$e^+e^- \to \nu_e\bar{\nu}_e W^+W^-$ and $e^+e^- \to \nu_e\bar{\nu}_e Z^0 Z^0$

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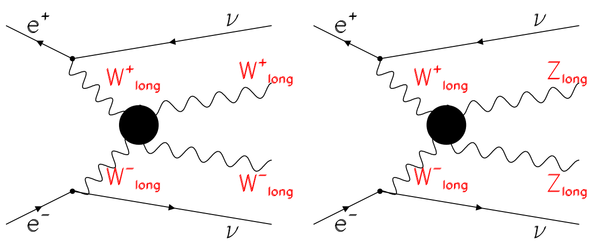
- WW scattering analysis
- Breit-Wigner width @ W/Z
- Z/W separation
- Summary and outlook

WW scattering

- **WW scattering**



- **Published works @ Linear Collider**
  - **LC-PHSM-2001-038: SIMDET for TESLA @ 800 GeV**
  - **. . . . .**
- **Improvement @ this work (work in progress)**
  - **LDC00Sc detector model**
  - **PandoraPFO PFA**
  - **C++ k_t jet finder: KtJet package in Marlin**

WW/ZZ event selection @ 500 GeV

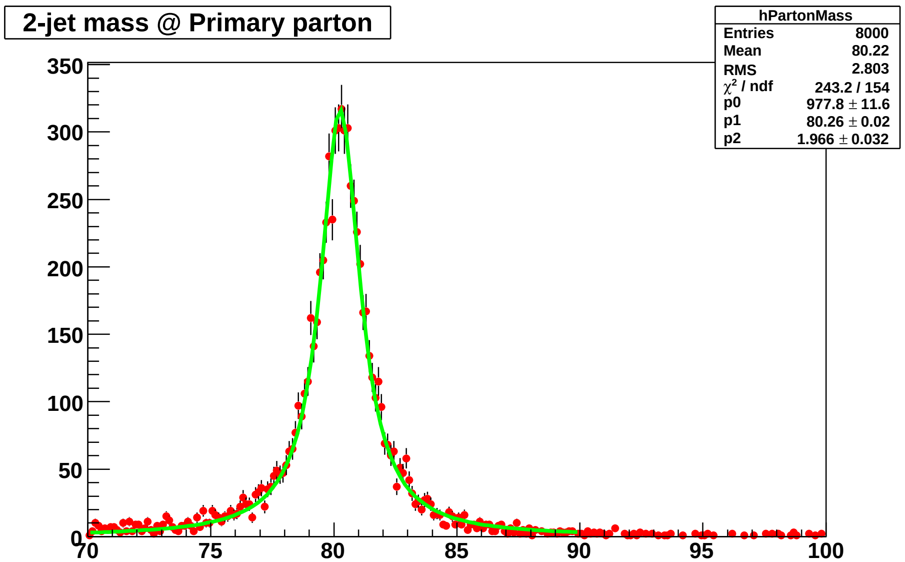
- **We follow the paper LC-PHSM-2001-038, and need to tune cut value in the future.**

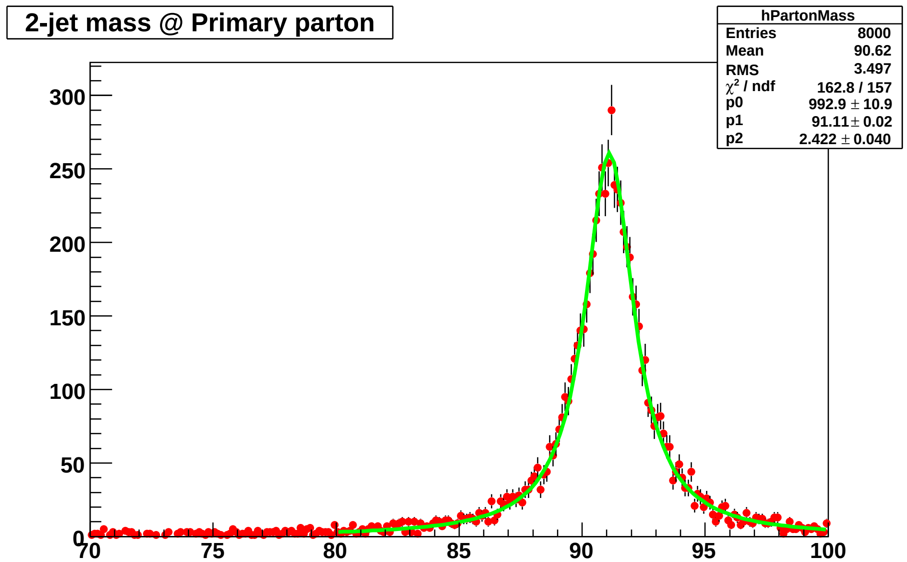
- **Event selection: select events with a significant fraction of neutrinos**
  - **Recoil mass:** $M_{recoil} >= 120.0$ **GeV**
  - **Total transverse momentum:** $p_T >= 12$ **GeV**
  - **Total transverse energy:** $E_T >= 90$ **GeV**
  - **Total missing momentum and most energetic track:** $|\cos(\theta)| < 0.99$
  - **Energy in a** 5^o **cone of most energy track:** $E_{cone} >= 2.0$ **GeV**
  - **Force events to have 4 jets, and** $Y_{34} > 0.001$
    * **Jet energy:** $E_{jet} > 10.0$ **GeV**
    * **Jet theta:** $|\cos(\theta)| < 0.99$

- **Kinematic fitting:**
  - **1C: the two dijet masses are constrained to be equal**

Breit-Wigner width @ four primary partons

- **4 primary quarks @ $e^+e^- \rightarrow \nu_e\bar{\nu}_e W^+W^- \rightarrow \nu_e\bar{\nu}_e q_1q_2q_3q_4$ and @ $e^+e^- \rightarrow \nu_e\bar{\nu}_e Z^0Z^0 \rightarrow \nu_e\bar{\nu}_e q_1q_2q_3q_4$**



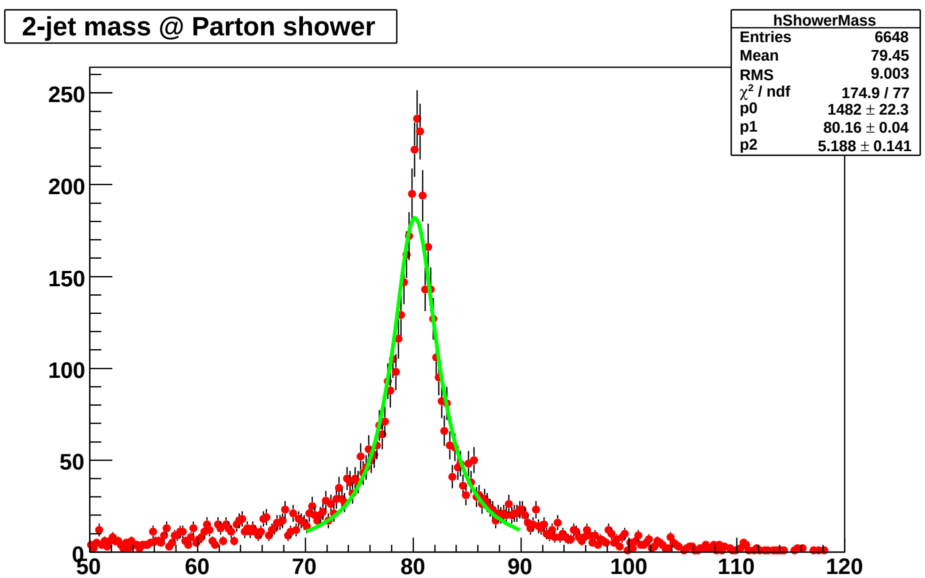


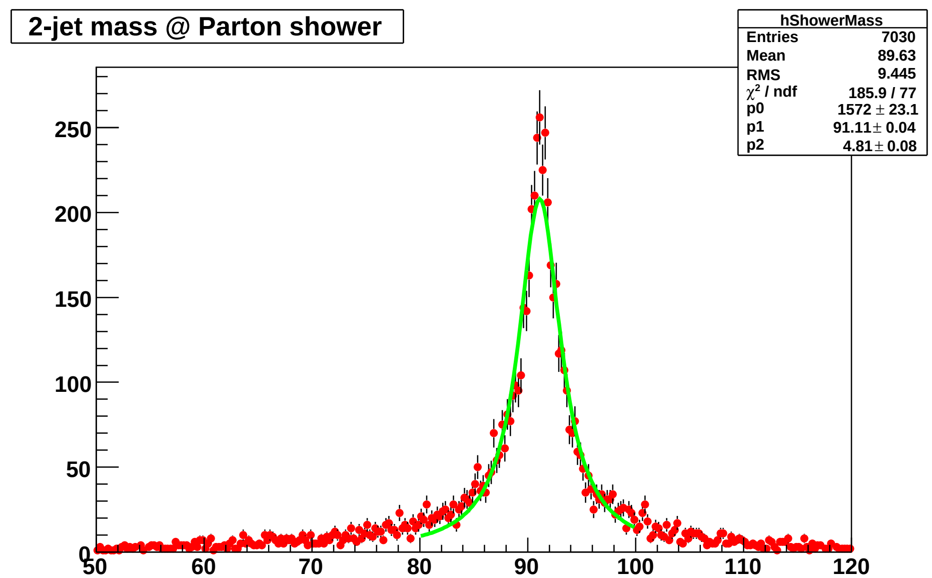
- **PYTHIA: W: 2.085 GeV Z: 2.4973 GeV**

- **Breit-Wigner width Γ is close to natural widths**

Breit-Wigner width @ parton shower

- **Partons after parton shower by four primary partons**
- **Matching four primary partons to reconstructed jets in $\eta - \phi$ plane $\Longrightarrow$ correctly combine two jets into one W**

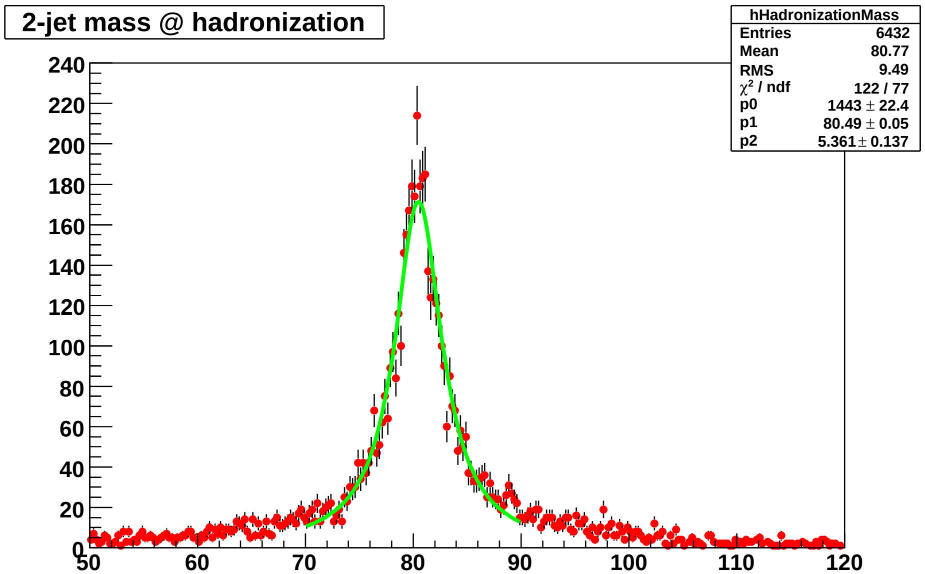


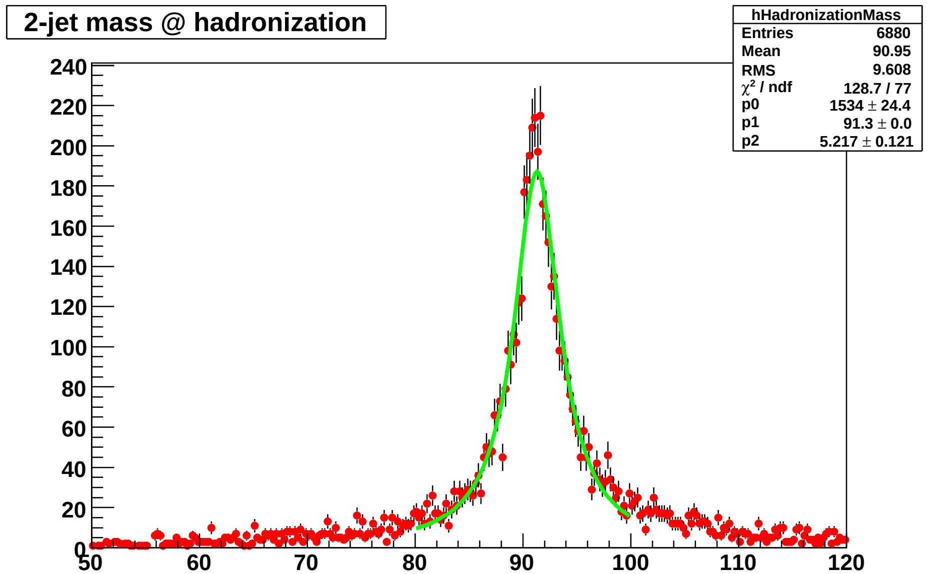


- **Breit-Wigner Γ: increase by factor $\sim$ 2.6(W)/2.0(Z) with respect to four primary partons**

Breit-Wigner width @ hadronization

- **Stable hadrons after hadronization**
- **Matching four primary partons to reconstructed jets in $\eta - \phi$ plane**

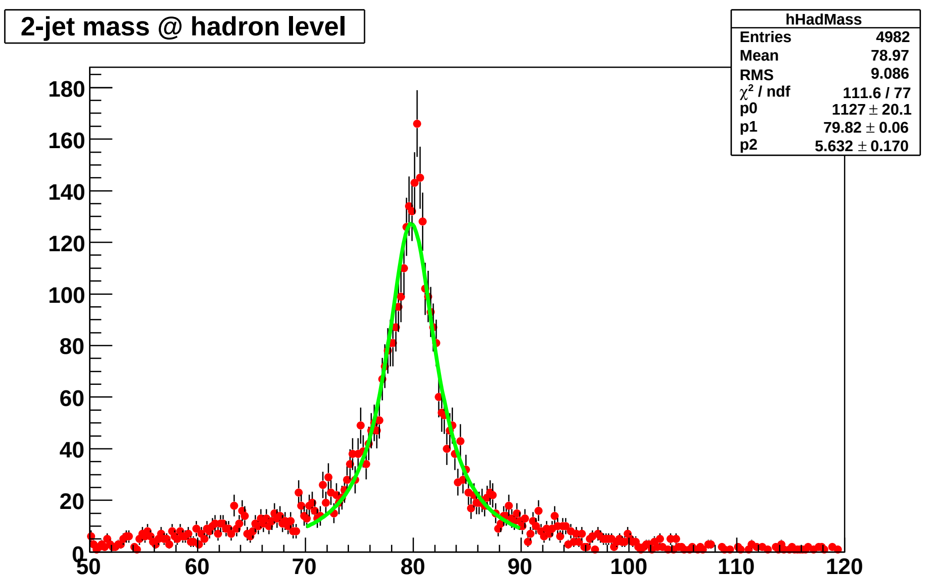


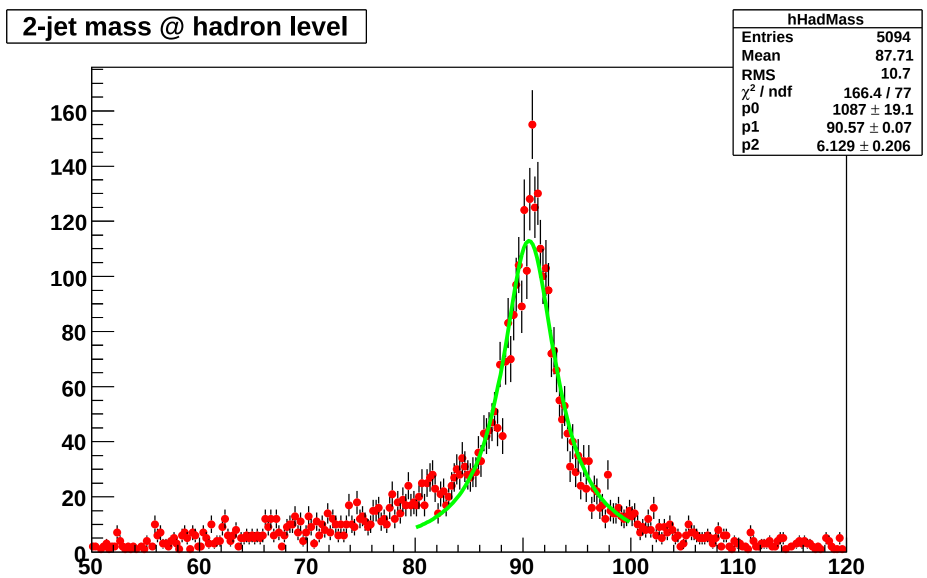


- **Breit-Wigner Γ: increase by factor $\sim$ 1.03(W)/1.08(Z) with respect to parton level**

Breit-Wigner width @ before detector simulation

- **Hadrons after hadronization: stable particle in the generator, remove neutrinos and particle in beam pipe ($TMath :: Abs(\cos(\theta)) < 0.995$)**
- **Matching four primary partons to reconstructed jets in $\eta - \phi$ plane**

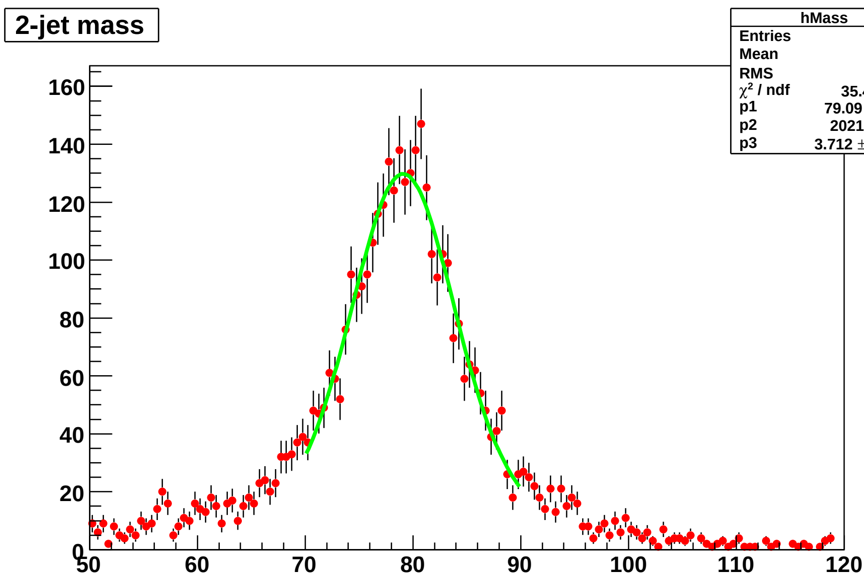


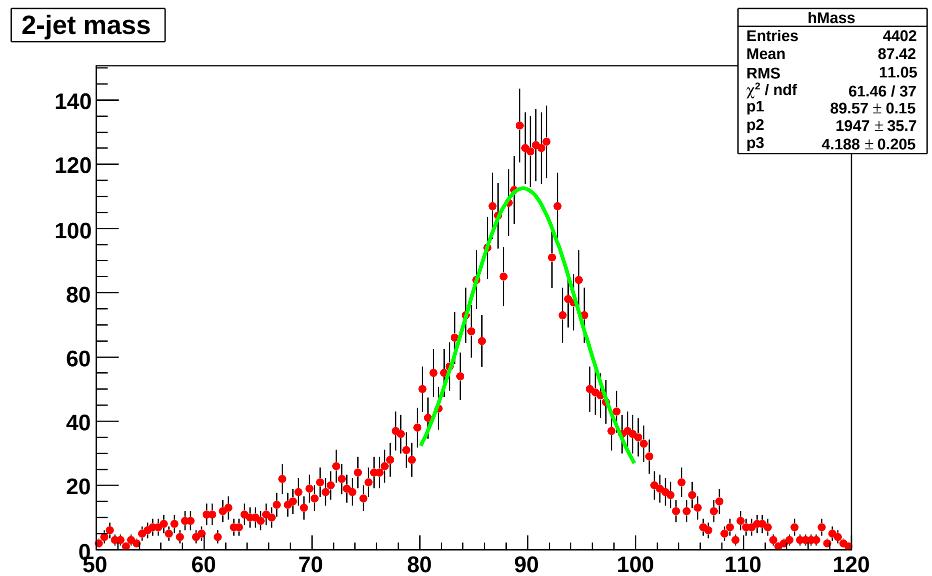


- **Breit-Wigner Γ: increase by factor $\sim$ 1.05(W)/1.17(Z) with respect to complete hadronic final state**

Breit-Wigner width @ detector level

- **Particle flow objects: PandoraPFO PFA**
- **Matching four primary partons to reconstructed jets in $\eta - \phi$ plane**

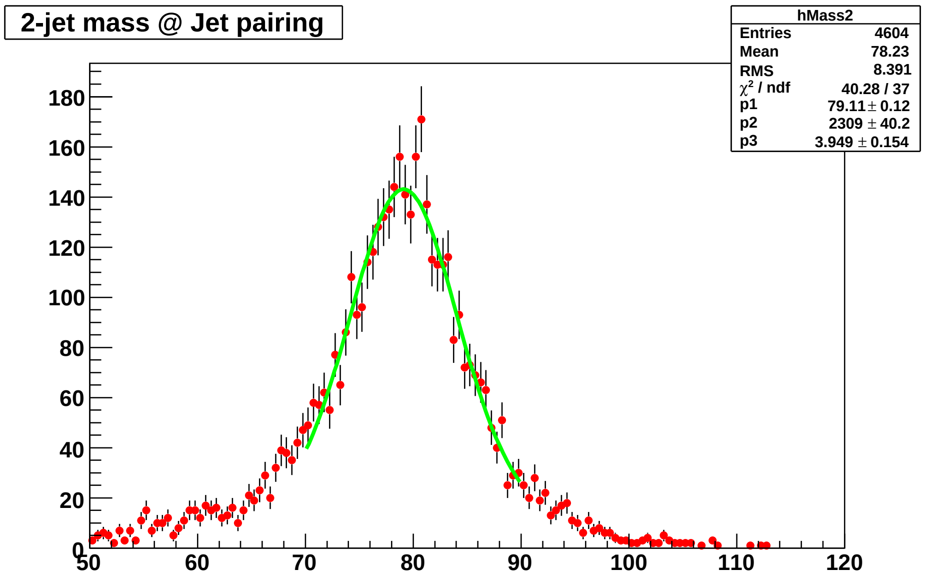


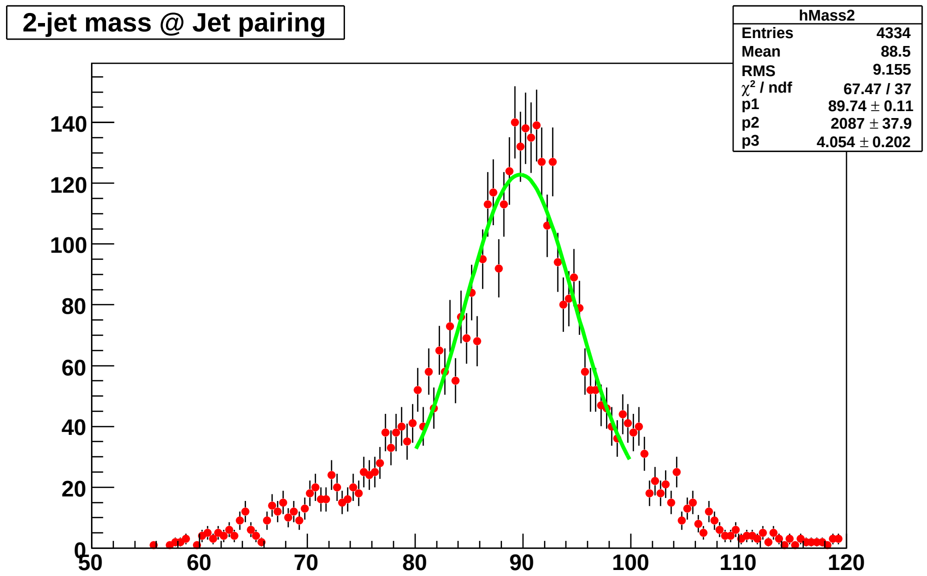


- **Breit-Wigner $\otimes$ Gaussian fitting: Fixing Breit-Wigner width (W: 5.63 GeV; Z: 6.13 GeV;) as Breit-Wigner width @ before detector simulation, Gaussian width describe the contribution to resolution from PFA and detector effect, which are $\sim$ 3.71(W)/4.19(Z)**

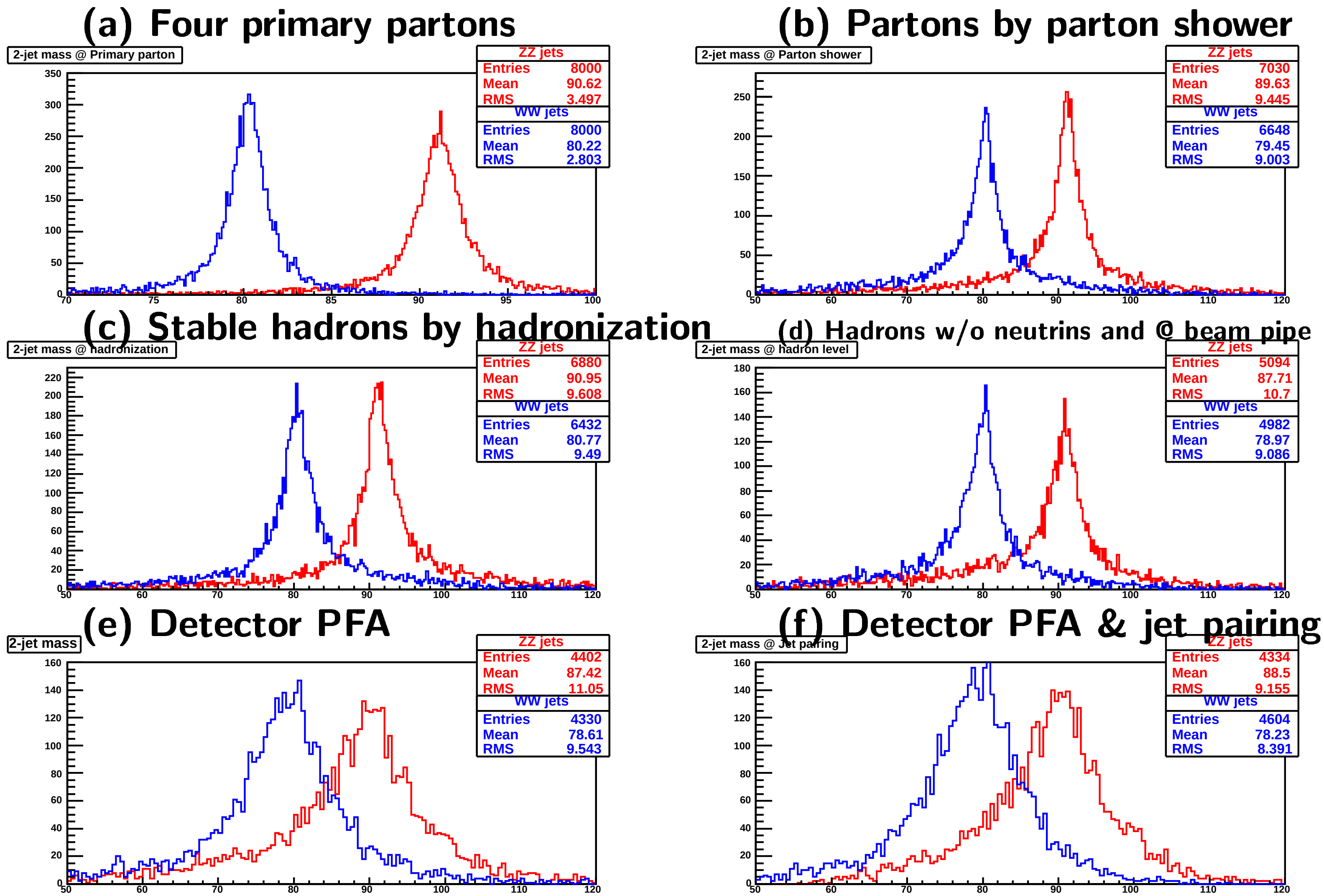
Breit-Wigner width @ detector level

- **Particle flow objects: PandoraPFO PFA**
- **Four jets $\Longrightarrow C_4^2/2 = 6/2 = 3$ pairs (pair: two 2-jet groups) per event**
- **Select a good jet pairing**
  - $|M_{jj}^A - M_{W/Z}| + |M_{jj}^B - M_{W/Z}|$: **Min. value**
  - **Min.** $|M_{jj}^A - M_{W/Z}| + |M_{jj}^B - M_{W/Z}| < 36.0$ **GeV**



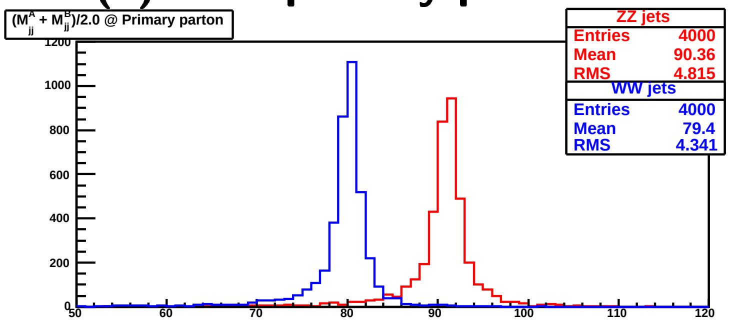


Z/W separation

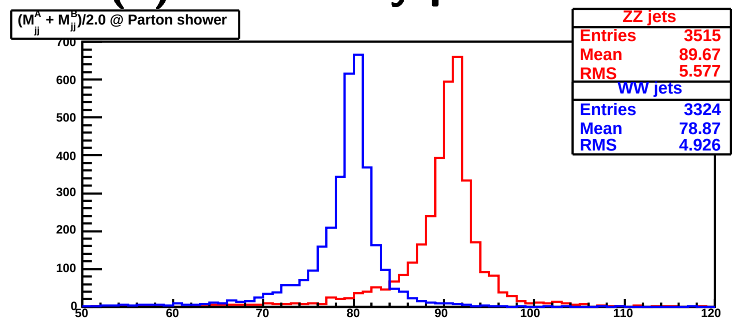


Z/W separation: $(M_{jj}^{A} + M_{jj}^{B})/2.0$

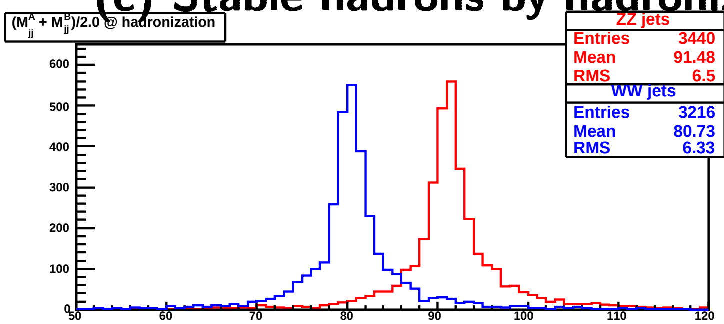
(a) Four primary partons



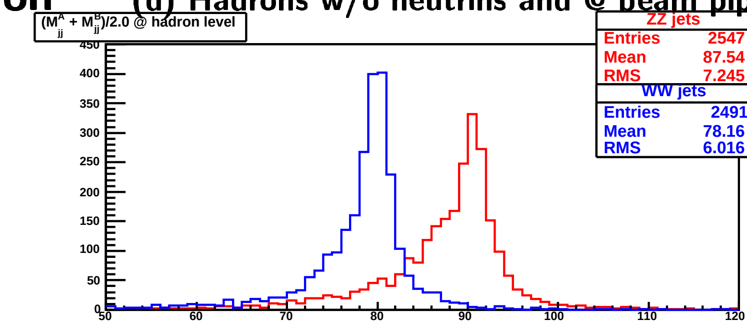
(b) Partons by parton shower



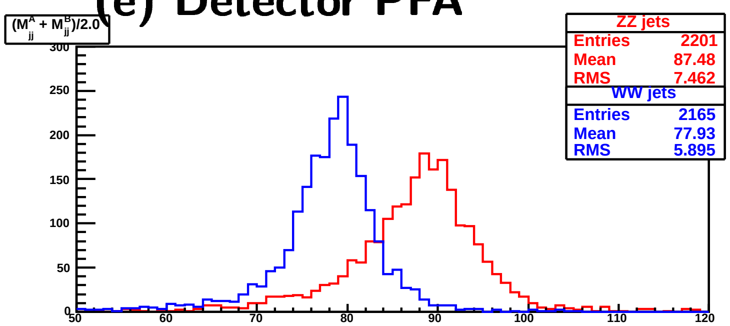
(c) Stable hadrons by hadronization



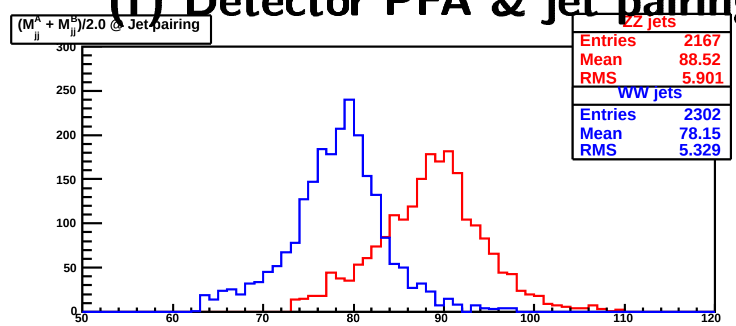
(d) Hadrons w/o neutrins and @ beam pipe



(e) Detector PFA

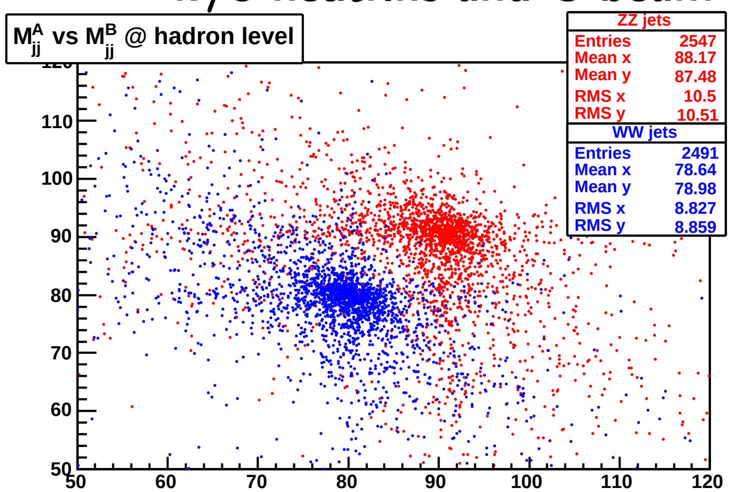


(f) Detector PFA & jet pairing

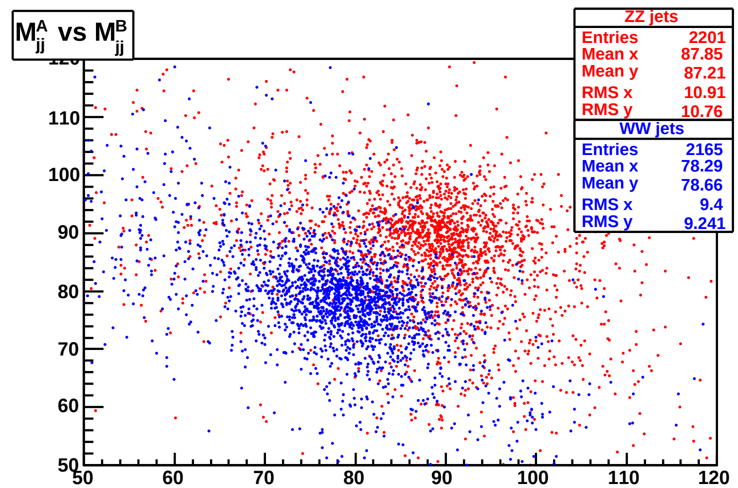


Z/W separation: M_{jj}^{A} vs. M_{jj}^{B}

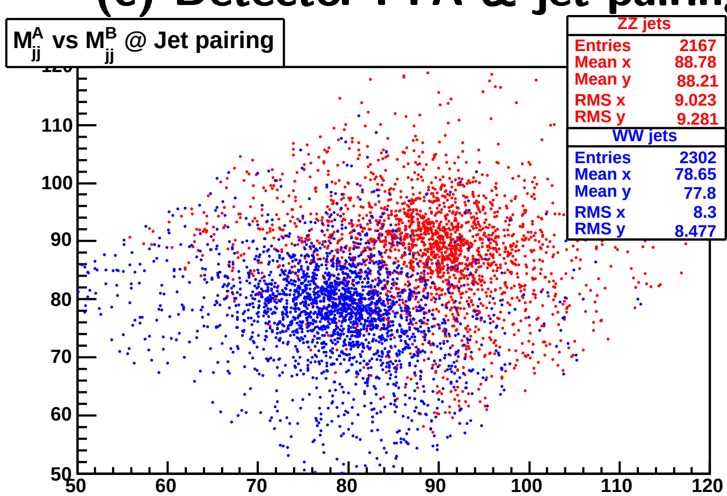
(a) Stable hadrons by hadronization w/o neutrins and @ beam pipe



(b) Detector PFA

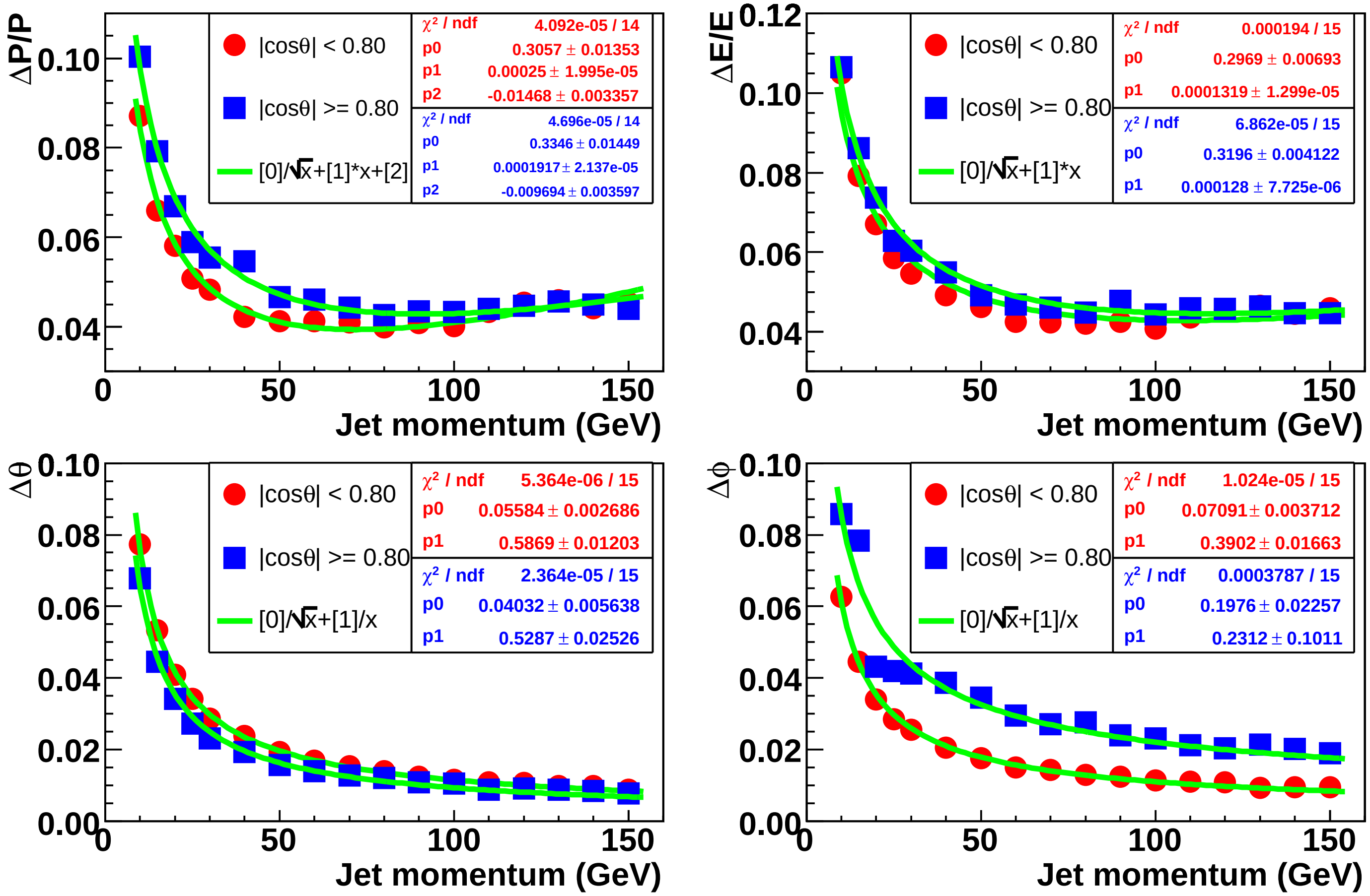


(c) Detector PFA & jet pairing



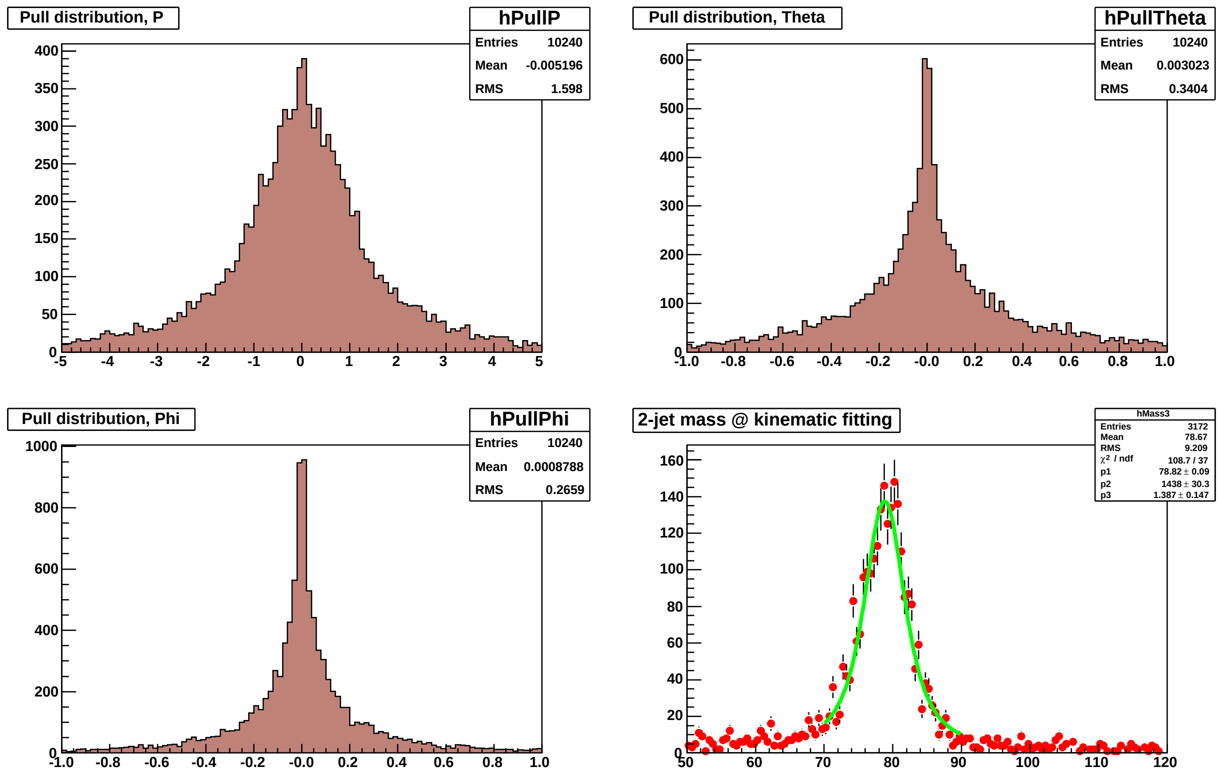
Jet resolution: $e^+e^- \to q\bar{q}$

- **Jet resolution: Jet Momentum, θ and ϕ**



1C kinematic fitting

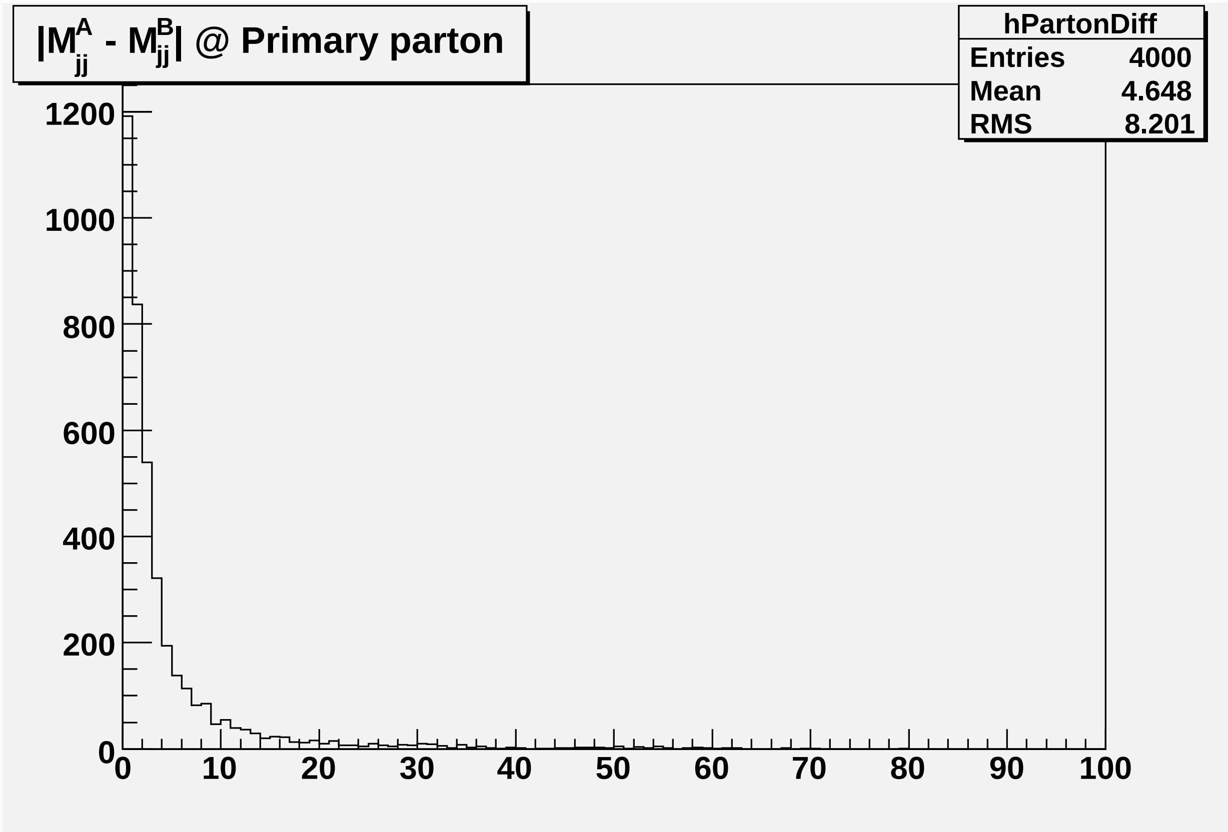
- **1C fitting: the two dijet masses are constrained to be equal**



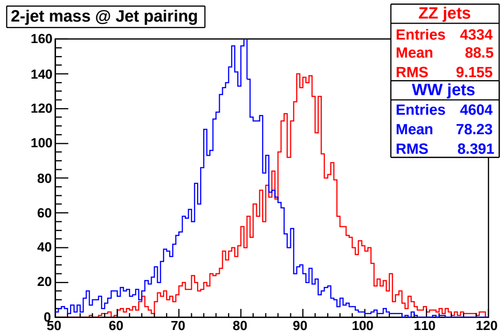
- **WW events: inprove resolution 4.0 GeV $\rightarrow$ 1.4 GeV**

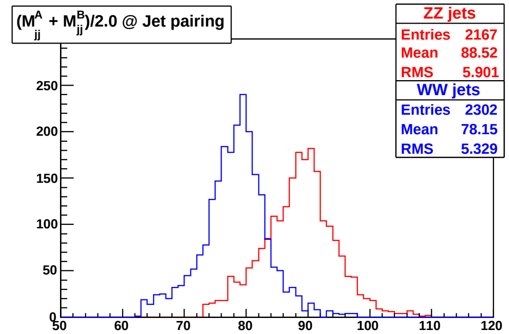
1C kinematic fitting

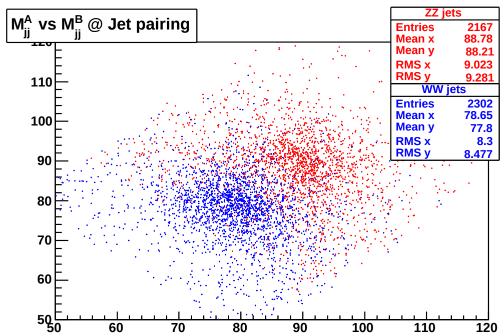
- **1C fitting: the two dijet masses are constrained to be equal**
- **Four primary parton:** $M_{jj}^{A} = M_{jj}^{B}$ **???**

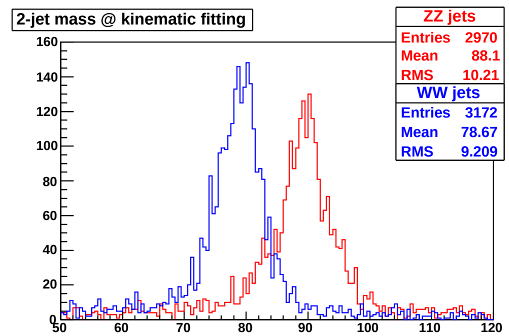


1C kinematic fitting









	$(M^A_{jj} + M^B_{jj})/2.0$ (GeV)	
	Judged W: $<=$ 85.5	Judged Z: $>$ 85.5
WW events	84.5% (89.3%)	15.5% (10.7%)
ZZ events	31.3% (27.0%)	68.7% (73.0%)
Black: before kinematic fitting		
Red: after kinematic fitting		

Summary and outlook

- **Breit-Wigner width of W/Z by using the partons at parton level and k_T jet finder increase by factor $\sim$ 2.6(W)/2.0(Z) with respect the natural width.**
- **Hadronization and missing particle (neutrinos and particle in beam pipe) have small effect ($\sim$ 10%) to Breit-Wigner width.**
- **Breit-Wigner $\otimes$ Gaussian fitting have $\sim$ 3.95(W)/4.05(Z) GeV for detector and PFA effect.**
- **W/Z separation plots are available.**
- **1C fitting inprove resolution.**
- **Plan: Using Monte Carlo generator Whizard to study WW scattering**