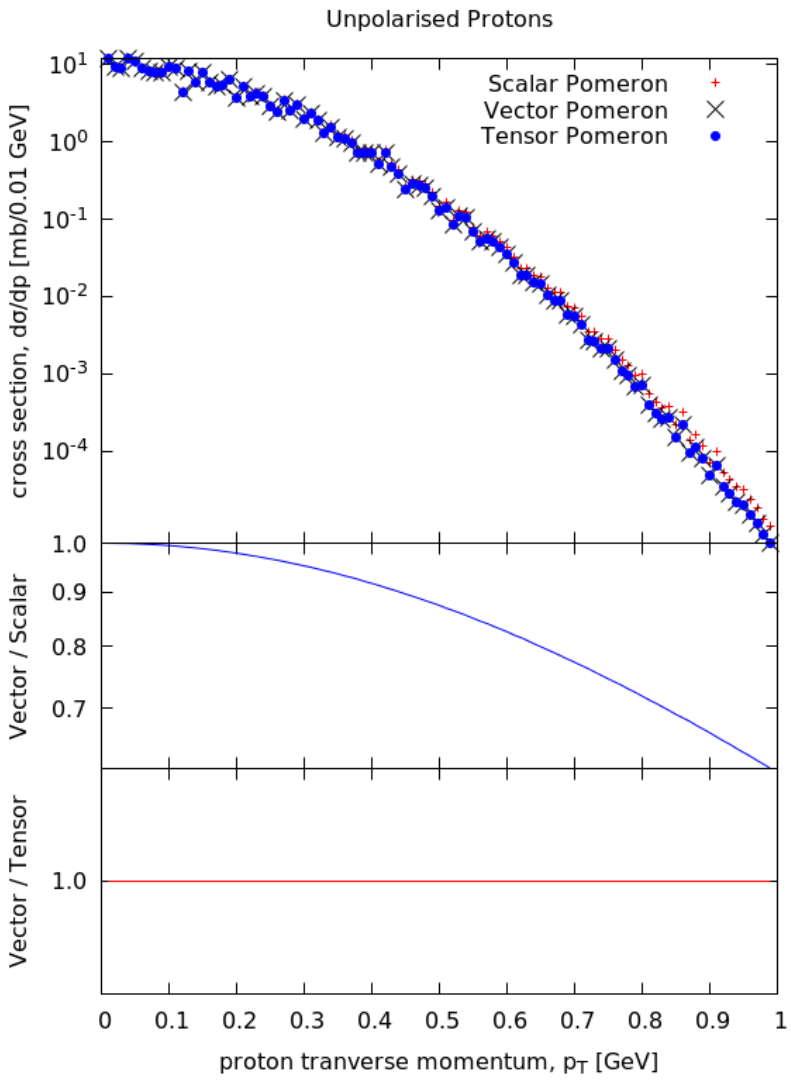
Unpolarized Elastic Cross Section

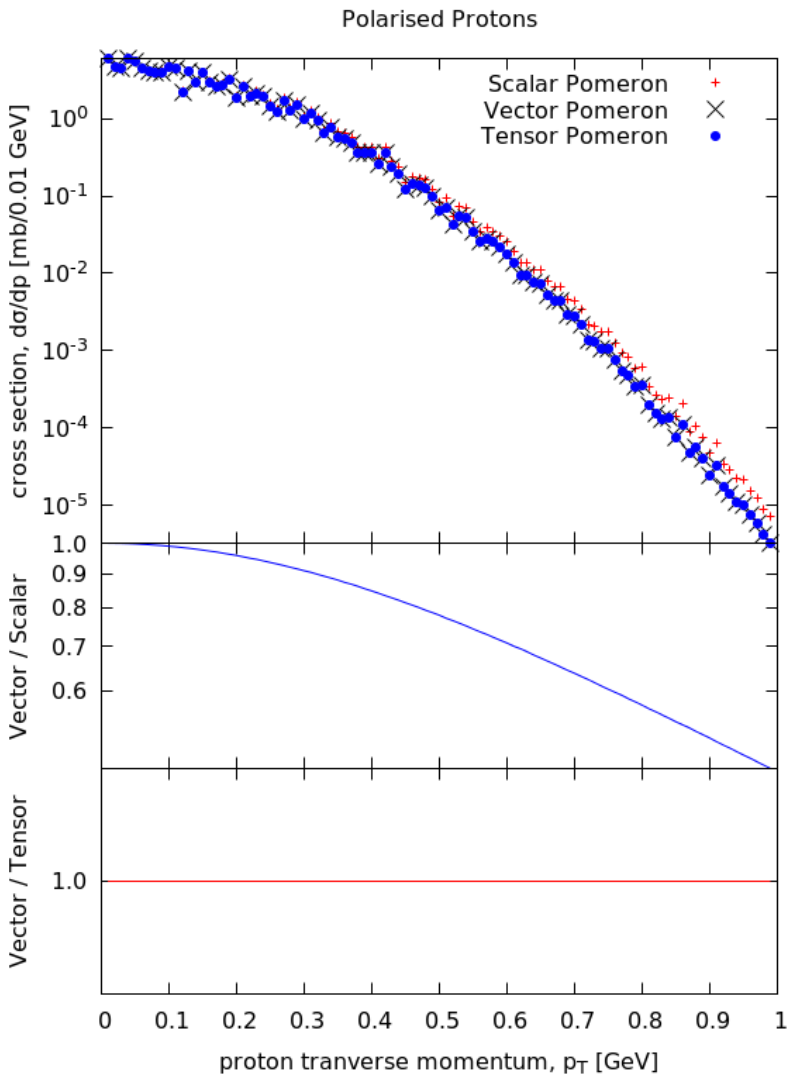


- Tensor (green line) and vector (blue line) Pomeron models give exactly the same results.
- For the small momentum transfers the predictions of scalar model (red line) predictions are also comparable.
- They start to differ (up to a factor of 10) with the increasing value of the four momentum transfer.

Generation Example

Left: unpolarized protons (LHC).
Right: polarized protons (++ → anything; RHIC).





Summary and Outlook

- Elastic scattering process was implemented to GenEx:
  - scalar, vector and tensor models,
  - proton spin.
- Simple exercise, to prepare structures for more difficult processes.
- Results consistent with analytical calculations.
- Constructed framework works correctly.
- Next steps – implementation of tensor Pomeron model for:
  - non-resonant
  - resonant

  exclusive pion and kaon productions.

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Thank you!