Status of new generator for Bhabha scattering

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Why new generator?

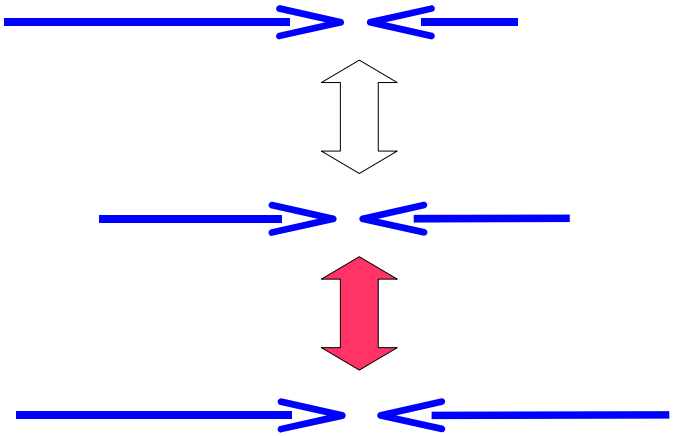
- **Single generator** for the whole kinematic region,
- that includes **background processes**,
- **beam polarization**, ~ few precent contribution
- that is capable to generate events **with actual beam energy spectrum**. ~ up to few precent error in current scheme

Event scaling error

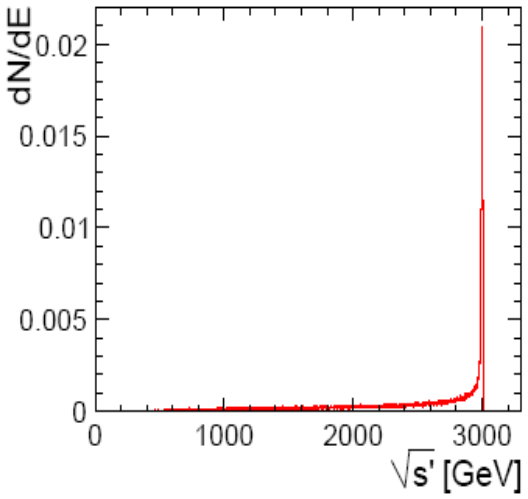
- **In current scheme the event is**

  1. boosted to c.m. Frame,

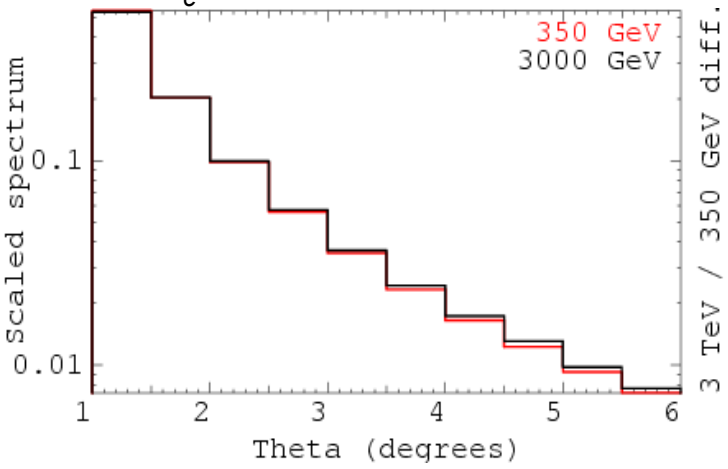
  2. scaled to nominal energy.



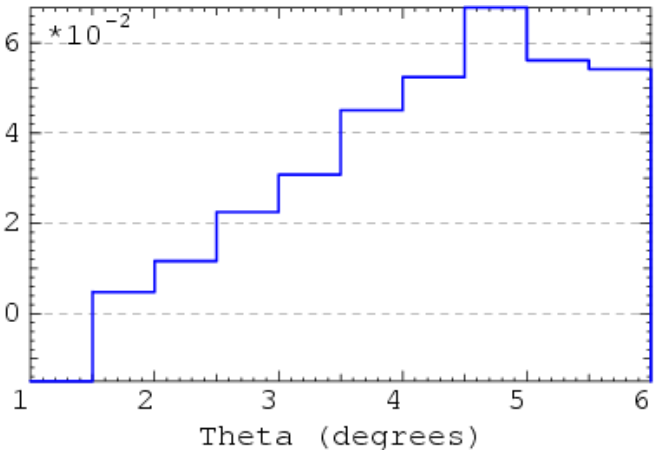
CLIC CDR' 2012



θ_e spectrum (0.35, 3 TeV)



difference in θ_e spectra (%)

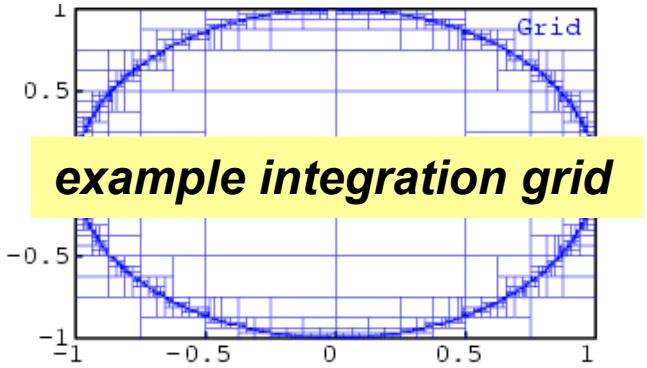


the error may achieve 4-5% in single event
but < 1% for realistic spectrum

Events with beam energy spectrum

Fixed energy generator

1. Integrate cross section and arrange a phase space grid. Each cell contains proper partial cross section.



example integration grid

2. Generate unweighted event:
   - select cell (according to its weight)
   - generate event in cell.
     - *using the approximate maximum function f_{max} value in the cell.*

Performance of generator appears equal to performance of the WORST cell!

Spread energy generator

1. Integrate cross section • ΔE for every energy step (in c.m.s.)

$$[E_i – E_{i+1}].$$

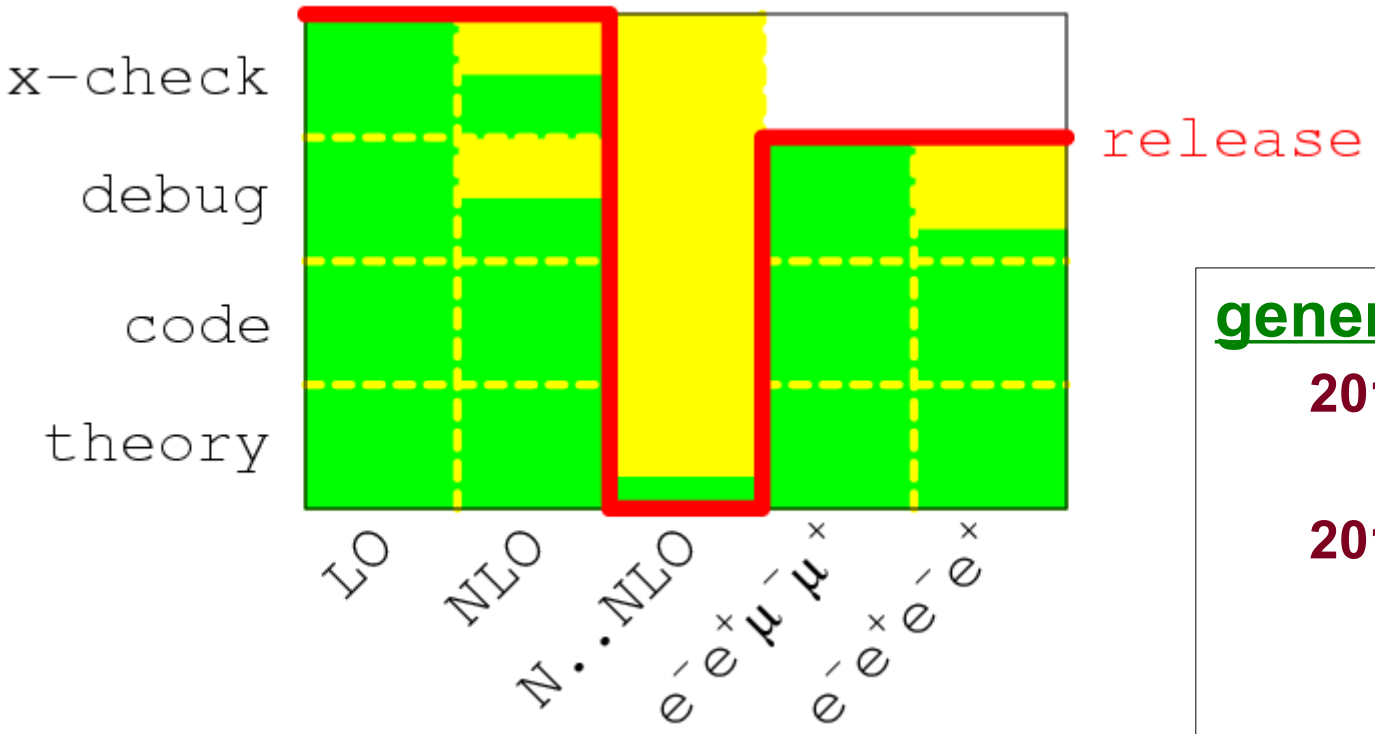
Arrange a separate phase space grid for every energy region.

2. Generate event for a certain energy:
   - select cell (according to its ***incorrect*** weight),
     - try to generate event **once** *using the* ***average*** *function* f_{ave} *in the cell, multiplied by safety factor* k_{Safe}
     - if failed – repeat cell selection.

Requirements:

1. $k_{Safe} \bullet f_{ave} > f_{max}$,
2. k_{Safe} – ***fixed in whole region*** $[E_i – E_{i+1}]$.

Generator status



1% precision is expected in first release

generator team:

2013:

- ***0.5*** person

2014:

- ***1*** person
- ***+1*** student

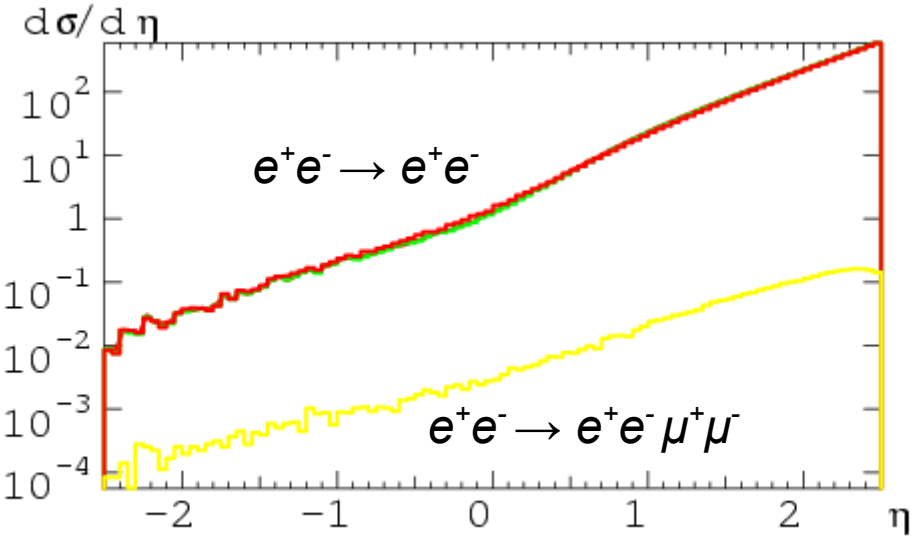
(probably, starting in summer)

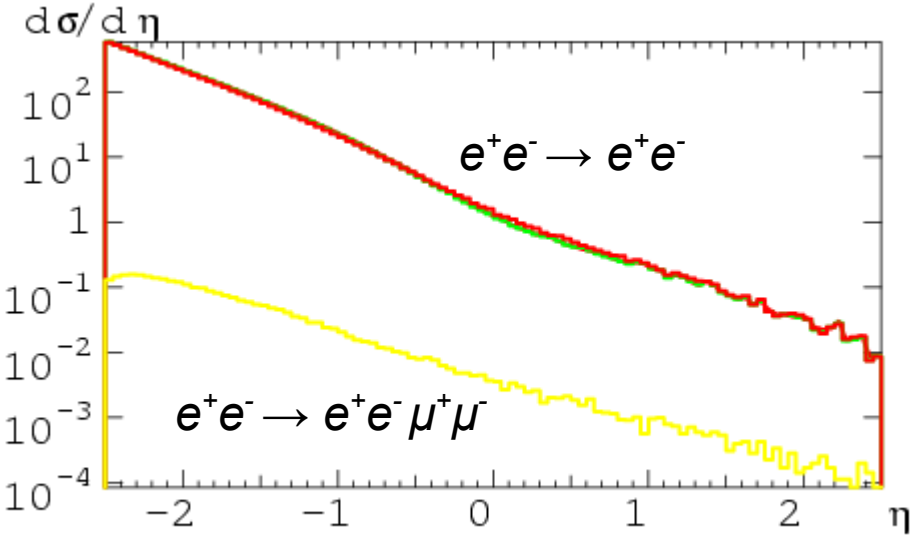
- preliminary agreement

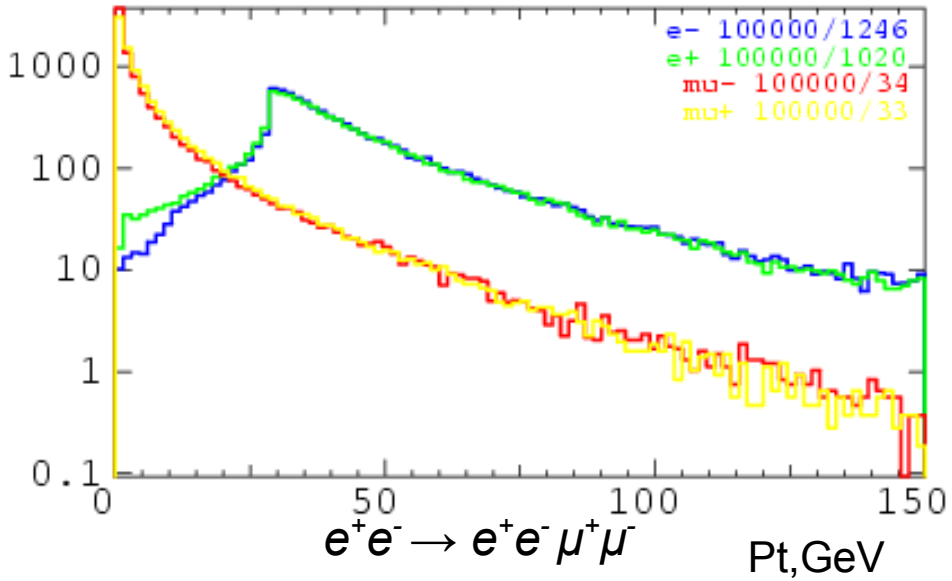
of collaboration with N..NLO expert

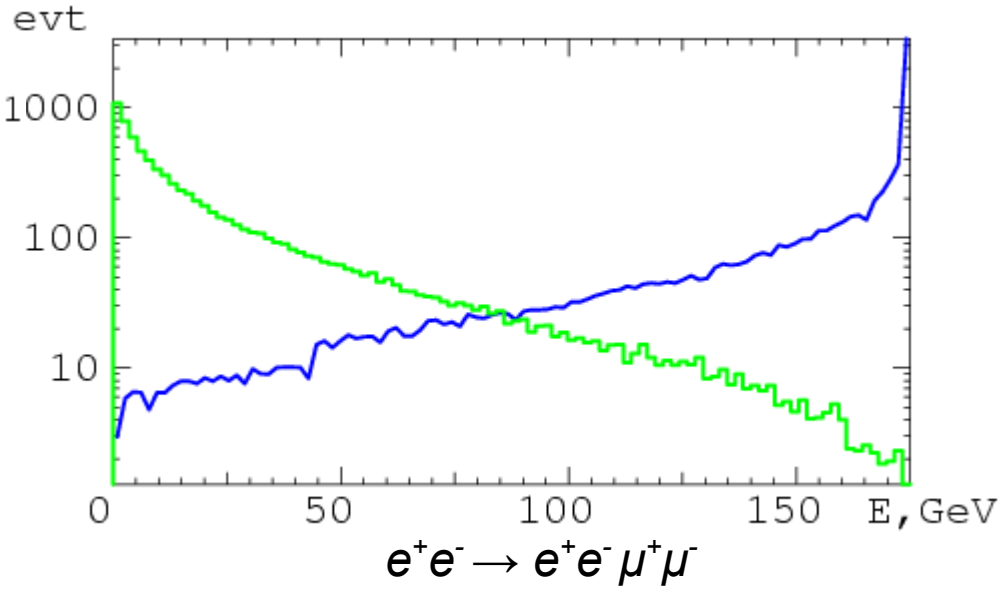
sufficient acceleration expected in 2014

Some results









Conclusions

- **New generator precision is (expected) ~1% (within first release)**
  - we don't need new generator to fix scaling error,
  - but we need new generator to simulate polarized beams
- **Background processes cross section is below ~1%**
- **More manpower will be recruited this year**
  - including experts in N..NLO calculations

Back-up slides

Generator structure

- **NLO generator for Bhabha scattering:**
  - Born, 1-Loop, soft+hard bremsstrahlung,
  - both electron and positron are polarized,
  - estimated error < 1%

comparison to BHLUMI / BHWIDE (unpolarized case)

- **Background processes:**
  - $e^+e^- \rightarrow e^+e^- e^+e^-$,
  - $e^+e^- \rightarrow e^+e^- \mu^+\mu^-$ (if both electrons are detected),
  - very small cross section => LO only

- **Initial beam energy spread simulation:**
  - *center-of-mass energy may be changed event-by-event*

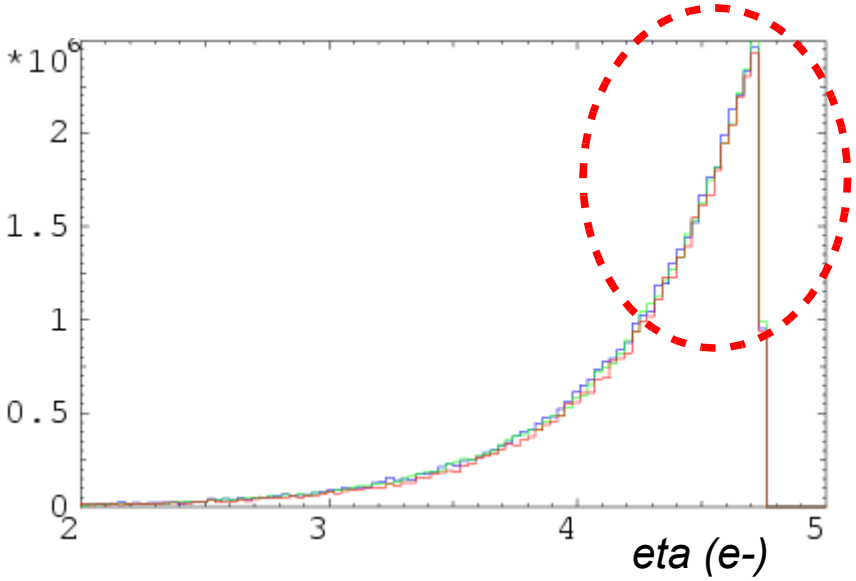
- Event loop user access,
- LHE output,
- LCIO interface,
- Internal histogram classes for stand-alone use

Implementation features

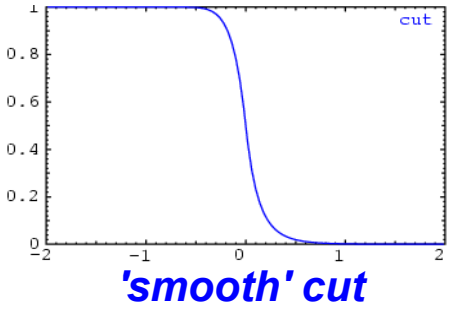
- **Problem #1: numerical stability**
  - huge numerical cancellations,

low-angle results still need to be validated

(+systematic error needs to be estimated)



- **Problem #2:**
  - integration of cut-using functions
  - use 'smooth' cuts at pre-integration step



'smooth' cut

Current status

- **NLO generator for Bhabha scattering:**
  - validation is required for small theta (~ 20 mrad)
  - need to estimate systematic error of generator

- **Background processes:**
  - $e^+e^- \rightarrow e^+e^-\mu^+\mu^-$, $e^+e^- \rightarrow e^+e^-e^+e^-$
    - validation required ← nothing to compare

- **Initial beam energy spread simulation:**
  - *ready*

- Other technical issues
  - *ready*

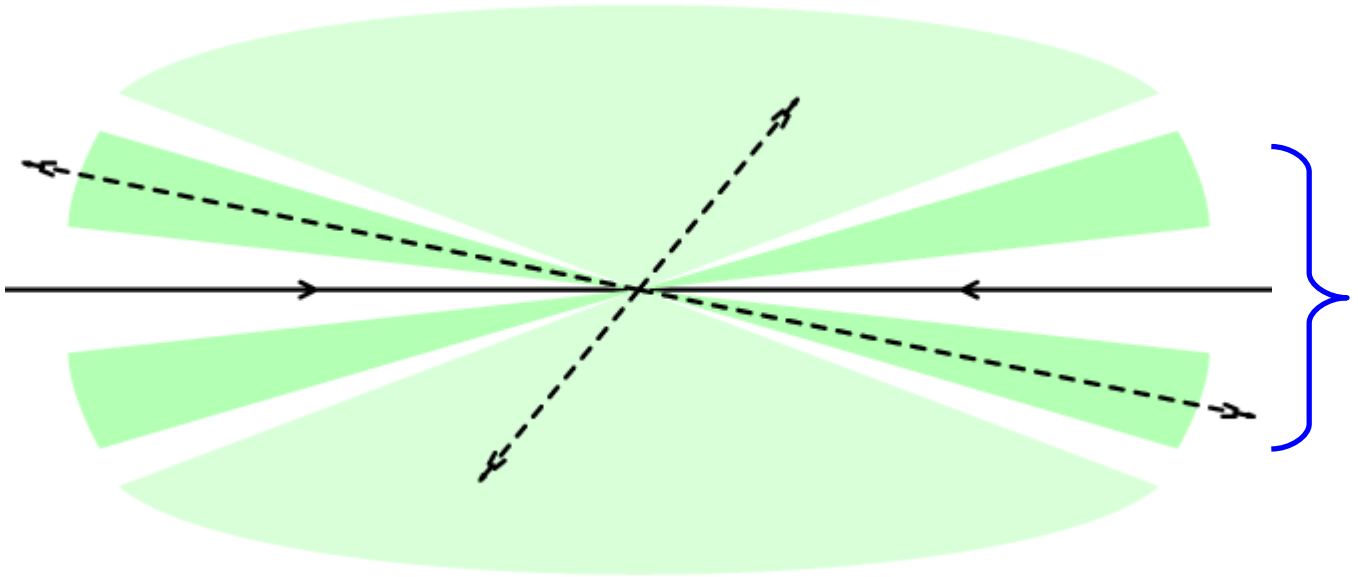
- LCIO interface
  - *to be implemented after generator validation*

Motivation

Luminosity at CLIC will be measured using quasi-elastic Bhabha scattering:

– forward events (LumiCal, BeamCal),

– wide scattering (in discussion)



forward scattering, polar angle ~ 1º–6º

wide region, polar angle > 6º

Event selection:

– coincidence of two quasi-collinear leptons,

– pair energy close to beam energy

Background processes:

– $e^+e^- \rightarrow e^+e^- + N\gamma$,

– $e^+e^- \rightarrow e^+e^- e^+e^-$,

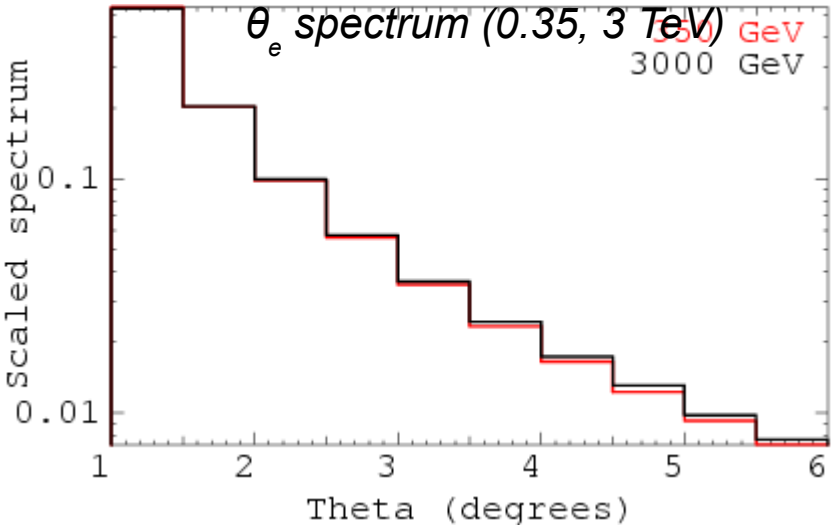
– $e^+e^- \rightarrow \gamma\gamma \rightarrow$ hadrons

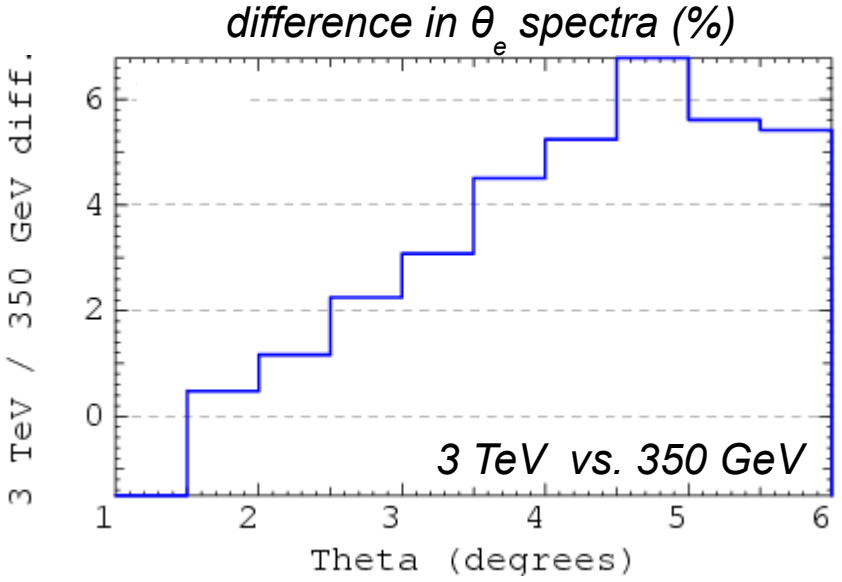
Beam spectrum

- Both **BHWIDE and BHLUMI** requires re-initialization if energy is changed,
  - correct simulation takes about 1 event/sec – **not acceptable!**

- **Current scheme**:
  1. generate BHLUMI / BHWIDE event at nominal (fixed) c.m. energy,
  2. scale (and boost) event to actual beam energy.

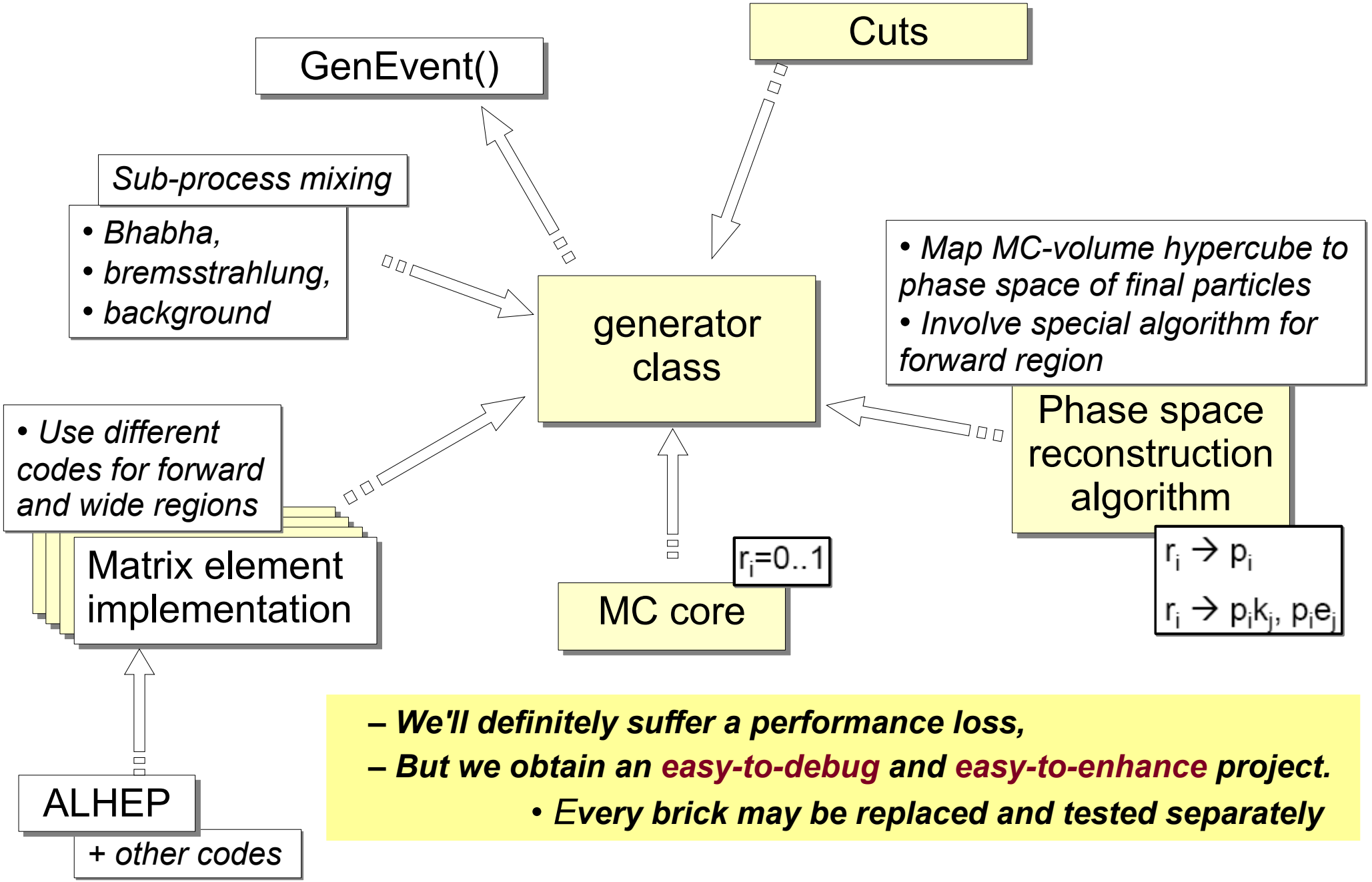
One presumes that angular distrubution is same for every c.m.s. energy





The difference in angular spectrum may achieve 4-5%!

Brick-based architecture



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

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

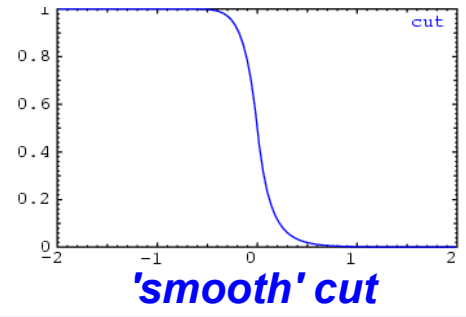
• *Every brick may be replaced and tested separately*

Cross-checks

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 forms of matrix elements

try different variables selection for faster integration convergence

Phase space reconstruction algorithm

try different algorithms

Matrix element implementation

MC core

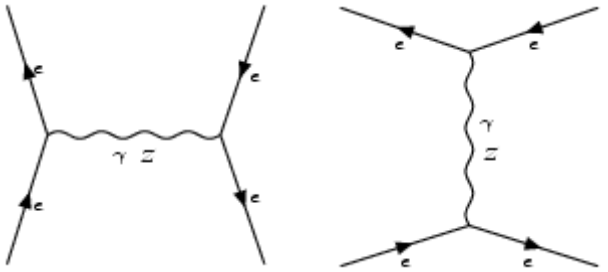
try different MC algorithms

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

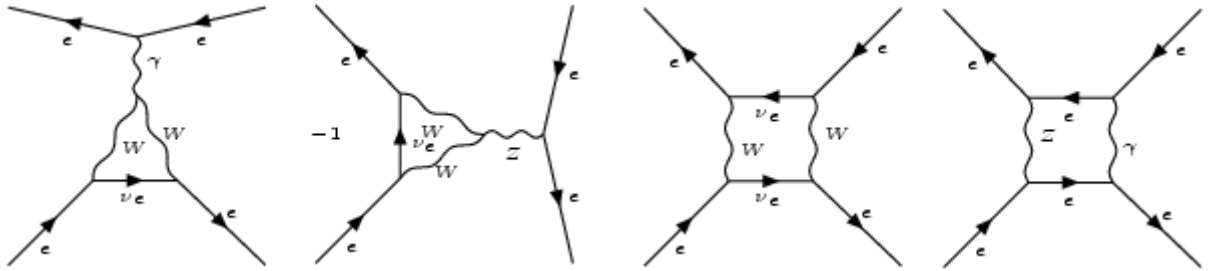
keep automatically-built version of ME

Processes

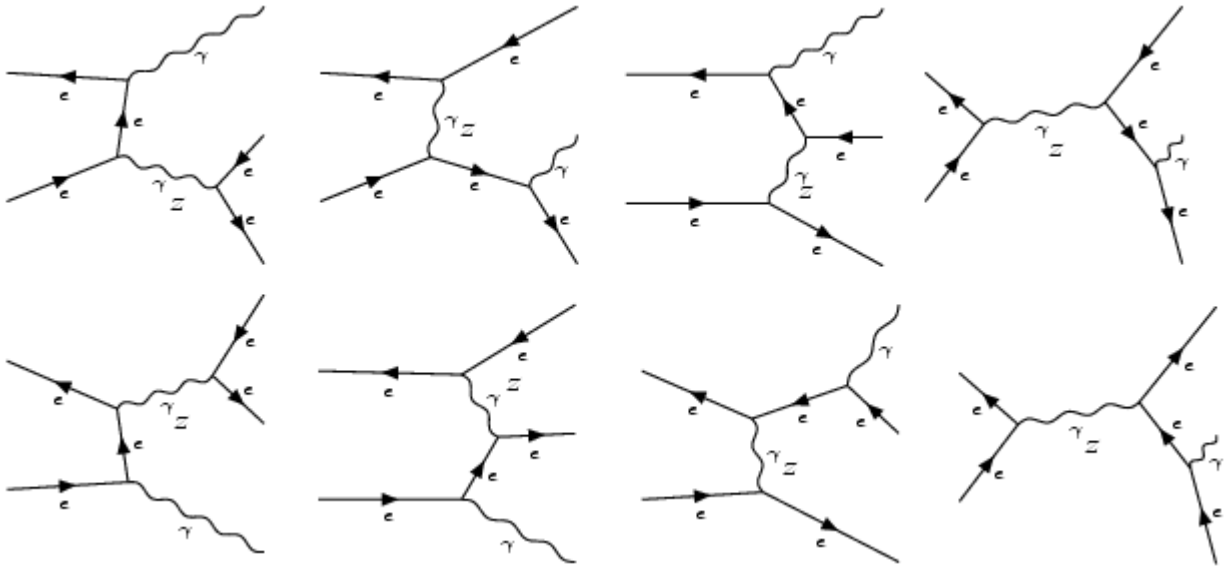
Bhabha scattering (NLO)



LO



loops (total 298 diagrams)



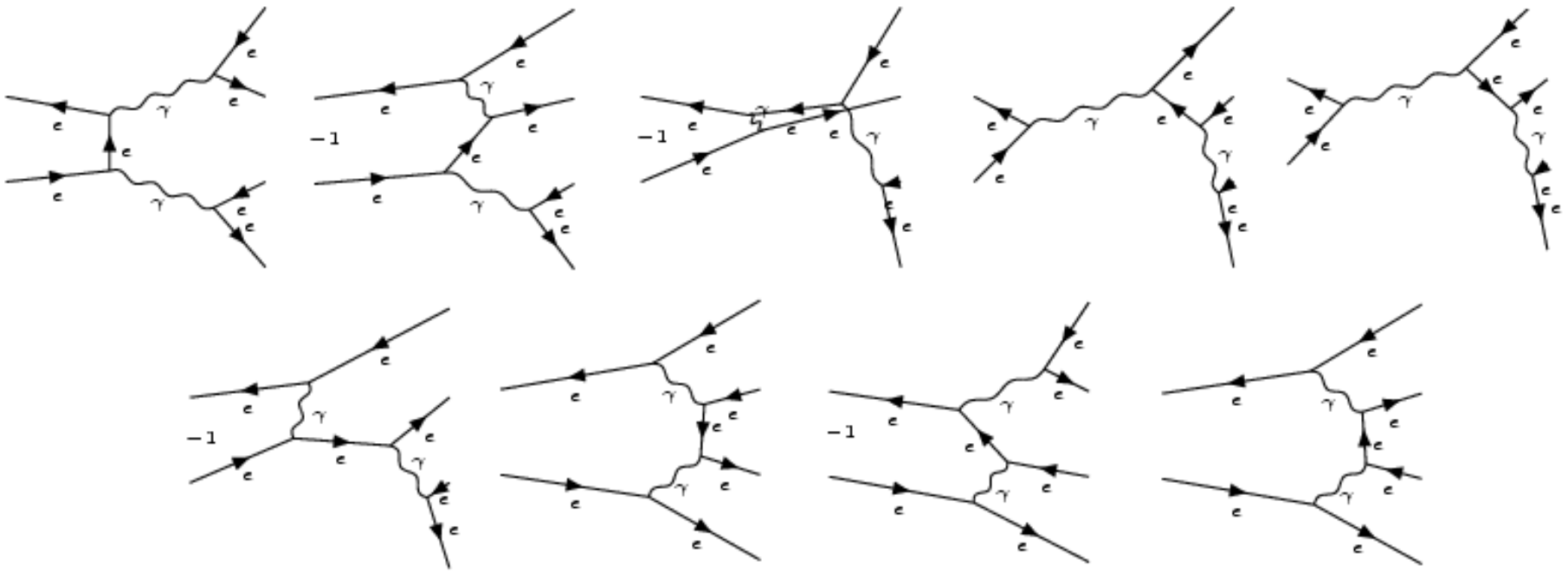
single bremssthahlung

Processes

Background process

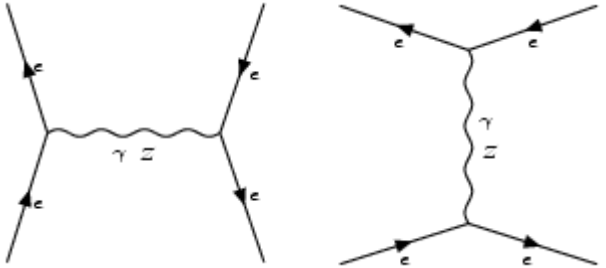
to be implemented

$$e^+e^- \to e^+e^- + e^+e^-$$



(total 88 diagrams)

BHLUMI and BHWIDE



Basic Bhabha scattering generators:

- **BHWIDE** for wide region scattering

(S. Jadach, W. Placzek and B.F.L. Ward)

precision: 0.1 – 0.5% (depending on c.m.s. energy),

- **BHLUMI** for forward scattering

(S. Jadach, W. Placzek, E. Richter-Was, B.F.L. Ward and Z. Was)

precision: up to 0.11% (at LEP1 energy)

Both generators:

– very precise,
– great performance *(> 1000 events / sec)*
– based on Yennie-Frautschi-Suura exponentiation,
– cross check each other in common kinematic region,

but

– contain no polarization,
– no background (lepton pair production) processes,
– use fixed beam energy

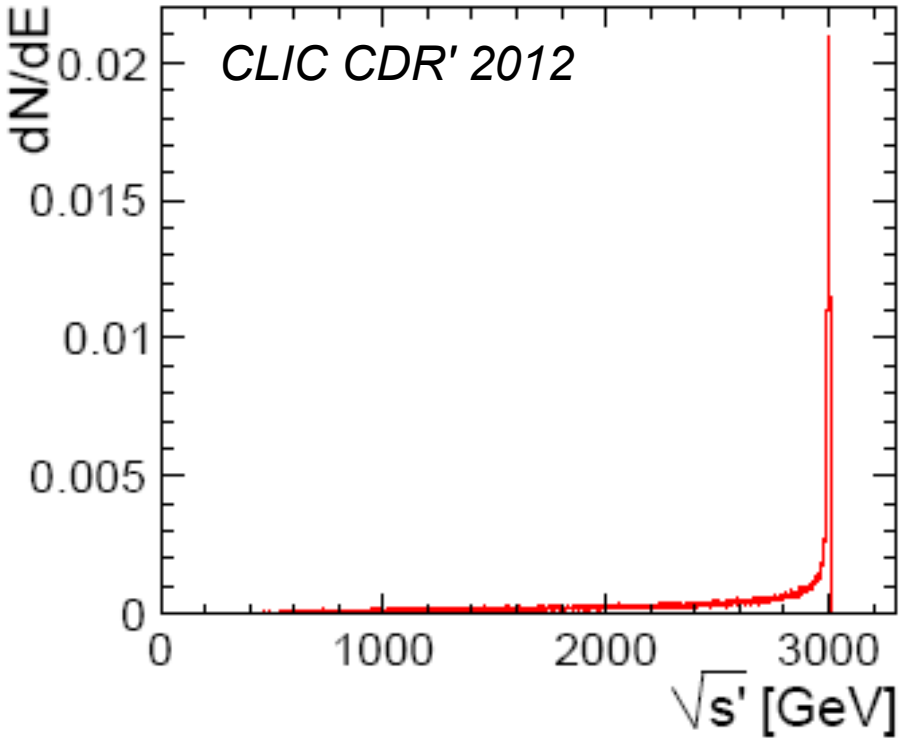
CLIC requirements

- **Single generator** for the whole kinematic region,
- that includes **background processes**,
- **beam polarization**,

P(e-)	P(e+)
0	0
-80	0
-80	+30

polarization effects were small at LEP energies, but...

- that is capable to generate events **with actual beam energy spectrum.**



- **Precision** of 1% is enough for CLIC at current stage.

Precision required:
- ILC: < 0.1%
- CLIC: ~1% ?

- Need **interface** to include NN..NLO effects, other backgrounds etc.