Direct W mass reconstruction at and above WW threshold at the FCC-ee

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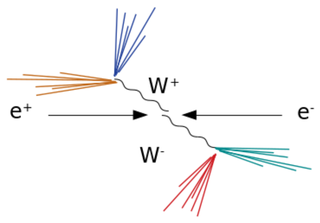
Hadronic channel study



Study at $\sqrt{s}$**= 162.6, 240 and 365 GeV**, with 8, 5 and 1.7 ab^{-1} respectively. The background is not included yet.

4 jets reconstruction

- Events generated with PYTHIA ;
- Fast simulation of the silicon-based detector, CLD ;
- Jet clustering with Durham algorithm, events constrained to form four jets ;
- Four jet pairing : minimisation with respect to the nominal W mass ;
- Optional use of a cone in the jets clustering to remove the particles most affected by the Final State Interaction (FSI). Particles outside the opening angle of 0.4 radians from the jet axis are rejected.

Direct invariant mass reconstructions

- **Raw dijet mass** : Dijet invariant mass computed from the momenta of jets particles ;
- **4C kinematic rescaling** : Jet four-momentum rescaled to satisfy the total energy-momentum conservation, while keeping their angles and velocities $\beta_i = p_i/E_i$ fixed to their measured values ;
- **Kinematic Fit** : Reconstruction with four jets-momenta corrected by kinematic constraints. The jet energies and directions are fitted by minimising the following χ^2.

$$\chi^2 = \frac{\sum_{i=1}^{4}(\alpha_i - \alpha_{i0})^2}{\sigma_\alpha^2} + \frac{\sum_{i=1}^{4}(\theta_i - \theta_{i0})^2}{\sigma_\theta^2} + \frac{\sum_{i=1}^{4}(\phi_i - \phi_{i0})^2}{\sigma_\phi^2} + \frac{\sum_{i=1}^{4}(v_i - v_{i0})^2}{\sigma_v^2} + 2\sum_{i=1}^{4}\lambda_i f_i(\alpha, \theta, \phi, v)$$

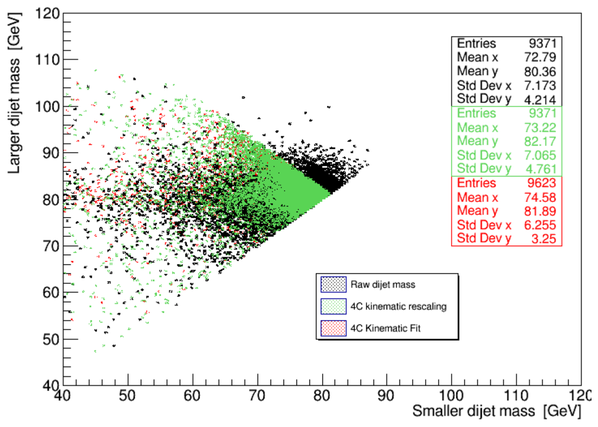
where the Lagrange multipliers λ hold for total energy and momentum conservation.

Statistical uncertainty on the W mass

The expected statistical uncertainty on the W mass peak value ($\Delta M_{W,stat}$) is estimated with a binned max likelihood fit on the reconstructed M_W distributions, using templates with different nominal W mass values. The final expected uncertainty is the result of the combination of the measurements of the two reconstructed masses.
With the cone, the mass resolution is degraded because of the information loss. This loss is expected to be compensated by a decrease of the FSI systematic uncertainty.

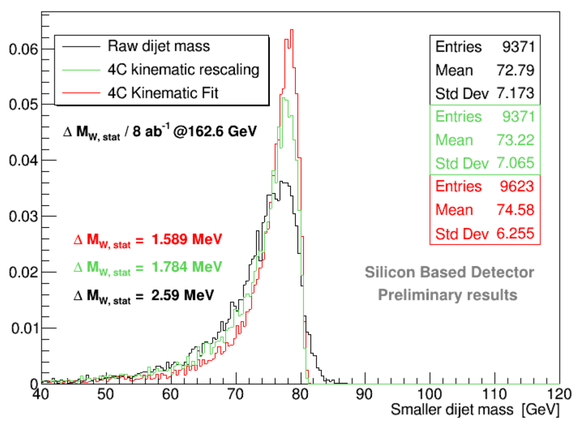
Reconstructed W mass at 162,6 GeV

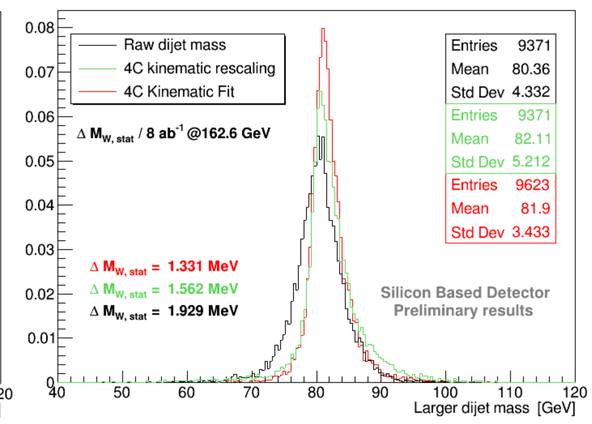
18.6 millions events in four jets



At threshold :

- Off shell and on shell W mass ;
- The W mass can be precisely measured with the cross section.



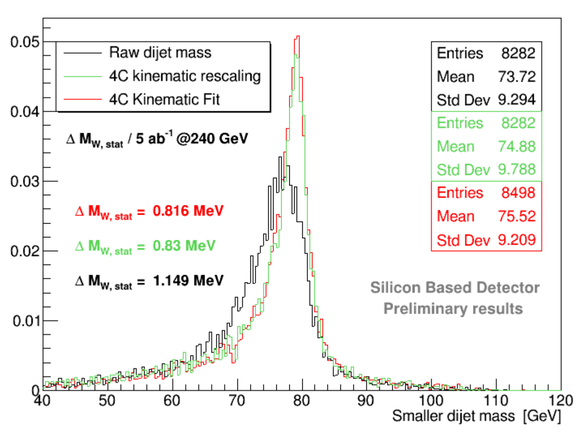


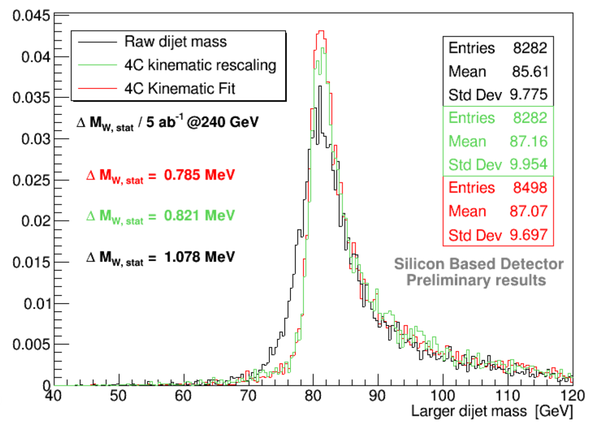
- Combined uncertainties :
  $\Delta M_{W\ \mathrm{stat,\ comb}}(4C\,\mathrm{fit}) = 1.02$ MeV
  $\Delta M_{W\ \mathrm{stat,\ comb}}(4C\,\mathrm{rescaling}) = 1.18$ MeV
  $\Delta M_{W\ \mathrm{stat,\ comb}}(\mathrm{raw\ mass}) = 1.55$ MeV
- With the cone :
  $\Delta M_{W\ \mathrm{cone,\ comb}}(4C\,\mathrm{fit}) = 1.11$ MeV
  $\Delta M_{W\ \mathrm{cone,\ comb}}(4C\,\mathrm{rescaling}) = 1.34$ MeV $\Delta M_{W\ \mathrm{cone,\ comb}}(\mathrm{raw\ mass}) = 1.49$ MeV

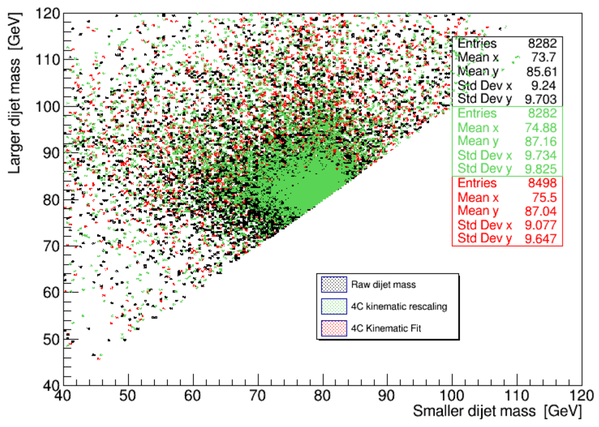
The **direct measurement is possible** at threshold and the 4C kinematic fit gives slightly better statistical uncertainty. The $\sqrt{s}$ used in the jets rescaling is measured by the **resonant depolarisation and would be reach a precision of 0.1 MeV**.

Reconstructed W mass at 240 GeV

38 millions events in four jets



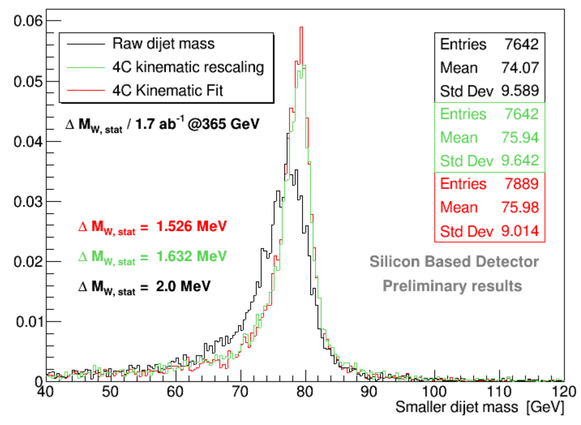


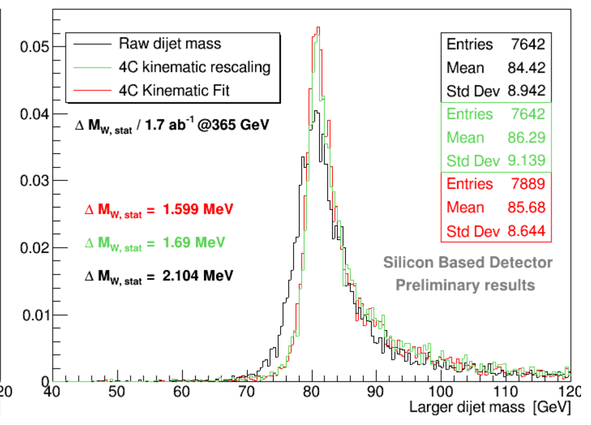


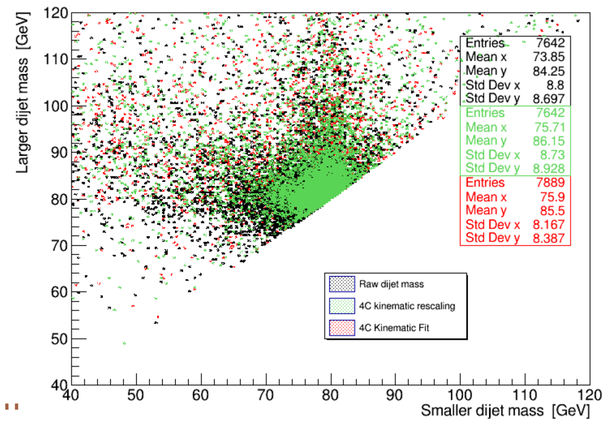
- Combined uncertainties :
  $\Delta M_{W\ \mathrm{stat,\ comb}}(4C\,\mathrm{fit}) = 0.56$ MeV
  $\Delta M_{W\ \mathrm{stat,\ comb}}(4C\,\mathrm{rescaling}) = 0.58$ MeV
  $\Delta M_{W\ \mathrm{stat,\ comb}}(\mathrm{raw\ mass}) = 0.79$ MeV
- With the cone :
  $\Delta M_{W\ \mathrm{cone,\ comb}}(4C\,\mathrm{fit}) = 1.17$ MeV
  $\Delta M_{W\ \mathrm{cone,\ comb}}(4C\,\mathrm{rescaling}) = 1.24$ MeV
  $\Delta M_{W\ \mathrm{cone,\ comb}}(\mathrm{raw\ mass}) = 1.23$ MeV

Reconstructed W mass at 365 GeV

9.3 millions events in four jets





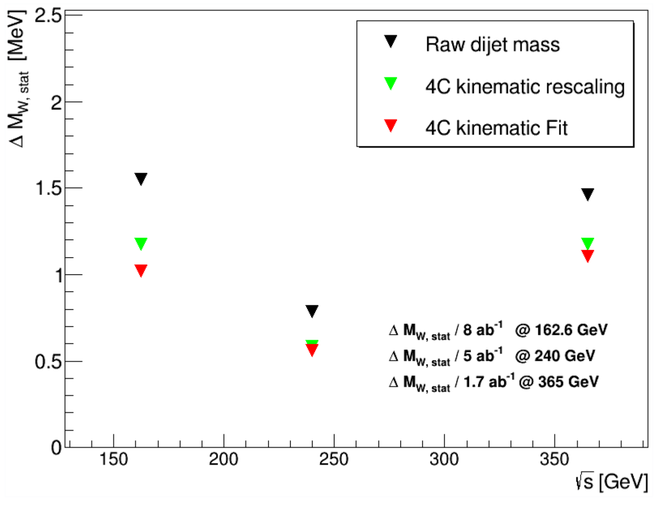


- Combined uncertainties :
  $\Delta M_{W\ \mathrm{stat,\ comb}}(4C\,\mathrm{fit}) = 1.10$ MeV
  $\Delta M_{W\ \mathrm{stat,\ comb}}(4C\,\mathrm{rescaling}) = 1.17$ MeV
  $\Delta M_{W\ \mathrm{stat,\ comb}}(\mathrm{raw\ mass}) = 1.46$ MeV
- With the cone :
  $\Delta M_{W\ \mathrm{cone,\ comb}}(4C\,\mathrm{fit}) = 1.15$ MeV
  $\Delta M_{W\ \mathrm{cone,\ comb}}(4C\,\mathrm{rescaling}) = 1.27$ MeV
  $\Delta M_{W\ \mathrm{cone,\ comb}}(\mathrm{raw\ mass}) = 1.15$ MeV

At 240 and 365 GeV the **4C kinematic fit also gives the better statistical uncertainty**. At these energies, the resonant depolarisation is not available and the $\sqrt{s}$ should be measured with **alternative method** like the radiative return to the Z peak. If the precision on $\sqrt{s}$ is larger than $\Delta M_{W,stat}$ **the W mass measurement from the WW decay can be used to determine $\sqrt{s}$ at high energies**.

Statistical uncertainty on W mass according to $\sqrt{s}$

Statistical uncertainties without the cone as a function of the energy in the center of mass.



The 4C kinematic provides the best statistical uncertainty at each $\sqrt{s}$ with bigger precision at 240 GeV (more events).

Outlook

- **5C kinematic fit** : 4C kinematic fit and equality of the two reconstructed masses ;
- Study of the **semi-leptonic WW decay** channel (two jets, one lepton and one neutrino) ;
- Determination of $\sqrt{s}$ **at high energies**.