GenEx

Exclusive Meson Generator

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QCD challenges in pp, pA and AA collisions at high energies

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Motivation

- Exclusive meson production is possible to be measured by RHIC and LHC experiments.
- Monte Carlo generator is needed in order to include detector effects (acceptance, efficiency) in theory-data comparison.
- There are few MC generators available, *e.g.* SuperCHIC, DIME.
- We would like to introduce a tool complementary to the existing ones in terms of implemented processes and calculation methods.
- For now, implemented models are based mainly on work of P. Lebiedowicz, A. Szczurek & co.
- This includes:
  - non-resonant (continuum) pion and kaon pair production,
  - $f_0(500)$, $f_0(980)$, $f_0(1370)$, $f_0(1500)$, $f_2(1270)$, $f_2'(1520)$ and ρ_0 particles and their decays into two pions or kaons.

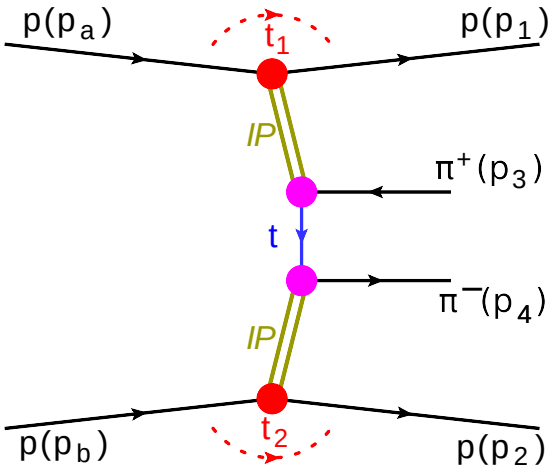
Generator

- GenEx – a C++ class structure for the construction of a Monte Carlo event generators which can produce unweighted events within relativistic phase space.
- Generator is self-adapting to the provided matrix element and acceptance cuts.

- Existing and planned features:
  - resonant and non-resonant exclusive meson production processes,
  - scalar, vector and tensor Pomeron,
  - pp and $p\bar{p}$ collisions,
  - spin (polarization) effects,
  - absorption and re-scattering corrections,
  - simple, user friendly interface,
  - output in formats usable by experiments (LesHouches, HEPMC, ...).

- First version (basic features) is already available: `https://github.com/rkycia/GenEx`.

Process Type 1: Non-resonant Pion Pair Production



- $pp \to p\pi^+\pi^- p$ (continuum),
- model based on: Phys. Rev. D **93** (2016) 054015,
- off-shell pion exchanged in the t-channel,
- tensor Pomeron exchange,
- absorptive nor re-scattering corrections are off,
- spin polarization.

$$\mathcal{M}^{(\hat{t})}_{\lambda_a\lambda_b\to\lambda_1\lambda_2\pi^+\pi^-} = \quad \text{matrix element}$$

$$(-i)\bar{u}(p_1,\lambda_1)i\Gamma^{(IPpp)}_{\mu_1\nu_1}(p_1,p_a)u(p_a,\lambda_a)\times \quad \text{proton-Pomeron vertex}$$

$$i\Delta^{(IP)\mu_1\nu_1,\alpha_1\beta_1}(s_{13},t_1)\times \quad \text{Pomeron propagator}$$

$$i\Gamma^{(IP\pi\pi)}_{\alpha_1\beta_1}(p_t,-p_3)\times \quad \text{Pomeron-pion vertex}$$

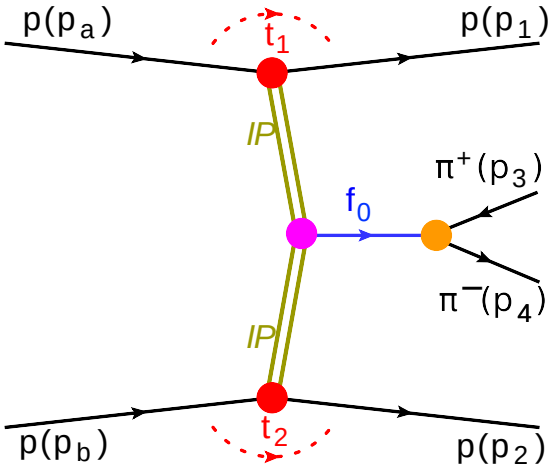
$$i\Delta^{(\pi)}(p_t)\times \quad \text{pion propagator}$$

$$i\Gamma^{(IP\pi\pi)}_{\alpha_2\beta_2}(p_4,p_t)\times \quad \text{pion-Pomeron vertex}$$

$$i\Delta^{(IP)\alpha_2\beta_2,\mu_2\nu_2}(s_{24},t_2)\times \quad \text{Pomeron propagator}$$

$$\bar{u}(p_2,\lambda_2)i\Gamma^{(IPpp)}_{\mu_2\nu_2}(p_2,p_b)u(p_b,\lambda_b) \quad \text{Pomeron-proton vertex}$$

Process Type 2: Pion Pair Production via f_0 Resonance



- $pp \to p(f_0 \to \pi^+\pi^-)p$,
- model based on: Phys. Rev. D **93** (2016) 054015,
- tensor Pomeron exchange,
- absorptive nor re-scattering corrections are off,
- spin polarization.

$$\mathcal{M}^{(IPIP\to f_0\to\pi^+\pi^-)}_{\lambda_a\lambda_b\to\lambda_1\lambda_2\pi^+\pi^-} =$$ matrix element

$$(-i)\bar{u}(p_1,\lambda_1)i\Gamma^{(IPpp)}_{\mu_1\nu_1}(p_1,p_a)u(p_a,\lambda_a)\times$$ proton-Pomeron vertex

$$i\Delta^{(IP)\mu_1\nu_1,\alpha_1\beta_1}(s_1,t_1)\times$$ Pomeron propagator

$$i\Gamma^{(IPIPf_0)}_{\alpha_1\beta_1,\alpha_2\beta_2}(q_1,q_2)\times$$ Pomeron-f_0 vertex

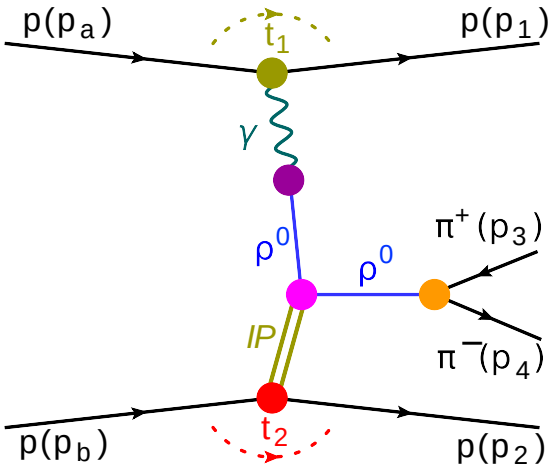
$$i\Delta^{(f_0)}(p_{34})\times$$ f_0 propagator

$$i\Gamma^{(f_0\pi\pi)}(p_{34})\times$$ f_0-pion vertex

$$i\Delta^{(IP)\alpha_2\beta_2,\mu_2\nu_2}(s_2,t_2)\times$$ Pomeron propagator

$$\bar{u}(p_2,\lambda_2)i\Gamma^{(IPpp)}_{\mu_2\nu_2}(p_2,p_b)u(p_b,\lambda_b)$$ Pomeron-proton vertex

Process Type 3: ρ^0 Photoproduction



- $pp \to p\pi^+\pi^- p$ via $\gamma p \to (\rho^0 \to \pi^+\pi^-)p$,
- model based on: arXiv:1412.3677,
- tensor Pomeron exchange,
- absorptive nor re-scattering corrections are off,
- spin polarization.

$$\mathcal{M}^{(\gamma IP)}_{\lambda_a\lambda_b\to\lambda_1\lambda_2\pi^+\pi^-} =$$ matrix element

$(-i)\bar{u}(p_1,\lambda_1) i\Gamma^{(\gamma pp)}_{\mu}(p_1,p_a) u(p_a,\lambda_a)\times$ proton-photon vertex

$i\Delta^{(\gamma)\mu\sigma}(q_1)\times$ photon propagator

$i\Gamma^{(\gamma\to\rho)}_{\sigma\nu}(q_1)\times$ photon-ρ vertex

$i\Delta^{(\rho)\nu\rho_1}(q_1)\times$ ρ propagator

$i\Gamma^{(IP\rho\rho)}_{\rho_2\rho_1\alpha\beta}(p_{34},q_1)\times$ ρ-Pomeron vertex

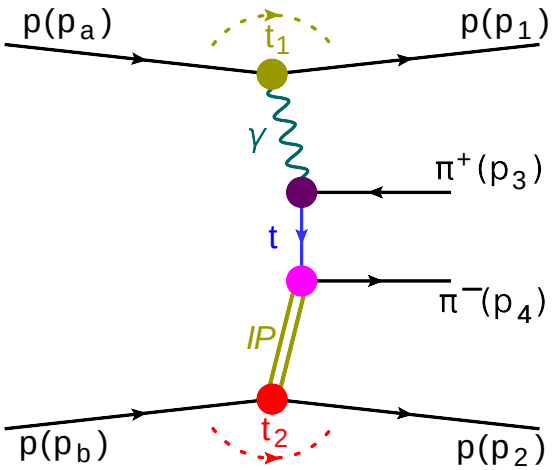
$i\Delta^{(\rho)\rho_2\kappa}(p_{34})\times$ ρ propagator

$i\Gamma^{(\rho\pi\pi)}_{\kappa}(p_3,p_4)\times$ ρ-pion vertex

$i\Delta^{(IP)\alpha\beta,\delta\eta}(s_2,t_2)\times$ Pomeron propagator

$\bar{u}(p_2,\lambda_2) i\Gamma^{(IPpp)}_{\delta\eta}(p_2,p_b) u(p_b,\lambda_b)$ Pomeron-proton vertex

Process Type 4: Photon-induced Continuum



- $pp \to p\pi^+\pi^- p$,
- model based on: arXiv:1412.3677,
- off-shell pion exchanged in the t-channel,
- tensor Pomeron exchange,
- absorptive nor re-scattering corrections are off,
- spin polarization.

$$\mathcal{M}^{(t)}_{\lambda_a\lambda_b\to\lambda_1\lambda_2\pi^+\pi^-} = \quad \text{matrix element}$$

$$(-i)\bar{u}(p_1,\lambda_1)i\Gamma^{(\gamma pp)}_{\mu}(p_1,p_a)u(p_a,\lambda_a)\times \quad \text{proton-photon vertex}$$

$$i\Delta^{(\gamma)\mu\nu}(q_1)\times \quad \text{photon propagator}$$

$$i\Gamma^{(\gamma\pi\pi)}_{\nu}(p_t,-p_3)\times \quad \text{photon-pion vertex}$$

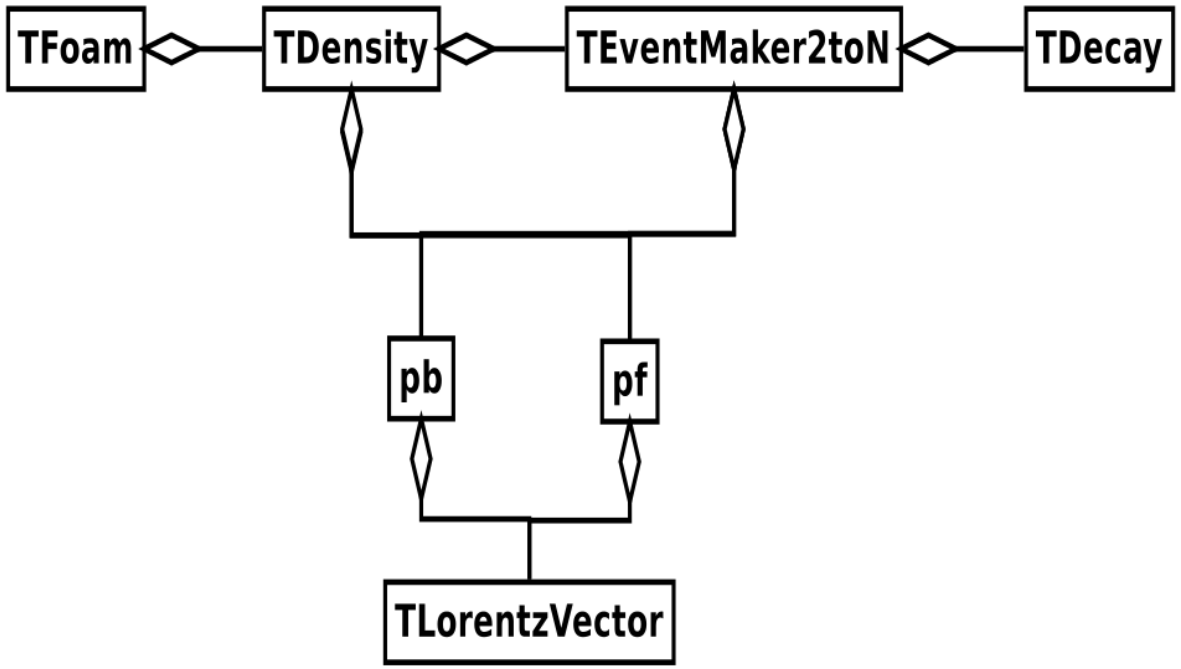
$$i\Delta^{(\pi)}(p_t)\times \quad \text{pion propagator}$$

$$i\Gamma^{(I\!P\pi\pi)}_{\alpha\beta}(p_4,p_t)\times \quad \text{pion-Pomeron vertex}$$

$$i\Delta^{(I\!P)\alpha\beta,\delta\eta}(s_2,t_2)\times \quad \text{Pomeron propagator}$$

$$\bar{u}(p_2,\lambda_2)i\Gamma^{(I\!Ppp)}_{\delta\eta}(p_2,p_b)u(p_b,\lambda_b) \quad \text{Pomeron-proton vertex}$$

Generator Structure



- *pb* and *pf* are event tables containing beam and final particles,
- TFoam – class of adaptive Monte Carlo simulator,
- TDensity – class with integrand function (calculated accordingly to a given event),
- TEventMaker2toN – generates two leading particles and a central blob which then is decayed by TDecay into $N-2$ remaining particles.

GenEx – Non-resonant Pion Pair Generation – Example

```
1  NumberOfEventsToGenerate  = 100000
2  IntegratorSetup = 1  #1 - FOAM (adaptive Monte Carlo
       integrator)
3
4  SaveEventDataRoot = 1
5  SaveEventDataLHE_XML = 0
6  SaveEventDataLHE_TXT = 0
7
8  idA = 2212 #PDG code of particle A
9  EA  = 6500.0
10 idB = 2212 #PDG code of particle B
11 EB = 6500.0
12
13 eventGenerationStrategy = 2 # 2 - generation by Lebiedowicz
       and Szczurek prescription (limited to 4 final particles)
14
15 ##Matrix Element - MODEL of REACTION
16 #  1 - Lebiedowicz & Szczurek 2p -> 2p + pi+ + pi-
17 #  2 - Lebiedowicz & Szczurek 2p -> 2p + K+ + K-
18 #  3 - Phase Space Integral; ME = 1
19 #  4 - Gauss matrix element exp(-alpha sum_i pt^2 )
20 weightStrategy = 1
21 Model1ConfFile = MODEL_DATA/LSpipi.dat
```

GenEx – Non-resonant Pion Pair Generation – Results

Usage

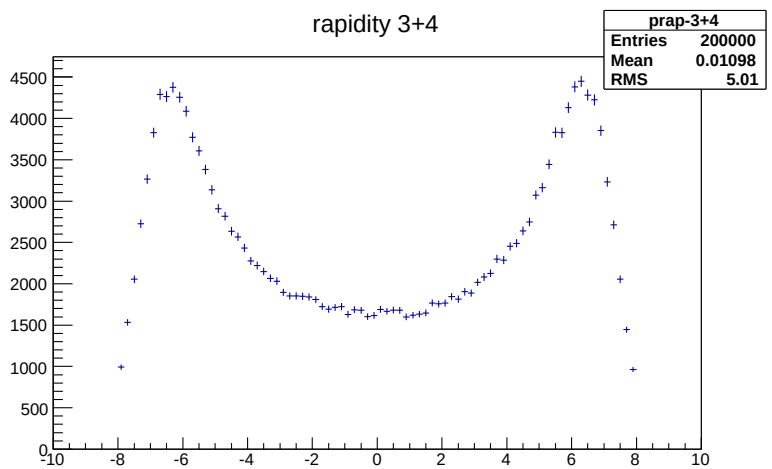
```
1  make all
2  vi Generator.dat #modify steering card
3  make run
```

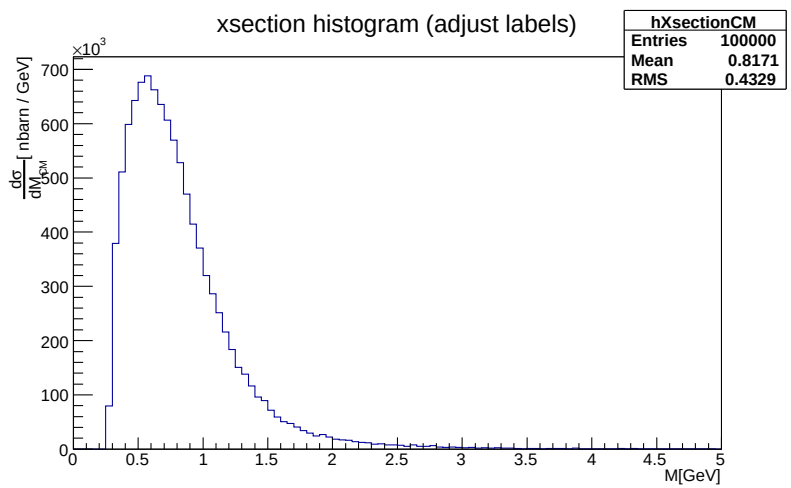
Event files:

```
1  maciek@laptop:~/GenEx-master$ ls -ltrh EVENTS/
2  -rw-rw-r-- 1 maciek maciek 7,3M lut 27 08:15 events.txt
3  -rw-r--r-- 1 maciek maciek  14M lut 27 08:15 events.root
4  -rw-rw-r-- 1 maciek maciek  15M lut 27 08:15 events.lhe
```

Histograms:

```
1  maciek@laptop:~/GenEx-master$ ls -ltrh
2  -rw-r--r-- 1 maciek maciek  44K mar  1 10:18 histograms.root
```





Summary

- First version of GenEx is available:
  `https://github.com/rkycia/GenEx`.
- It contains the generator structure and pion/kaon continuum production processes.

- In the near future a new version would allow to:
  - generate resonant production
    ($f_0(500)$, $f_0(980)$, $f_0(1370)$, $f_0(1500)$, $f_2(1270)$, $f_2'(1520)$ and ρ_0),
  - spin (polarization) effects,
  - absorption and re-scattering corrections.

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