# New NLO generator for Bhabha scattering

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# Motivation

- Motivation (in brief):
  - No precision generator for polarized Bhabha scattering exists;
  - No NLO Bhabha generator allows to change initial momenta for every event;
  - Precision of BHWIDE and BHLUMI codes is unknown at `TeV` scale.

# Energy spread simulation

## Fixed energy mode (simplistic):

```
evt->momentum[0].Set(E_0, Px_0, Py_0, Pz_0);
evt->momentum[1].Set(E_1, Px_1, Py_1, Pz_1);
gen->Initialize(E_cms);
...
for(;;){ gen->GenEvent(evt); }
```

$10^4 evt/s$

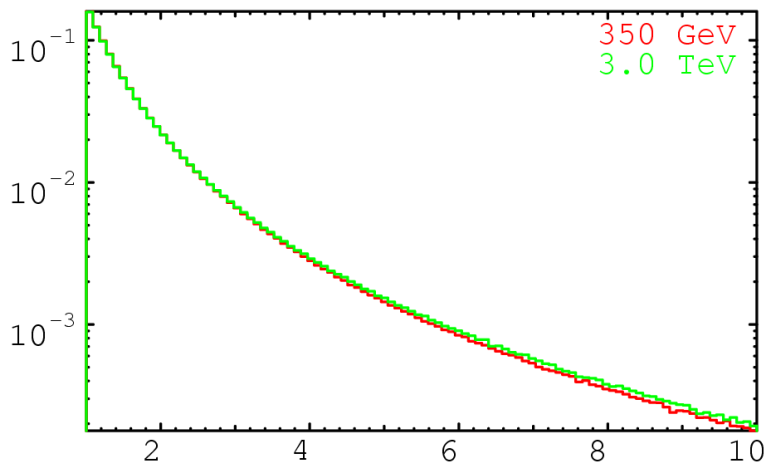
## Variable energy mode (simplistic):

```
gen->Initialize(E_cms_Min, E_cms_Max);
...
for(;;) {
      evt->momentum[0].Set(E_0, Px_0, Py_0, Pz_0);
      evt->momentum[1].Set(E_1, Px_1, Py_1, Pz_1);
      gen->GenEvent(evt);
}
```

$10^3 evt/s$

# Energy spread simulation

## Variable energy vs. Scaled events




- C.m.s. angular distribution at 350 GeV and 3 TeV;
- Error of event scaling may be up to 1-2%.

- It's reasonable to use fixed-energy generator for analysis.
- The variable-energy generator is useful for final precision run only.

# Current status

- (Mostly) completed modules:
  - NLO Bhabha scattering generator code;
  - LO generators for $e^+e^- \to e^+e^-e^+e^-$ and $e^+e^- \to e^+e^-\mu^+\mu^-$ processes;
  - The generator seems stable up to $\Theta_e \sim 5mrad$.

- Current focus on:
  - Error budget estimation for polarized scattering;
  - LL YFS exponentiation method implementation for independent cross-check of polarized effects.

# Error handling in BHWIDE and BHLUMI

- The physical uncertainties were estimated by comparison to results of independent calculations:
  - LL YFS exponentiation with precise phase space integration of hard photons emission;
  - precise NLO calculation;
  - semi-analytical precise N.NLO calculations (with no MC), ...
- The semi-realistic acceptance fits were used if MC is available.

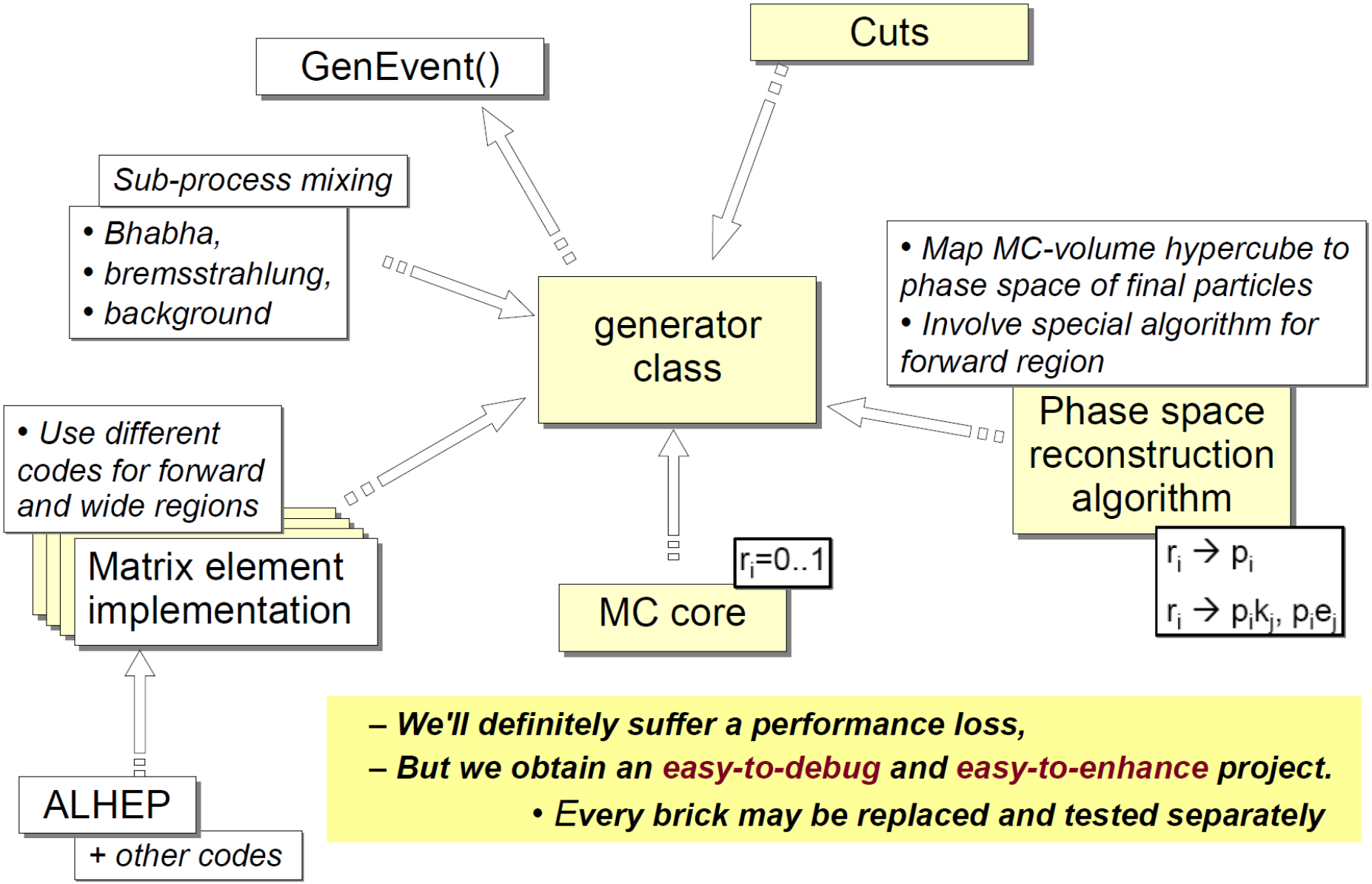
- **I.e. the independent calculation is required to estimate errors properly**

# Error handling in new generator

- Unpolarized cross section is compared to BHWIDE (and BHLUMI for small angles):
  - coincidence is within MC integration uncertainty 0.2–0.8% at `TeV` scale and $\Theta_e > 10 mrad$;
  - better precision requires both higher order RC calculation and improved error handling.

- **There is no independent N.LO code to cross-check polarized effects**
  - We can't estimate the generator precision here!
  - The independent code for YFS-exponentiation will solve the problem.

# Brick-based architecture




– ***We'll definitely suffer a performance loss,***

– ***But we obtain an easy-to-debug and easy-to-enhance project.***

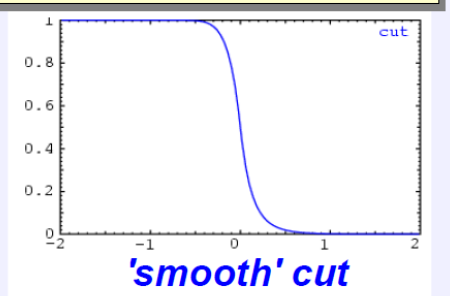
• *Every brick may be replaced and tested separately*

# Cross-checks available

compare to BHLUMI / BHWIDE (unpolarized case)

Cuts

***use 'smooth' cuts at pre-integration step***




***'smooth' cut***

***tune forward-wide regions separator***

generator class

*try different variables selection for faster integration convergence*

*try different forms of matrix elements*

Matrix element implementation

Phase space reconstruction algorithm

*try different algorithms*

MC core

*try different MC algorithms*

- *Own algorithm*
- *FOAM*
- *VEGAS**

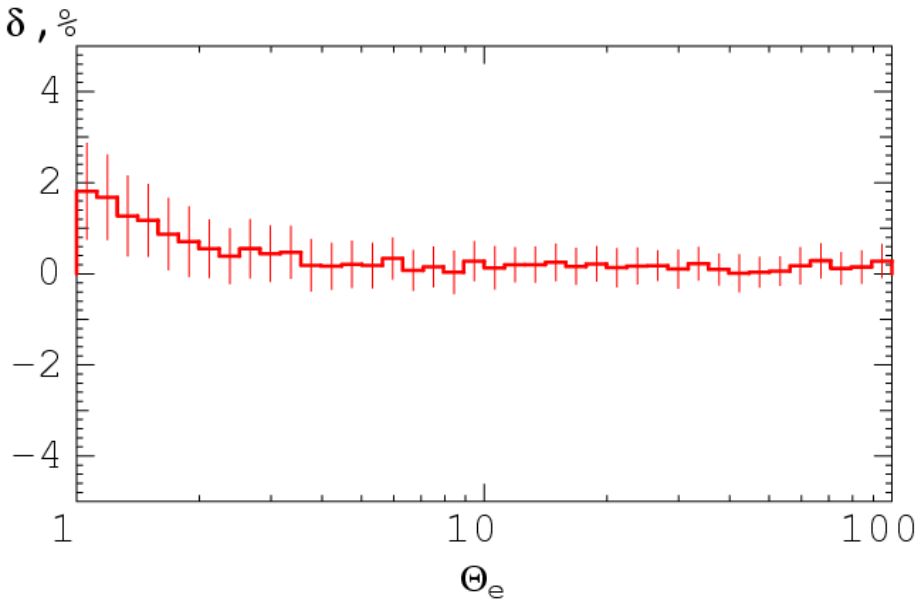
*keep automatically-built version of ME*

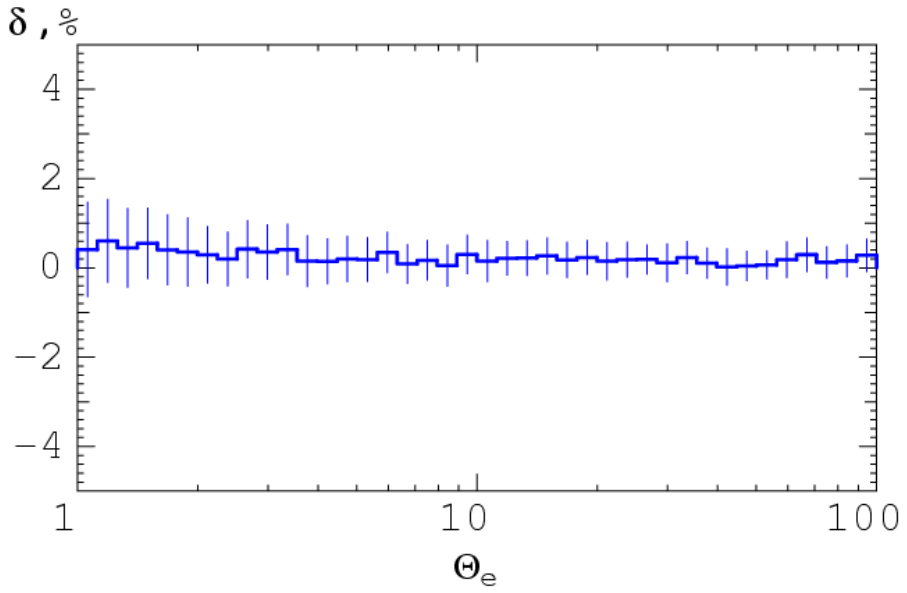
# Conclusions

- The difference to BHLUMI of up to 0.8% is sufficient and must be examined.
  - The former requirement of 1%-precision must be improved.
- It seems useless to release the **polarized** NLO generator until its uncertainty will be properly estimated.
  - Current focus on YFS-exponentiation mode for the generator.
  - If no unexpected problem appear, the period of $\sim$ 2 months seems reasonable to finalize the work.
- After the error handling is finalized (and a first version of code is released):
  - need to discuss required user interfaces (LCIO).
  - discuss if it's possible to publish the manual as CLICdp-Note?

# Back-up slides

# Systematic error example




- left (very early runs): systematic error observed,
- right: difference to BHWIDE within the Monte-Carlo error.

# Code performance

| | BHWIDE | New generator |
|---|---|---|
| initialization, $s$ | $\sim 10$ | $\sim 10^3 \cdots 10^4$<br>$\sim 10$ (using pre-created files) |
| event rate, $s^{-1}$ | $10^3 \cdots 10^4$<br>unweighted or weighted | $10^4$<br>unweighted only |
| flowed energy event rate, $s^{-1}$ | not available | $10^3$ |
| memory used | insignificant | up to 0.5 *GB* |

- The huge initialization time is the price for Monte-Carlo algorithm used,
  - both initialization time and required memory will be reduced by the release.

# Release announcement (deprecated)

- The generator will be published at `http://cern.ch/~makarenko/bhabha`

  The first release will include:
  - NLO precision code;
  - user manual with discussion of the methods used;
  - cross-check table to BHWIDE results (for unpolarized scattering);
  - standard output for polarized runs (for further cross-checks).

  - most of the technical problems seems solved;
  - need certain time for:
    - optimization (mostly to reduce the memory used),
    - manual text preparation.