A New Physics Book with PandaRoot – why, what, when?

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Panda Collaboration Meeting, 02.03.2009, GSI Darmstadt

Computing Parallel Session

Andy Warhol

Why this question?

- Statement by Bertram Kopf

  PandaRoot Meeting 27.01.2009

  from the minutes

  http://panda-wiki.gsi.de/cgi-bin/view/Computing/Minutes27Jan2009

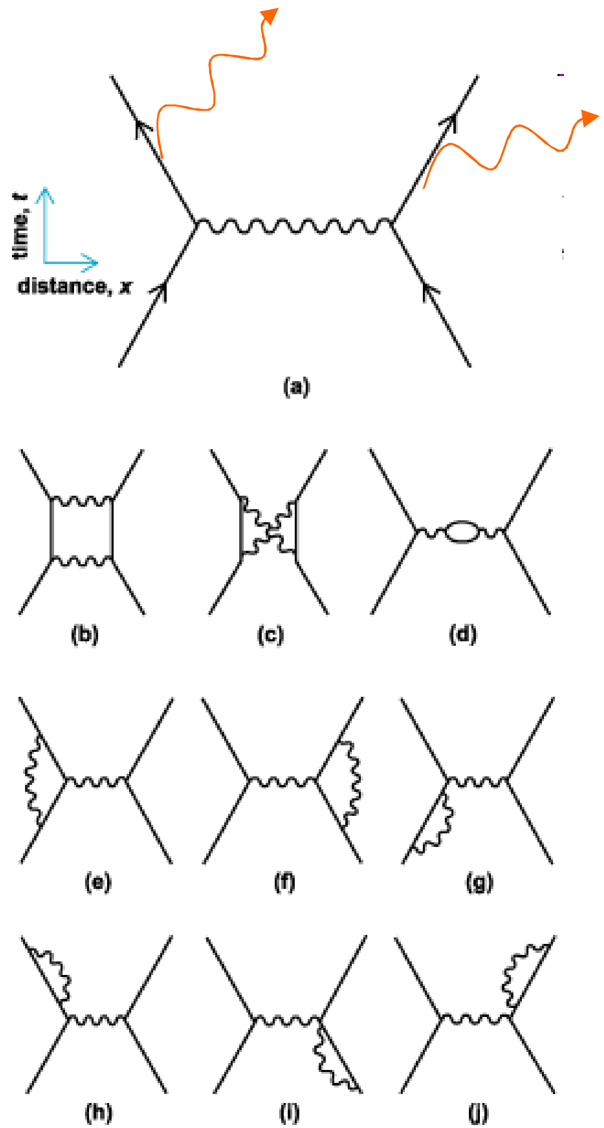
  „This, in particular in view of the near-future mass production for physics benchmark and, partly also, for the design studies. **Note that the plan is to redo - with PandaRoot - the various channels reported in the physics book in the very near future** and to extend the simulations with many more other channels for the "extended physics book" on a longer time scale.“

Why re-do the Physics Book (anyway)?

- Radiative Corrections
  (PHOTOS)
- Tracking Finder Efficiency
- Other issues
  - angular distributions
    phasespace vs. quantum numbers
    inclusion into systematic errors
  - EM showers
    Geant 4.7 vs. Geant 4.9
  - some other notes …
- all these issues are discussed for one example
  X(3872) -> J/Psi $\pi+$ $\pi-$
  J/ψ $\rightarrow$ e+ e−
  which is not in the physics book
  (but declared by QWG as high priority object,
  $\rightarrow$ DD* molecule candidate, quantum numbers of deuteron,
  radius of wavefunction larger than a ^{12}C nucleus)

1. Radiative Corrections

- Bremsstrahlung
- Any charged particle (quark, lepton) can at any time emit a photon
- These are 3 types
  - QED bremsstrahlung in production
  - QED bremsstrahlung in decay
  - QED bremsstrahlung in detector
- (c) is simulated by Geant
- (a) and (b) are simulated by PHOTOS in EvtGen



Computer Physics Communications 66 (1991) 115–128
North-Holland

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Photos – a universal Monte Carlo for QED radiative corrections in decays

Elisabetta Barberio [1], Bob van Eijk [2] and Zbigniew Wąs [3]
CERN, CH-1211 Geneva 23, Switzerland

Received 14 September 1990; in revised form 29 September 1990

In this paper we present an algorithm for the Monte Carlo simulation of QED single-photon radiative corrections in decays. The algorithm is implemented in an independent package written in FORTRAN 77. The program is universal, i.e. it allows for easy interfacing with "any" program generating decays of "any" particle. The program can be used to estimate the size of the QED bremsstrahlung in the leading-logarithmic (collinear) approximation. The proper soft-photon behavior is also reproduced. The program is designed such that the inclusion (if necessary) of the exact, process dependent, $\mathcal{O}(\alpha)$ matrix element is *possible* and straightforward. The program provides final states with their full topology, including kinematical effects due to massive particles. For Z decays into pairs of light fermions, an extensive comparison of our algorithm with programs based on exact $\mathcal{O}(\alpha)$ matrix elements was performed.

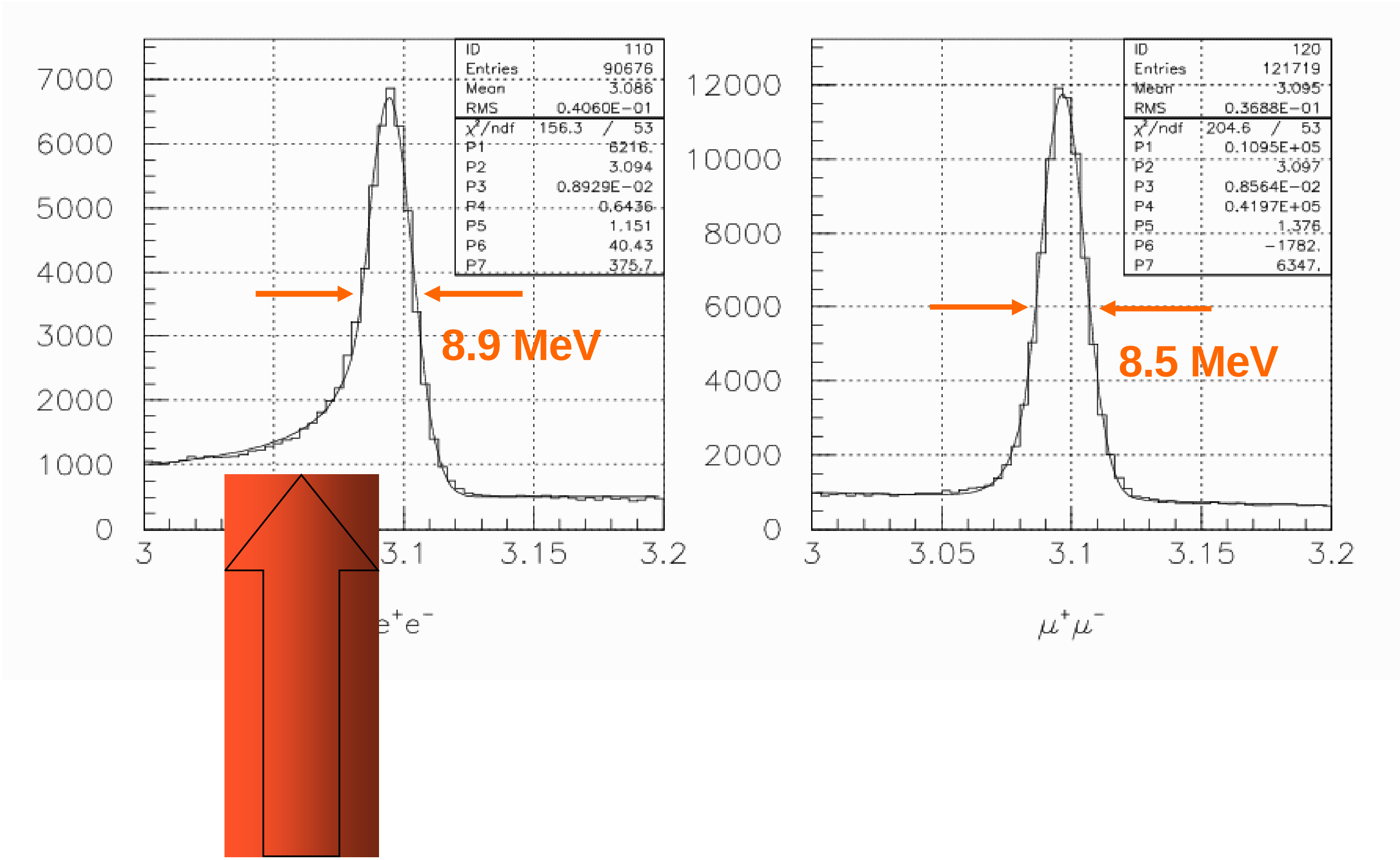
What does it mean for the physics book?

- PHOTOS is switched ON by default in EvtGen
- Thus, it is ON for all simulations for e.g. Belle (confirmed)
- However not for the physics book (confirmed by U. Wiedner, M. Pelizäus)

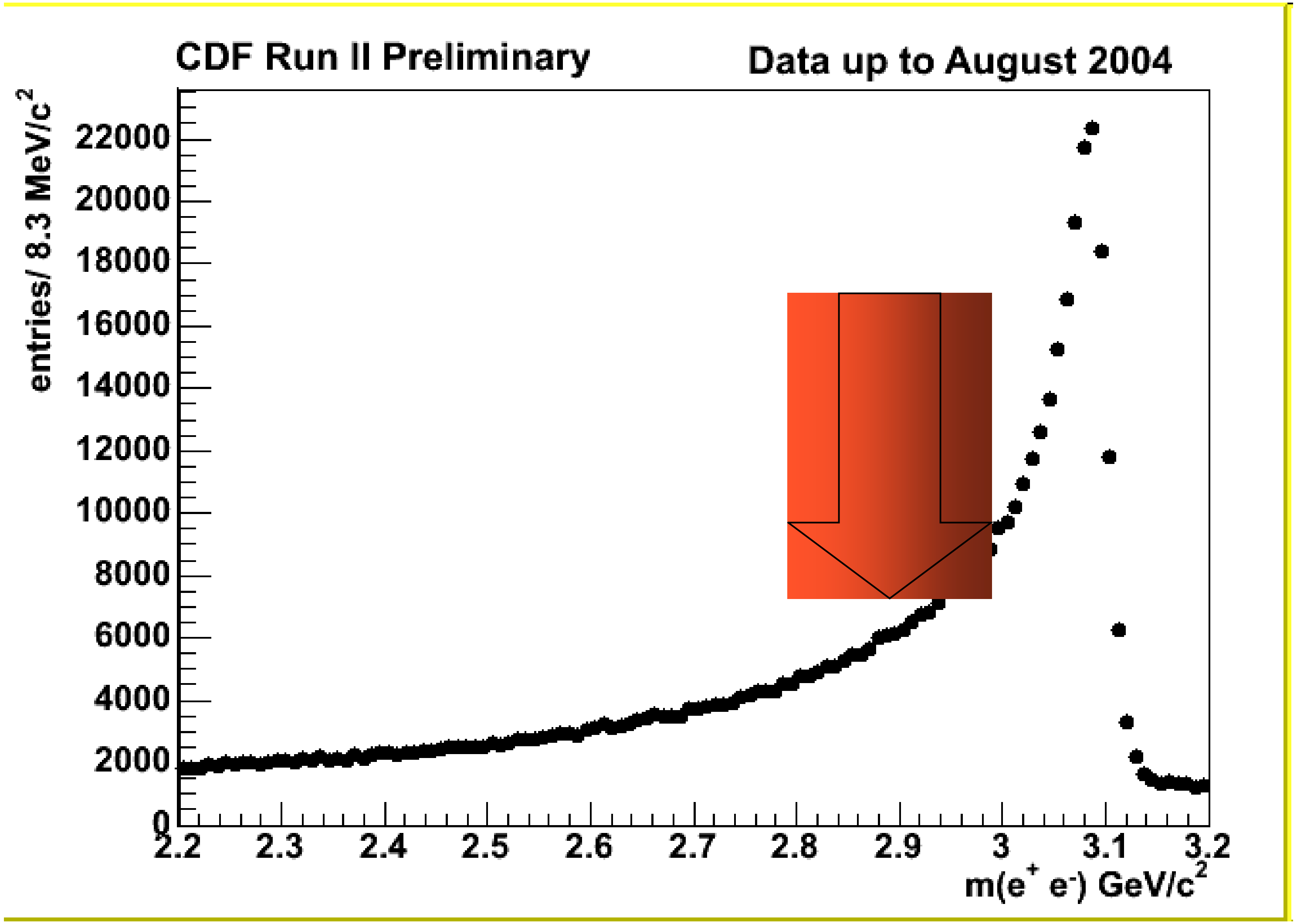
  Note for clarification (added due to questions during the talk). Statement by 18.07.2009 by email (translated from german). „In the reconstruction/analysis this effect is not corrected. J/Psi candidates with a invariant mass in the tail region are lost …[]… This is an important point for later". (i.e. after the physics book)

- How many photons are radiated?
  in ~30% in all X(3872)->J/Psi $\pi^+ \pi^-$, $J/\psi \to$ e+ e– decays
- How do other experiments work around it?
  e.g. CLEO, Phys.Rev.D71:111103,2005
  measurement of J/Psi $\to$ e+e- BR
  only via recoil mass against $\pi^+ \pi^-$
  (i.e. not invariant mass of $J/\psi \to$ e+ e– γ)

Example: Belle, J/ψ



Example: CDF, J/ψ



Counter-Example: Physics Book

No radiative tail in complete physics book.

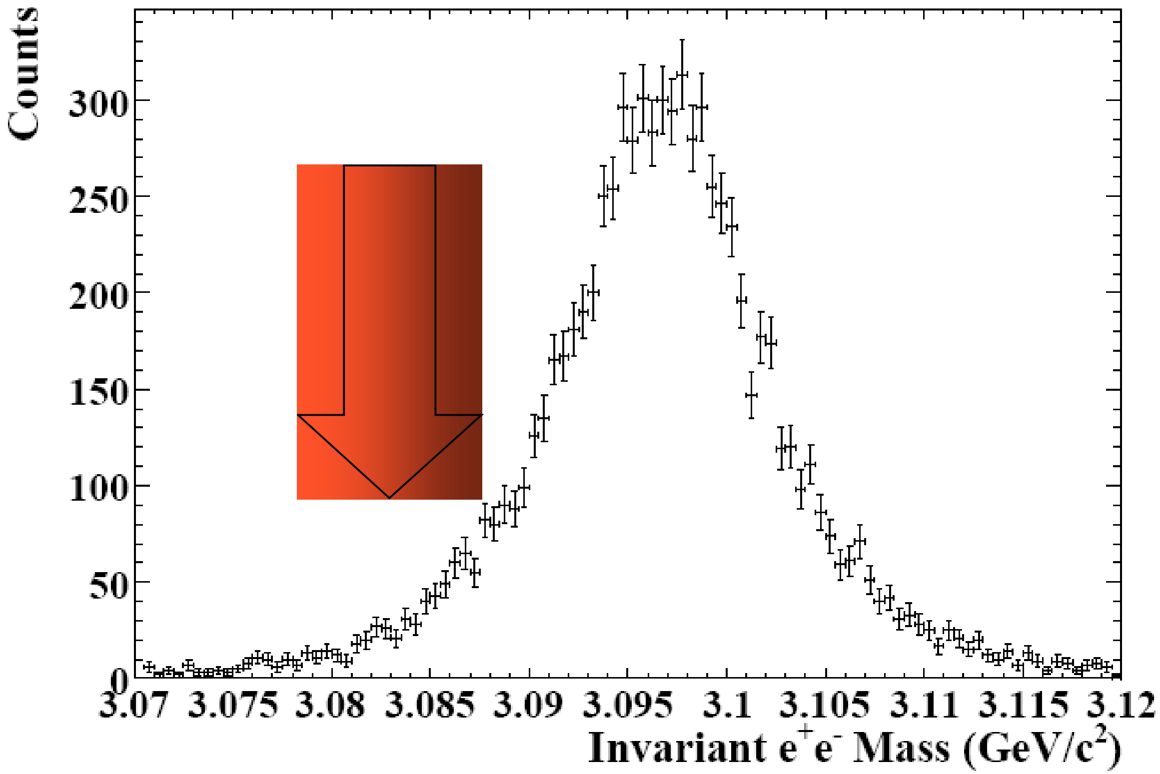
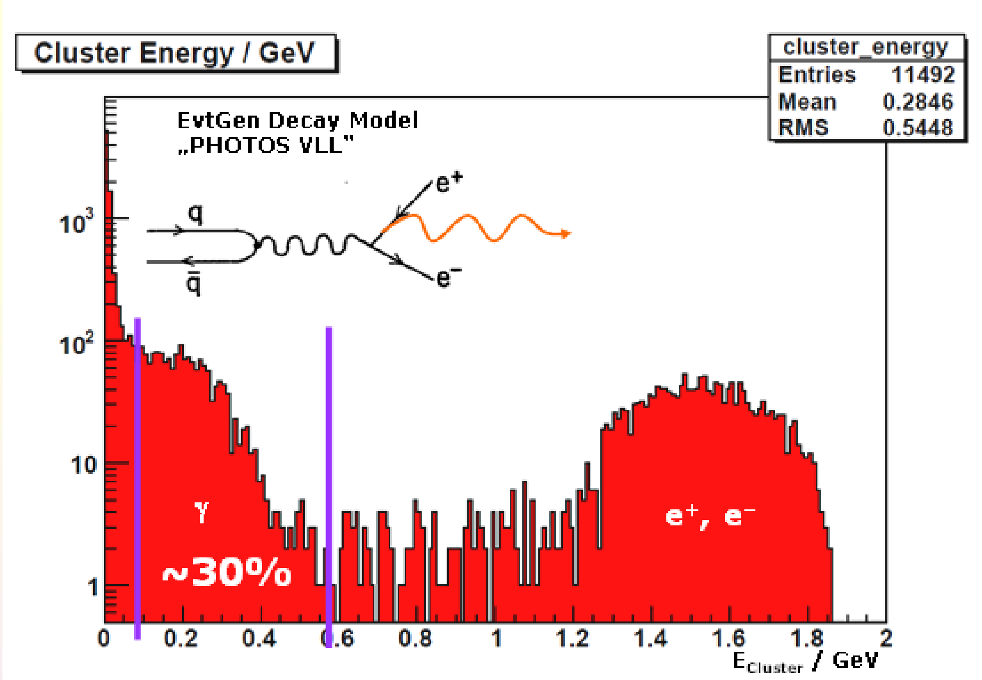


Figure 4.4: Invariant e^+e^- mass reconstructed at $\sqrt{s} = 4.260\,\mathrm{GeV}$.

- So, 30% additional photons. Visible in $E_{cluster}$

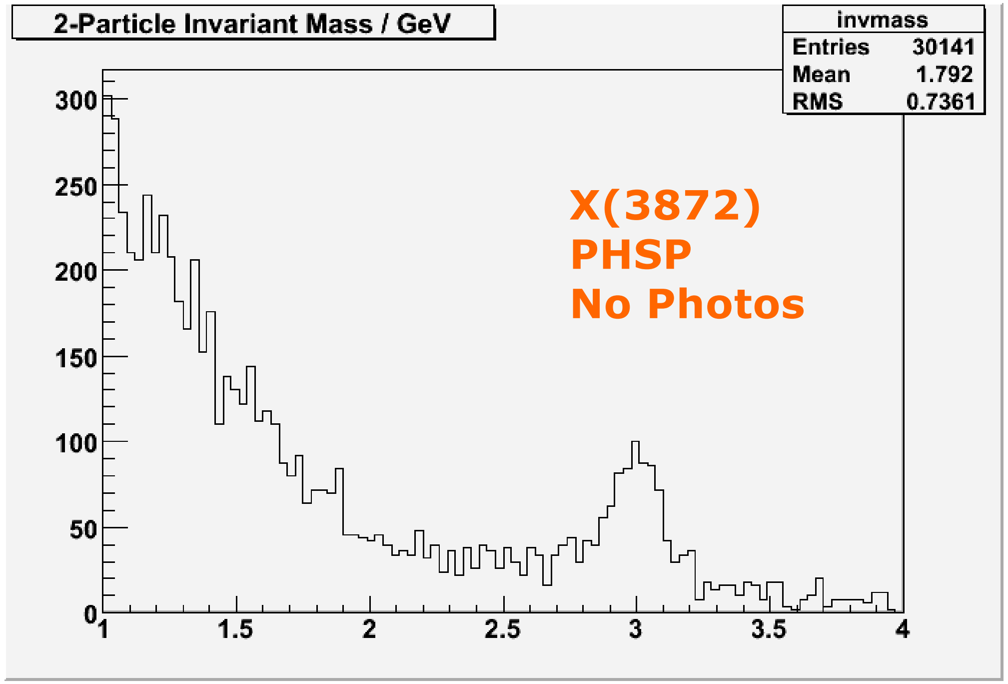


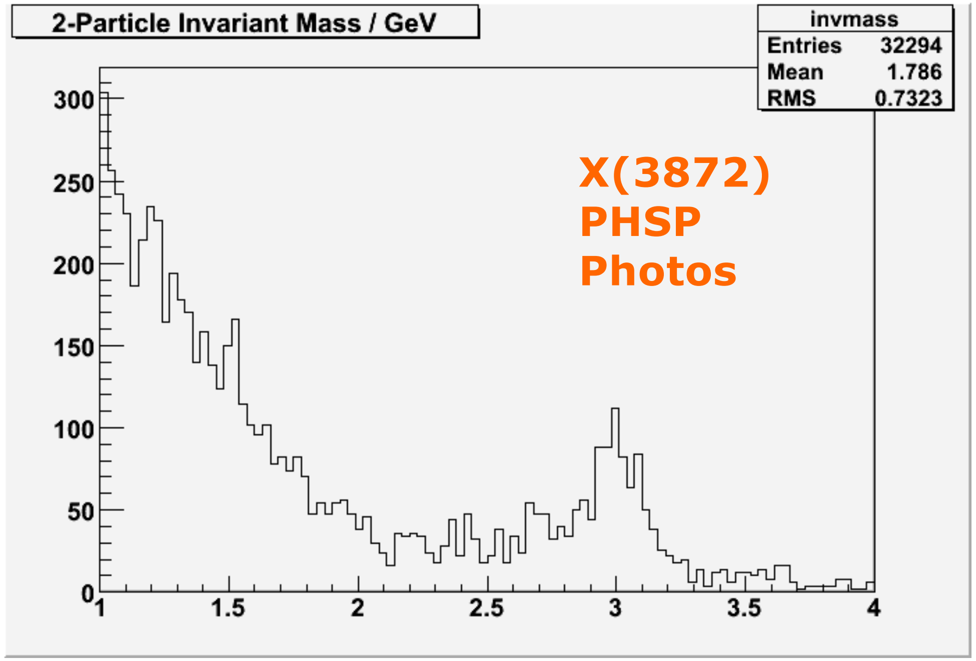
Talk Lange, Coll. June 2008, Krakow

- What is the effect on charged particles? by conversion $\gamma \rightarrow$ e+e− etc. (e.g. in the J/ψ peak?)

Effect of Radiation Corrections on charged particles

Example: X(3872) → J/ψ π+ π−, J/ψ → e+e−

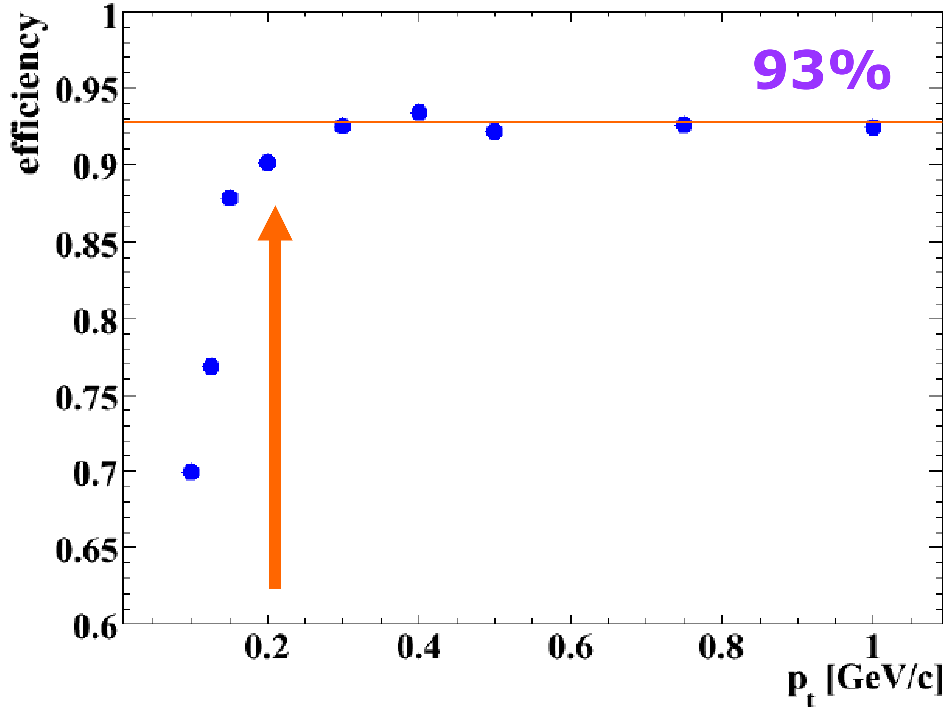




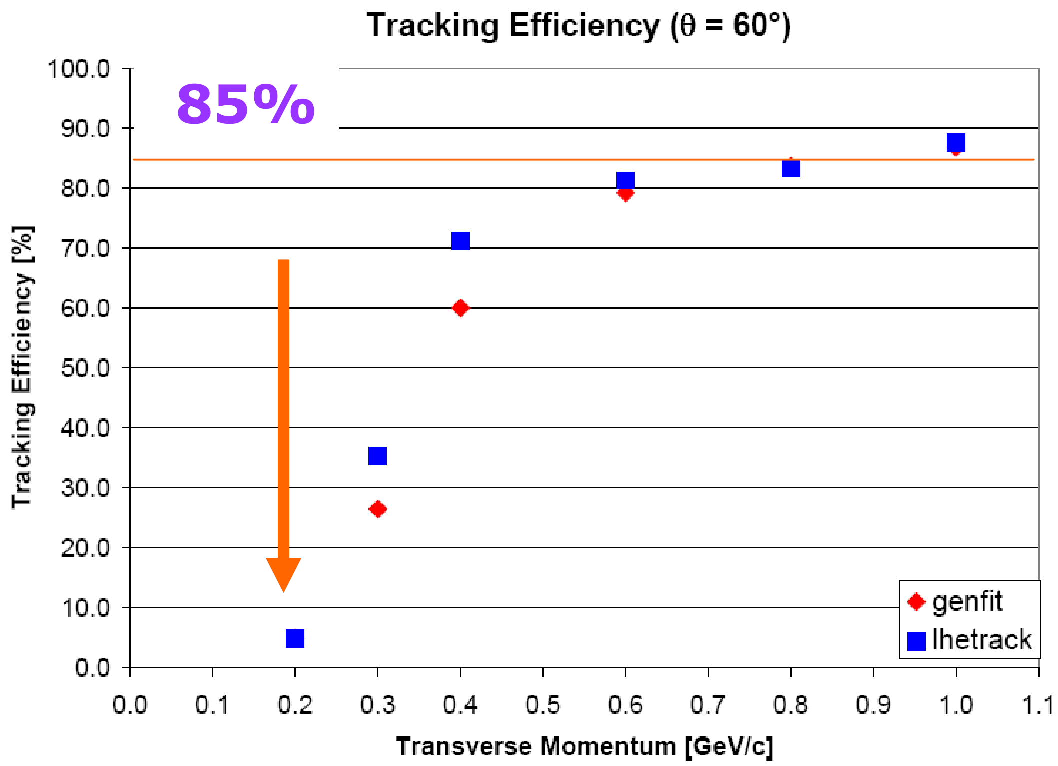
7.1% more e+e− pairs
4.6% less in J/Psi peak
2.8<mass(e+e−)<3.2 GeV

2. Track Finding Efficiency

Comparison of Physics Book (left) and PandaRoot (right)
Identical conditions (STT, ϑ=60°)



Physics Book Revision #726



PandaRoot, S. Spataro, this meeting

Why different $\varepsilon_{\text{track finder}}$?

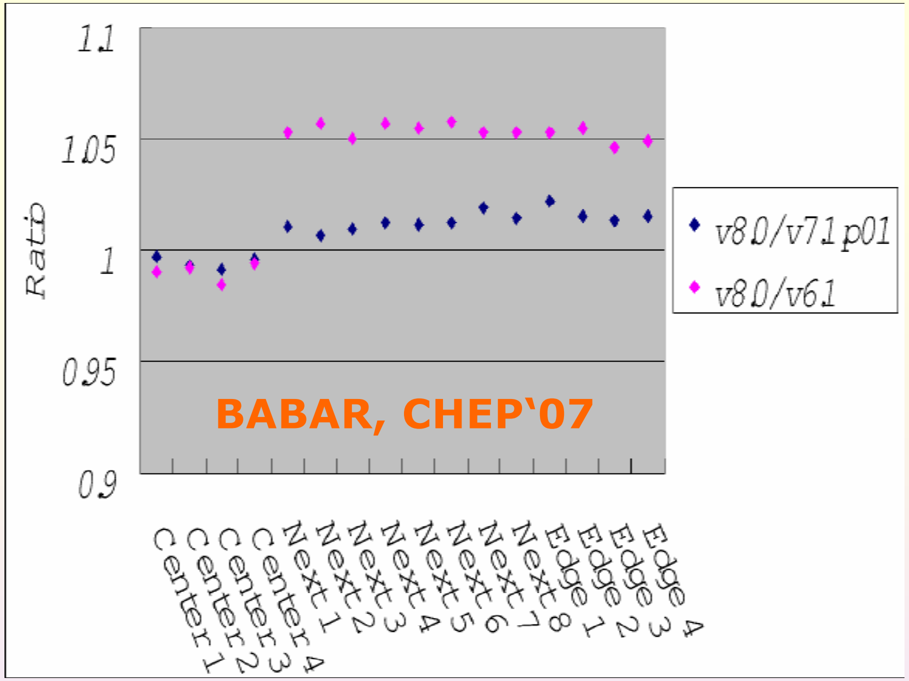
1. Track finding for physics book uses MC truth
   (i.e. it is a priori fixed,
   which hits belong to a track)
   PandaRoot has pattern recognition (here: conformal map)
2. Kalman Filter for physics book uses only
   simplified geometry model
   (in other words:
   for physics book all detector geometries
   are defined 2x)
3. PandaRoot uses field maps
   generated from TOSCA
   (although in solenoid region differences maybe negligible)

What does it mean for the Physics Book?

- Example: p pbar $\rightarrow$ D*+ D*− $\rightarrow$ K−π+ π − K+ π− π+
- 6 charged particles in final state
- All assuming maximum tracking efficiency
  (note: this is even too positive!
  slow pions from D* decays have low momentum!)
- For physics book
  $0.93^6 = 64.7\%$
- For PandaRoot
  $0.85^6 = 37.7\%$
- i.e.
  taking account a real track finder
  will reduce total reconstruction efficiency
  by ~70%

Other Issues: (a) Geant 4.7 vs. Geant 4.9

- Physics Book uses Geant 4.7
- PandaRoot uses Geant 4.9
- reported by BaBar on CHEP'07 that Geant 4.7 describes EMC shower shapes not correctly
- Multiple straggling had a major revision in Geant 4.8.
- There are ~5% differences in energy deposit per single cyrstal for 1 GeV photons
- This is maybe also the reason, why the leackage correction (9 free parameters)? seems to have problems in PandaRoot (EM shower is a priori different!)



$$
\begin{aligned}
f(lnE,\theta) = exp(a_0 + a_1\, lnE + a_2\, ln^2 E + a_3\, ln^3 E \\
+a_4 \cos(\theta) + a_5 \cos^2(\theta) + a_6 \cos^3(\theta) \\
+a_7 \cos^4(\theta) + a_8 \cos^5(\theta) \\
+a_9\, lnE \cos(\theta))
\end{aligned}
$$

Other issues:
(b) Effect of Angular Distributions for Systematic Errors

- Angular distribution differences seem not to be included into systematic error in physics book
- For estimate of size of effect:
  test example with PandaRoot
  3 different distributions
  - X(3872) by phasespace
    J/Psi by VLL (vector to lepton lepton)
  - X(3872) by vector->vector pi pi
    J/Psi by VLL
  - X(3872) into J/Psi rho
    1+ -> 1- 1- with L=1 (PARTWAVE decay model)
    rho -> pi pi with V->SS
    J/Psi by VLL

Other Issues, (b), Example from the Physics Book

Y(4260) → J/ψ π+ π−

In the simulation, the dipion invariant mass ($m_{\pi\pi}$) distribution was implemented according to the following parametrization [23]:

$$\frac{d\Gamma}{dm_{\pi\pi}} \propto PHSP \cdot \left(m_{\pi\pi}^2 - \lambda m_\pi^2\right)^2 \qquad (4.1)$$

where PHSP is the phase-space factor, m_π is the pion mass and λ is a parameter that can be obtained from the data; in this analysis we used $\lambda = 4.0$ [24]. This choice is motivated by measurements of $\psi(2S) \to J/\psi\pi^+\pi^-$, considering the fact that ψ' and $Y(4260)$ have the same quantum numbers.

$\sqrt{s}$ [GeV]	Eff [%]
3.526	27.52
3.686	30.90
3.872	32.07
4.260	32.58
4.600	30.60
5.000	29.70

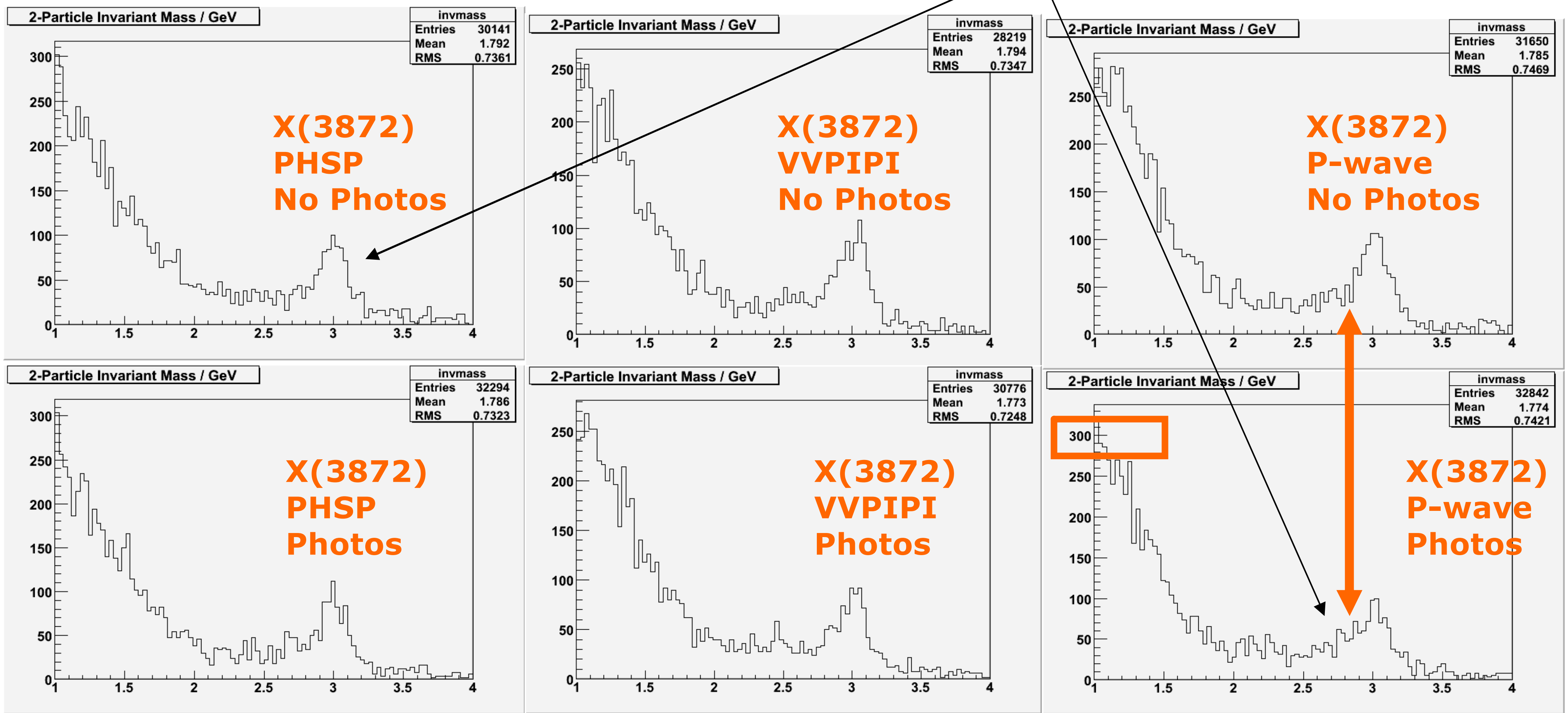
Table 4.2: Efficiencies and RMS of the reconstructed $J/\psi\pi^+\pi^-$ invariant mass distributions for each energy analyzed.

2 significant digits

Other Issues, (b), Test Example: X(3872) with PandaRoot

$X(3872) \rightarrow J/\psi\ \pi^+ \pi^-,\ J/\psi \rightarrow e^+ e^-$

Variation in J/Psi yield
2.8 < mass(e+e−) < 3.2 GeV
25.7%



Other Issues, (b), Test Example: X(3872) with PandaRoot

Decay Model	PHOTOS	number of e+e− pairs (full range, 0 < mass(e+e−) < 3.2 GeV)
PHSP	no	+6.8%
PHSP	yes	+14.4%
VVPIPI	no	normalization
VVPIPI	yes	+9.0%
PARTWAVE	no	+12.2%
PARTWAVE	yes	+16.4%

- Effect is quite large,
  larger than 2 significant digits in efficiency
- Note: **<u>only</u>** signal events generated and simulated
  these additional e+ e− pairs must be considered
  (eventually added to kinematic fit)

Other minor issues

- i.e. additional differences between physics book and PandaRoot
- B field maps from TOSCA
  in particular important in overlap region
- Cerenkov photon propagation in Geant
  (not parametrized)
  was not available for physics book
- new MDT geometry
- The 0+, 1+ states are not in the physics book
  e.g.
  the X(3872), molecule?
  the X(4140), hybrid ground state?
- ...

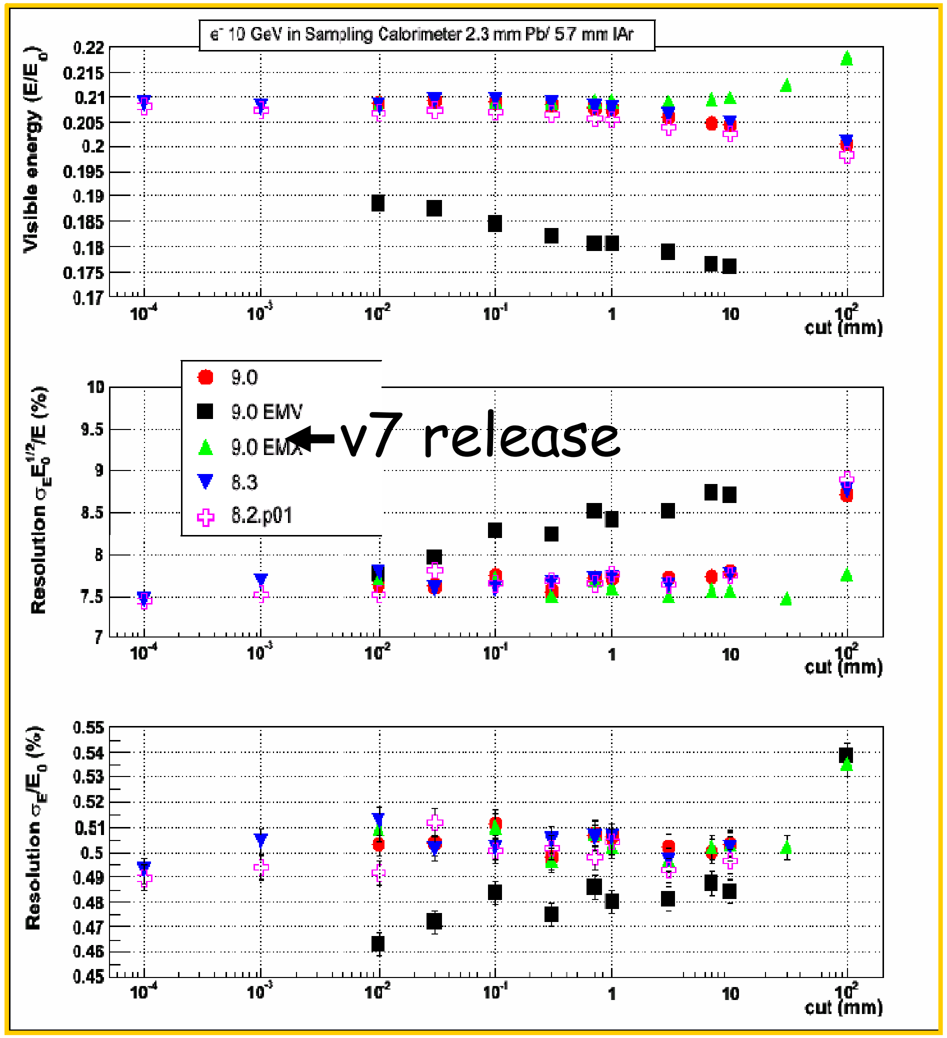
Summary

- a new physics book with PandaRoot seems to make sense.
- in short:
  how wrong do we calculate beamtime?
  (track finder efficiency, radiative corrections, etc.)
  Factor 2?
  Maybe more?
- Systematic errors may be larger than expected
  (at least one order of magnitude)
- Yet unconvered topics
  e.g. X(3872)

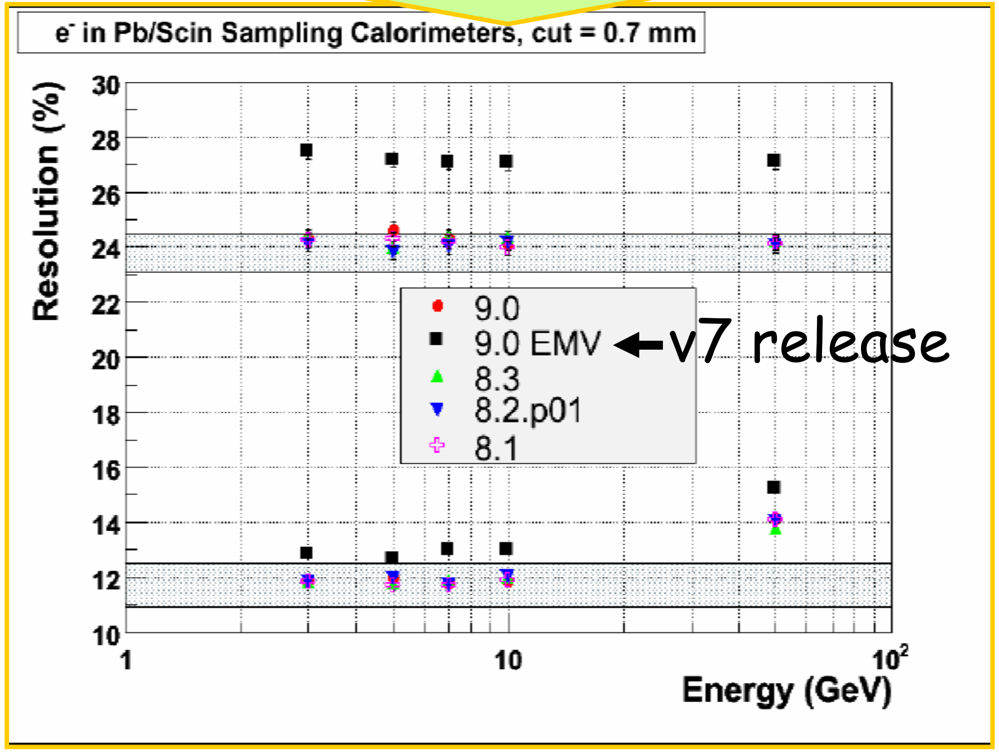
Backup Slides

Geant4 major upgrades

Since Geant4 v8 Multiple Scattering Models significantly upgraded



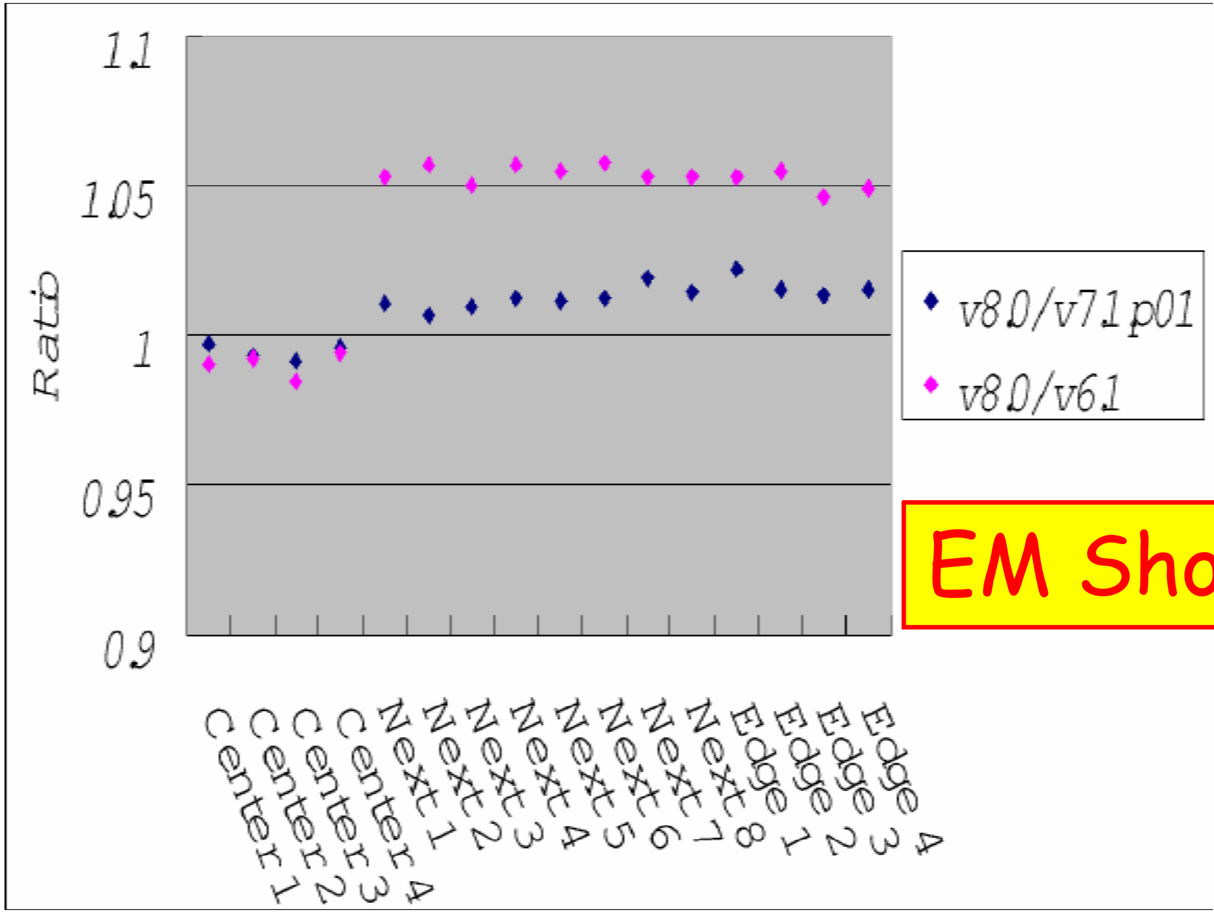
5 mm Pb/5 mm Scintillator
10 mm Pb/ 2.5 mm Scintillator



V. Ivanchenko (Geant4 team)

Geant4 major upgrades

Comparing average energy deposition with 1 GeV photon (normal incidence) of each CsI among **GEANT 4** versions



EM Shower Shape wider

S. Banerjee (BaBar)