Status of quarkonium MC

3rd BelleII Italian meeting

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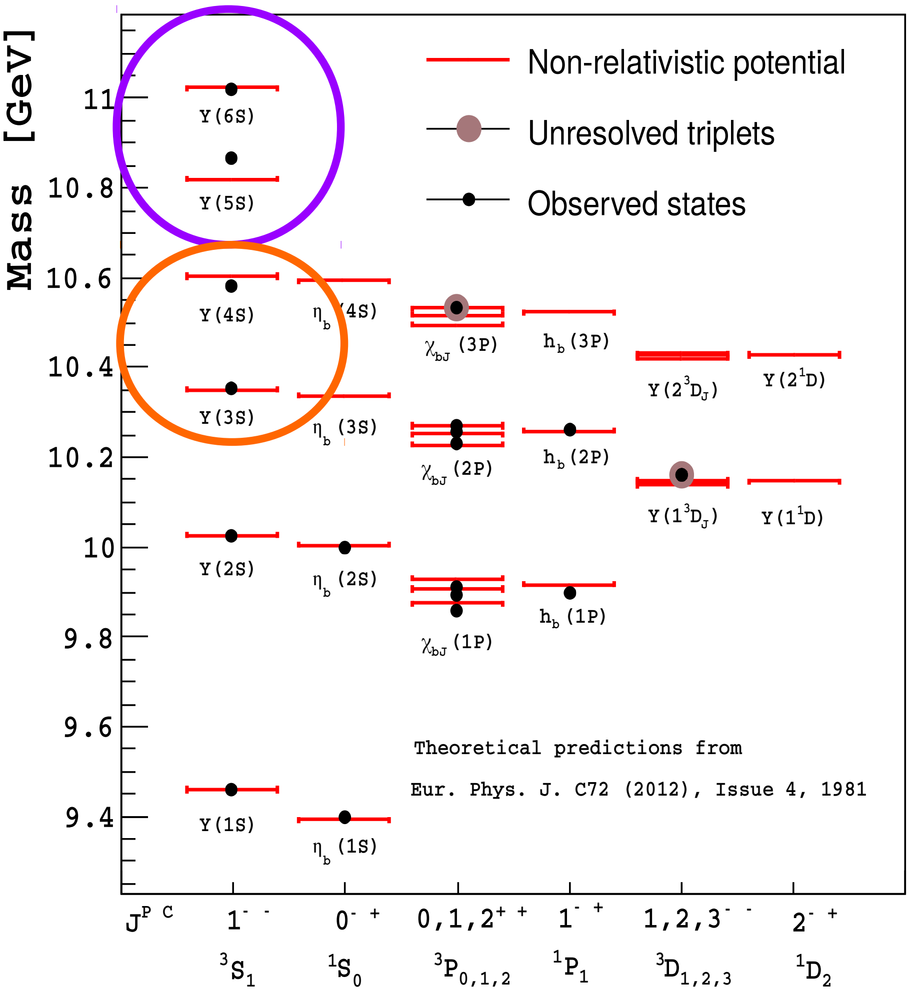
University of Torino

Status in November 2014

	New Analysis ?	Theoretical work needed?	EvtGen methods to be written?	Timescale	Priority	Contact person	Status
Fix DECAY.DEC	No	No	No	Short	HIGH	U. Tamponi	Ongoing
Pythia tune	Yes	No	No	Long	HIGH	U. Tamponi	Ongoing
ππ transitions Y(5S)	No	No	Yes	Medium	HIGH	R. Mizuk	?
Soft ISR	Sugg.	No	Maybe	Medium	**MEDIUM**	?	?
ππ transitions Y(4S)	Yes	No (?)	No (?)	Medium - Long	LOW (?)	?	?
ππ transitions among Y(nS)	Sugg.	No	**Maybe**	Medium	LOW	?	?
Y(nS) → γ ηb	Yes	Yes	Yes	Long	LOW	?	?

Overview



Y(5,6S)

Study of spin singlet states via $\pi\pi/\eta$ tag.

Exotic bottomonium-like states

Y(5,6S) structure

Y(3,4S)

Transitions among χ_b families

Study of spin singlet states via η tag.

Dipion transitions

What should we do for an optimal usage of EvtGen at Belle II?

→ **Errors in Decay.dec**

→ **Angular distributions for hadronic/ radiative transitions**

→ **Soft ISR effects**

→ **Y(nS) Hadronization mechanism in MC**

Bottomonium EvtGen validation group:
Bryan Fulsom,
Todd Pedlar,
U.T.

Errors in DECAY.dec

Can we use EvtGen as it comes?

```
Decay  Upsilon

0.024800000 e+ e-                                PHOTOS  VLL;
0.024800000 mu+ mu-                              PHOTOS  VLL;
0.026000000 tau+ tau-                            VLL;

0.014959973 d anti-d                             PYTHIA 32;
0.044879919 u anti-u                             PYTHIA 32;
0.014959973 s anti-s                             PYTHIA 32;
0.044879919 c anti-c                             PYTHIA 32;

0.774328202 g g g                                PYTHIA 4;
0.028922614 gamma g g                            PYTHIA 4;

0.000063000 gamma pi+ pi-                        PHSP;
0.000017000 gamma pi0 pi0                        PHSP;
0.000011400 gamma K+  K-                         PHSP;
0.000290000 gamma pi+ pi- K+ K-                  PHSP;
0.000250000 gamma pi+ pi+ pi- pi-                PHSP;
0.000250000 gamma pi+ pi+ pi+ pi- pi- pi-        PHSP;
0.000240000 gamma pi+ pi+ pi- pi- K+ K-          PHSP;
0.000150000 gamma pi+ pi- p+  anti-p-            PHSP;
0.000040000 gamma pi+ pi+ pi- pi- p+ anti-p-     PHSP;
0.000020000 gamma K+ K+ K-      K-               PHSP;
0.000037000 gamma f'_2                           PHSP;
0.000101000 gamma f_2                            PHSP;

Enddecay
```

Wrong charge ratios

$Y(1S) \rightarrow \gamma^* \rightarrow q\bar{q}$
Should scale with e_q^2
(i.e. ratios should be 1/ 4 instead of 1/3)

Double counting

With a correct hadronization all those modes should arise from the Inclusive $Y(1S) \rightarrow \gamma\, gg$ mode.
Remove them?

Errors in DECAY.dec

```
Decay  Upsilon(3S)
0.0181         e+ e-                  PHOTOS  VLL;
0.021800000    mu+ mu-                PHOTOS  VLL;

0.022900000 tau+    tau-              VLL;

0.044000000 Upsilon pi+ pi-           PHSP;
0.022000000 Upsilon pi0 pi0           PHSP;
0.024500000 Upsilon(2S) pi+ pi-       PHSP;
0.018500000 Upsilon(2S) pi0 pi0       PHSP;

0.059000000 gamma   chi_b0(2P)        HELAMP 1. 0. 1. 0.;
0.126000000 gamma   chi_b1(2P)        HELAMP 1. 0. 1. 0. -1. 0. -1.
0.131000000 gamma   chi_b2(2P)        HELAMP 2.4494897 0.
                                             1.7320508 0.
                                             1. 0.
                                             1. 0.
                                             1.7320508 0.
                                             2.4494897 0.;

0.050000000 Upsilon(2S) gamma gamma   PHSP;

0.00700 d anti-d                      PYTHIA 32;
0.02800 u anti-u                      PYTHIA 32;
0.00700 s anti-s                      PYTHIA 32;
0.02800 c anti-c                      PYTHIA 32;
0.37780 g g g                         PYTHIA 4;
0.01000 gamma  g g                    PYTHIA 4;
0.003000000 gamma   chi_b0            PHSP;
0.000510000 gamma   eta_b             PHSP;
Enddecay
```

Why different?

Definitively not Phase-space

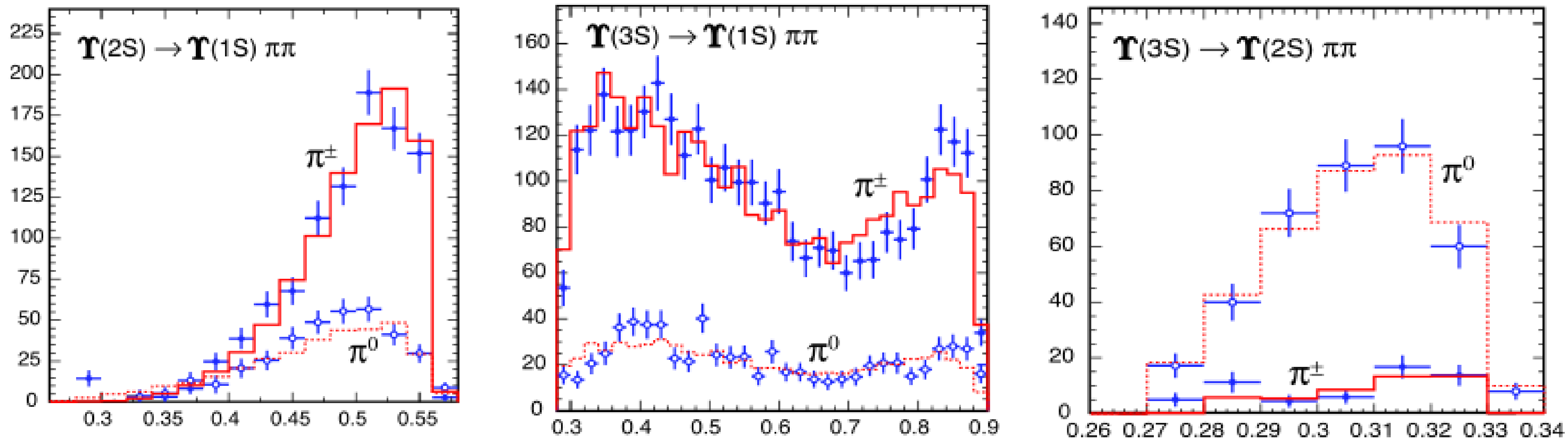
Should be saturated by χ_{bJ}(2P) cascades

Definitively not Phase-space

Missing $\chi_{b1,2}$(1P) transitions

Υ(3S) → ππ Υ(nS) transitions

Phys.Rev.D76:072001 (2007)

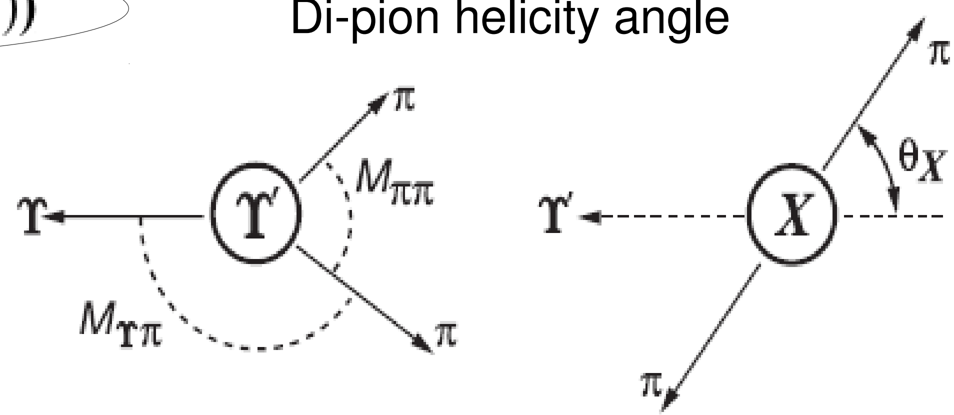


Matrix element:

$$\mathcal{M} = \mathcal{A}(\epsilon' \cdot \epsilon)(q^2 - 2M_\pi^2) + \mathcal{B}(\epsilon' \cdot \epsilon)E_1 E_2$$
$$+ \mathcal{C}((\epsilon' \cdot q_1)(\epsilon \cdot q_2) + (\epsilon' \cdot q_2)(\epsilon \cdot q_1))$$

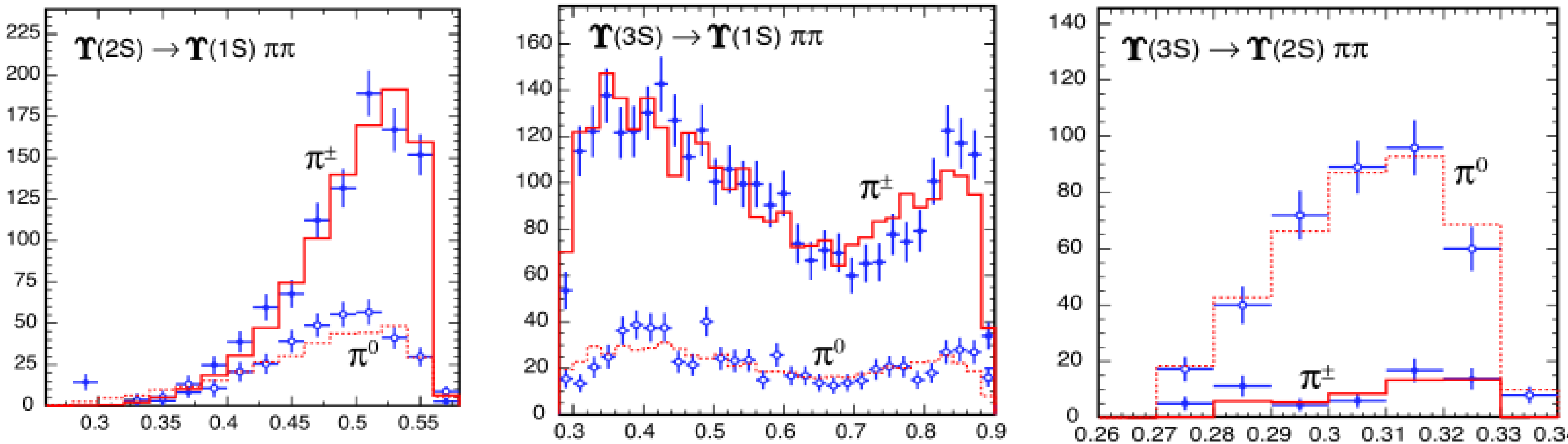
Chromomagnetic term:
Expected to be suppressed
by heavy quark spin symmetry

Dalitz plot observables:
Di-pion invariant mass
Di-pion helicity angle



Y(3S) → ππ Y(nS) transitions

Phys.Rev.D76:072001 (2007)



Fit, no $\mathcal{C}$, total error		
$\Upsilon(3S) \to \Upsilon(1S)\pi\pi$	$\Re(\mathcal{B}/\mathcal{A})$	-2.52 ± 0.04
	$\Im(\mathcal{B}/\mathcal{A})$	$\pm 1.19 \pm 0.06$
	$\lvert\mathcal{B}/\mathcal{A}\rvert$	2.79 ± 0.05
	δ_{BA}	$155(205) \pm 2$
$\Upsilon(2S) \to \Upsilon(1S)\pi\pi$	$\Re(\mathcal{B}/\mathcal{A})$	-0.75 ± 0.15
	$\Im(\mathcal{B}/\mathcal{A})$	0.00 ± 0.11
	$\lvert\mathcal{B}/\mathcal{A}\rvert$	0.75 ± 0.15
	δ_{BA}	180 ± 9
$\Upsilon(3S) \to \Upsilon(2S)\pi\pi$	$\Re(\mathcal{B}/\mathcal{A})$	-0.40 ± 0.32
	$\Im(\mathcal{B}/\mathcal{A})$	0.00 ± 1.1
Fit, float $\mathcal{C}$, total error		
$\Upsilon(3S) \to \Upsilon(1S)\pi\pi$	$\lvert\mathcal{B}/\mathcal{A}\rvert$	2.89 ± 0.25
	$\lvert\mathcal{C}/\mathcal{A}\rvert$	0.45 ± 0.40

Ok

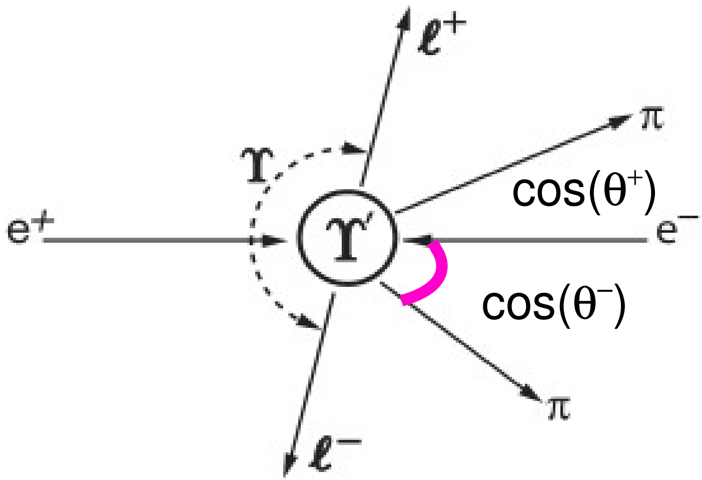
Ok

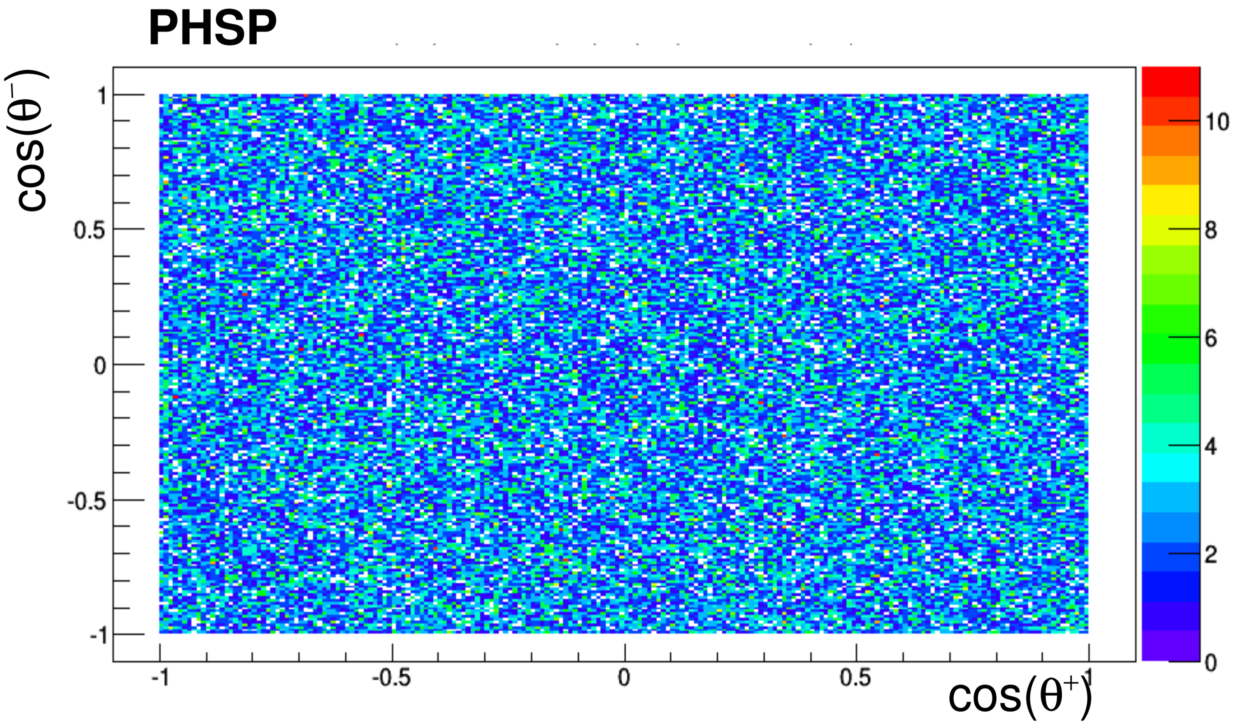
Large errors!

Chormomagnetic contribution compatible with 0

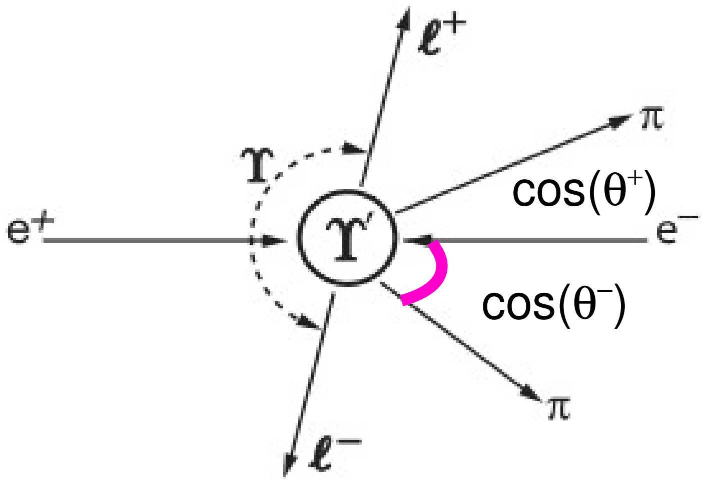
Implemented in the EvtGen model **EvtYmSToYnSpipiCLEO**

Υ(3S) → ππ Υ(2S): angular distributions

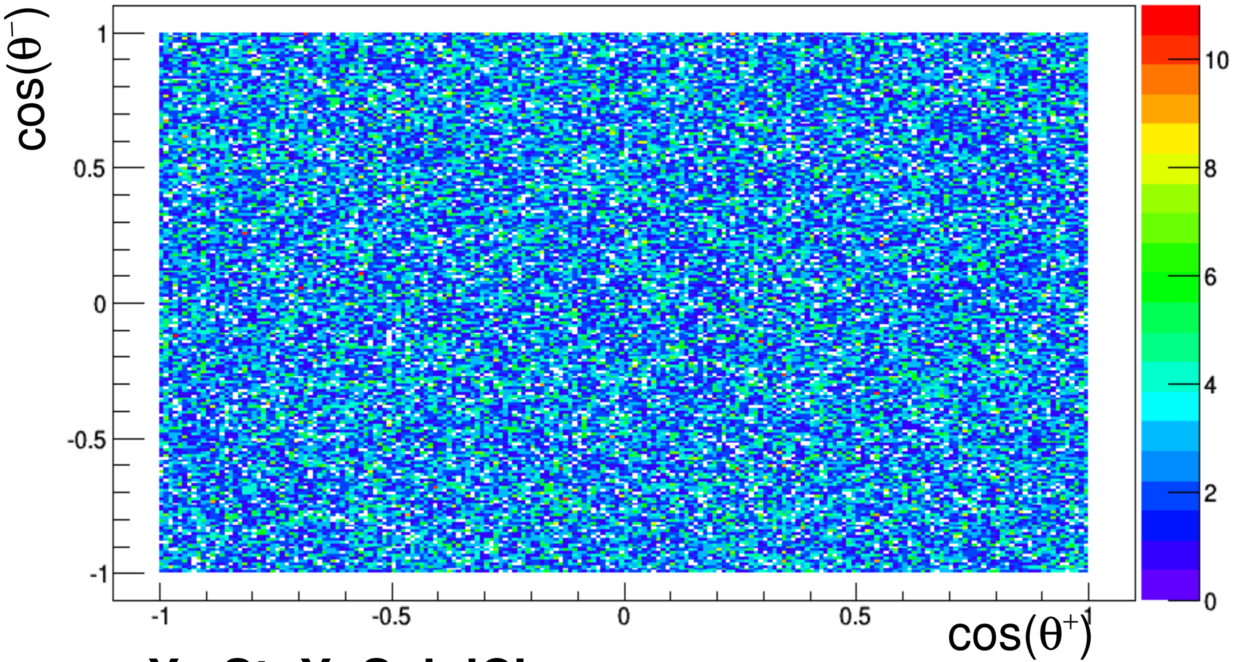


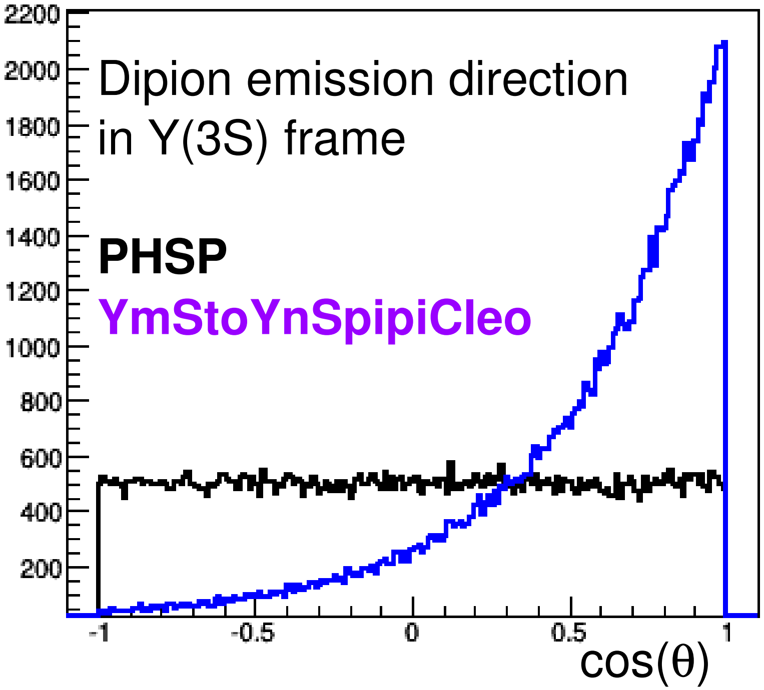


Υ(3S) → ππ Υ(2S): angular distributions

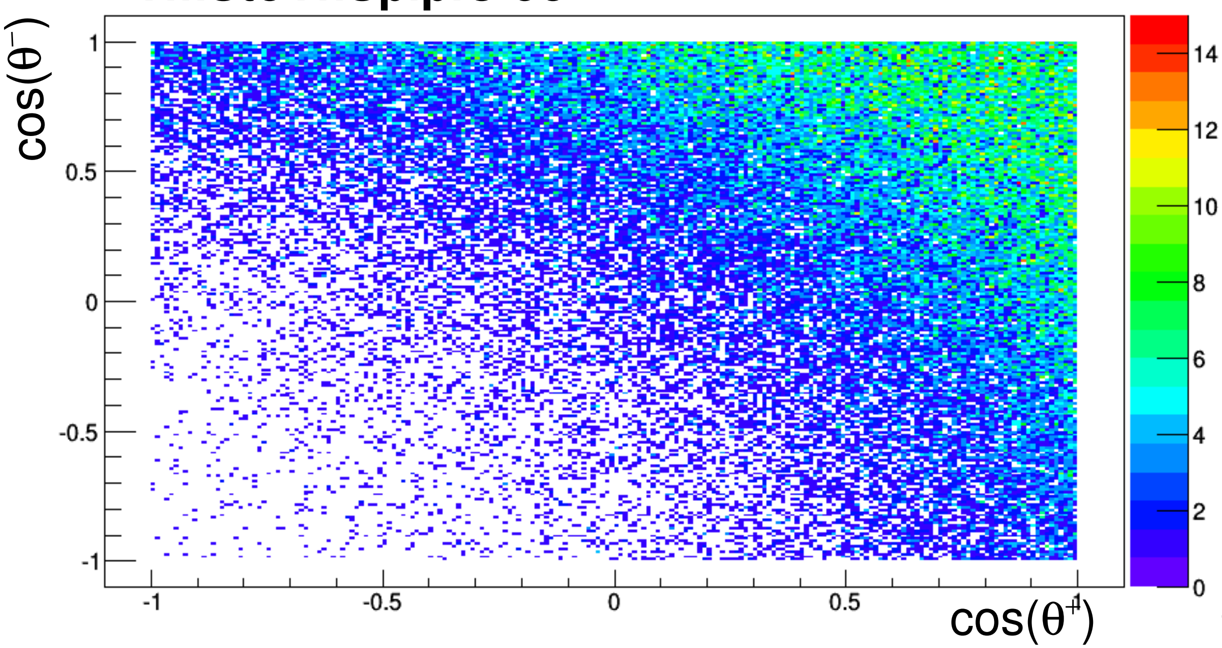


PHSP





YmStoYnSpipiCleo



Y(3S) → ππ Y(nS): debugging

Great effort by Bryan for debugging **YmStoYnSpipiCleo**

Original

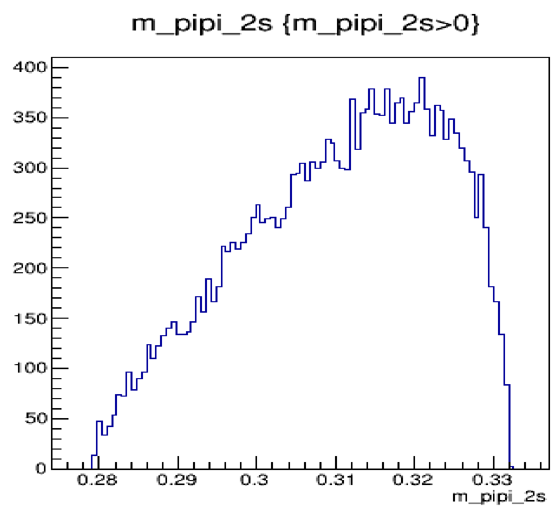
EvtVector4R P_YmS_X = boostTo(p->getP4(), P_X);

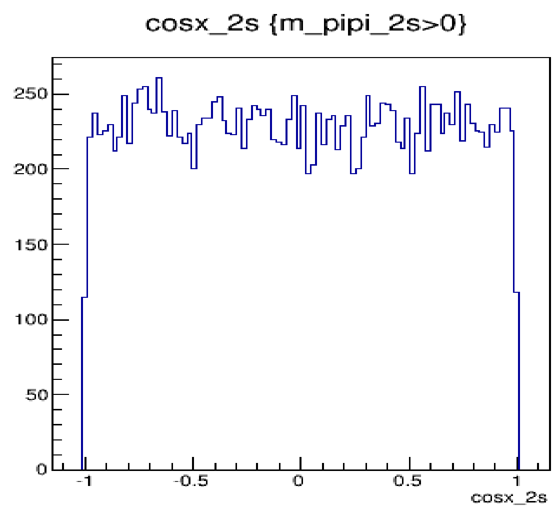
The dipion in boosted
In the **LAB frame**

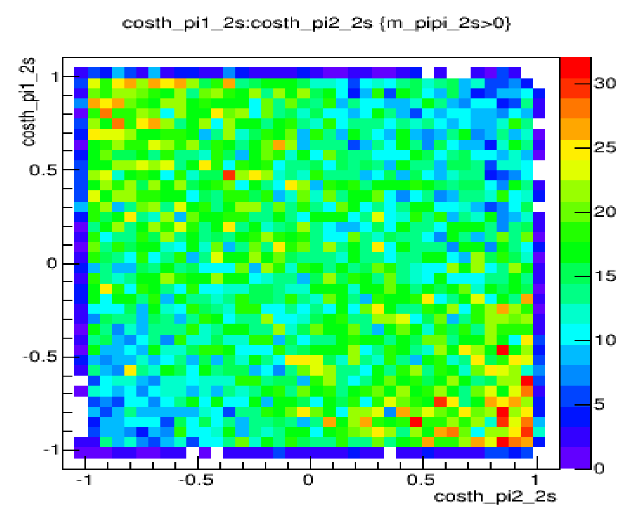
Correct

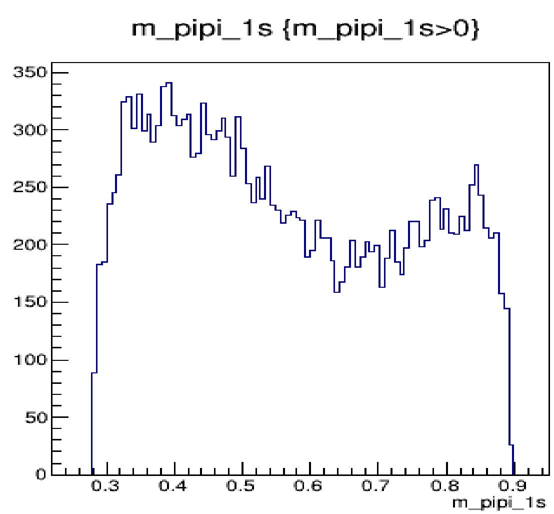
EvtVector4R P_YmS_X = boostTo(p->getP4Restframe(), P_X);

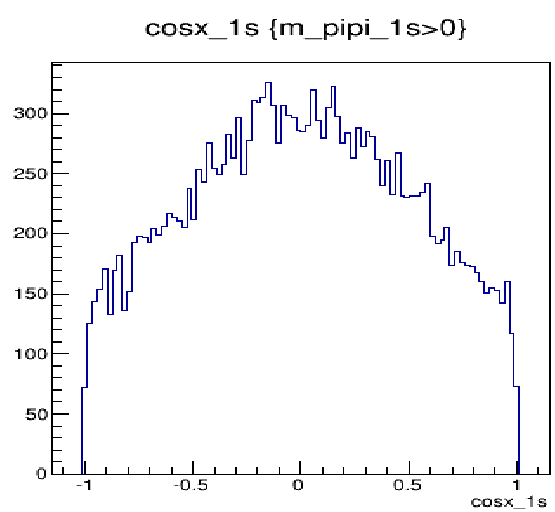
The dipion in boosted
in the **Y(3S) frame**

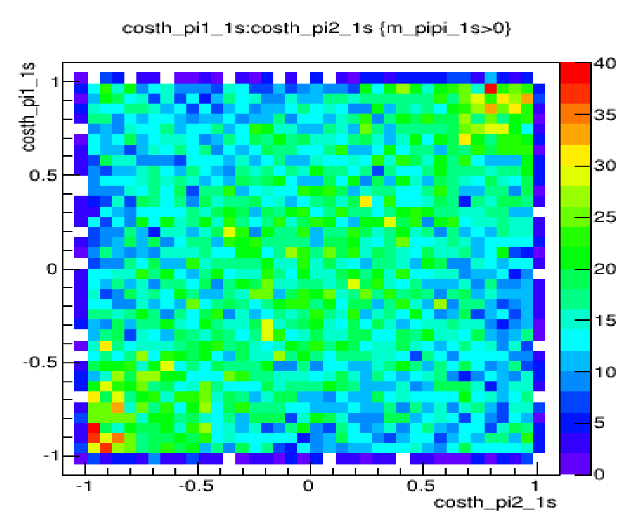






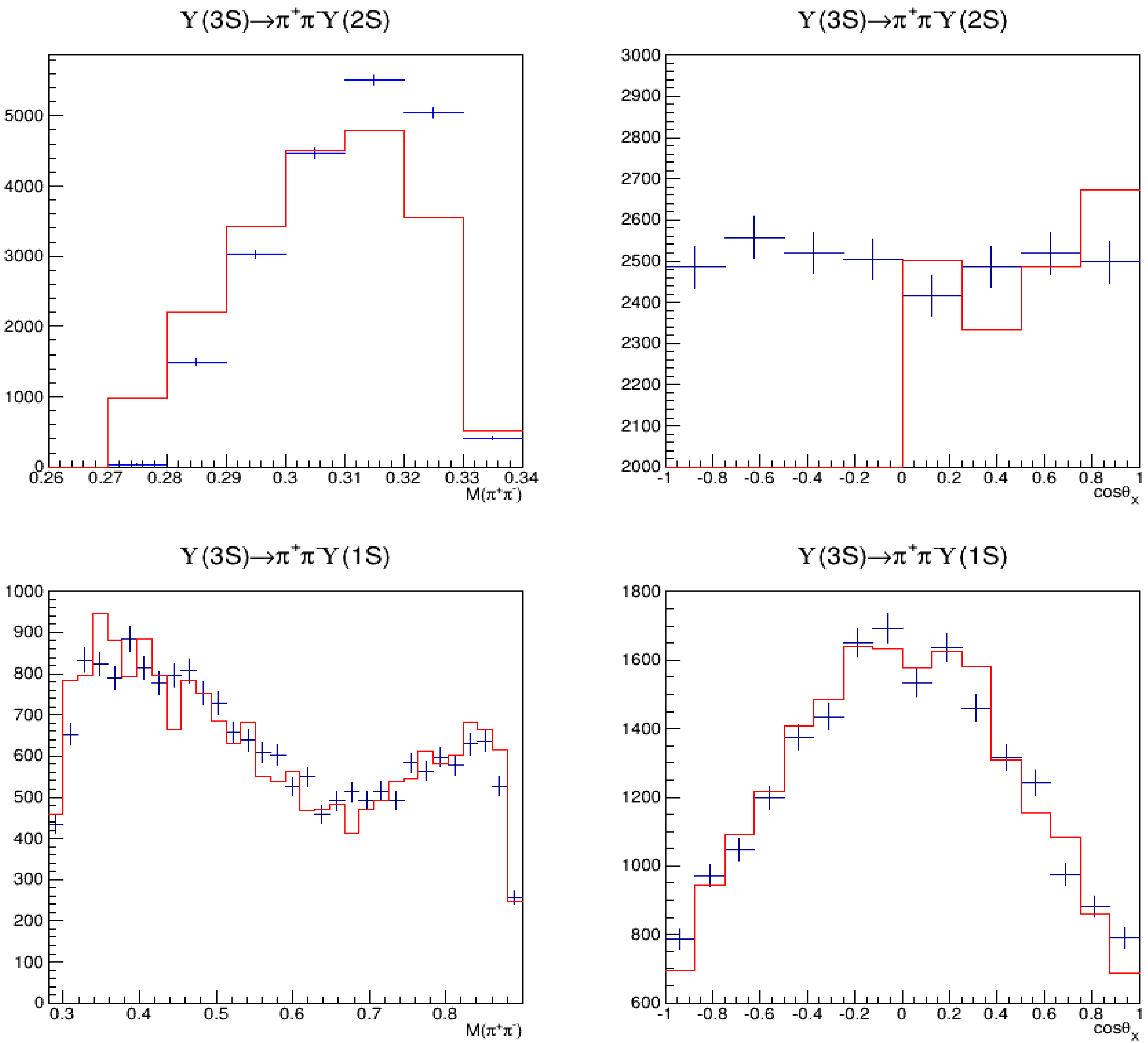






Υ(3S) → ππ Υ(nS): validation

Great effort by Bryan for debugging **YmStoYnSpipiCleo**



Cleo Data

BelleII MC

For CLEO we use the **neutral pion data** (larger statistics) with NO resolution deconvolution

Other transitions

Many (not so) rare transitions are modeled using PHSP:

$h_b(nP) \rightarrow \gamma\, \eta_b(mS)$

$1^{+-} \rightarrow 1^{--}\, 0^{-+}$

Pure S-wave

Official model:
PHSP

Correct model:
HELAMP 1.0 0.0 1.0 0.0

$Y(nS) \rightarrow \gamma\, \eta_b(mS)$

$1^{--} \rightarrow 1^{--}\, 0^{-+}$

Pure P-wave

Official model:
PHSP

Correct model:
HELAMP 1.0 0.0 -1.0 0.0

$Y(nS) \rightarrow \pi^0/\eta\; Y(mS)$

$1^{--} \rightarrow 0^{-+}\, 1^{--}$

Dominant P-wave

Official model:
PHSP

Correct model:
PARTWAVE 0. 0. 1. 0. 0. 0.

$Y(nS) \rightarrow \pi^0/\eta\;\; h_b(mP)$

$1^{--} \rightarrow 0^{-+}\, 1^{+-}$

Dominnt S-wave

Official model:
PHSP

Correct model:
PARTWAVE 1. 0. 0. 0. 0. 0.

Other transitions

Many (not so) rare transitions are modeled using PHSP:

$h_b(nP) \to \gamma\, \eta_b(mS)$

$1^{+-} \to 1^{--}\ 0^{-+}$

Pure S-wave

Official model:
PHSP

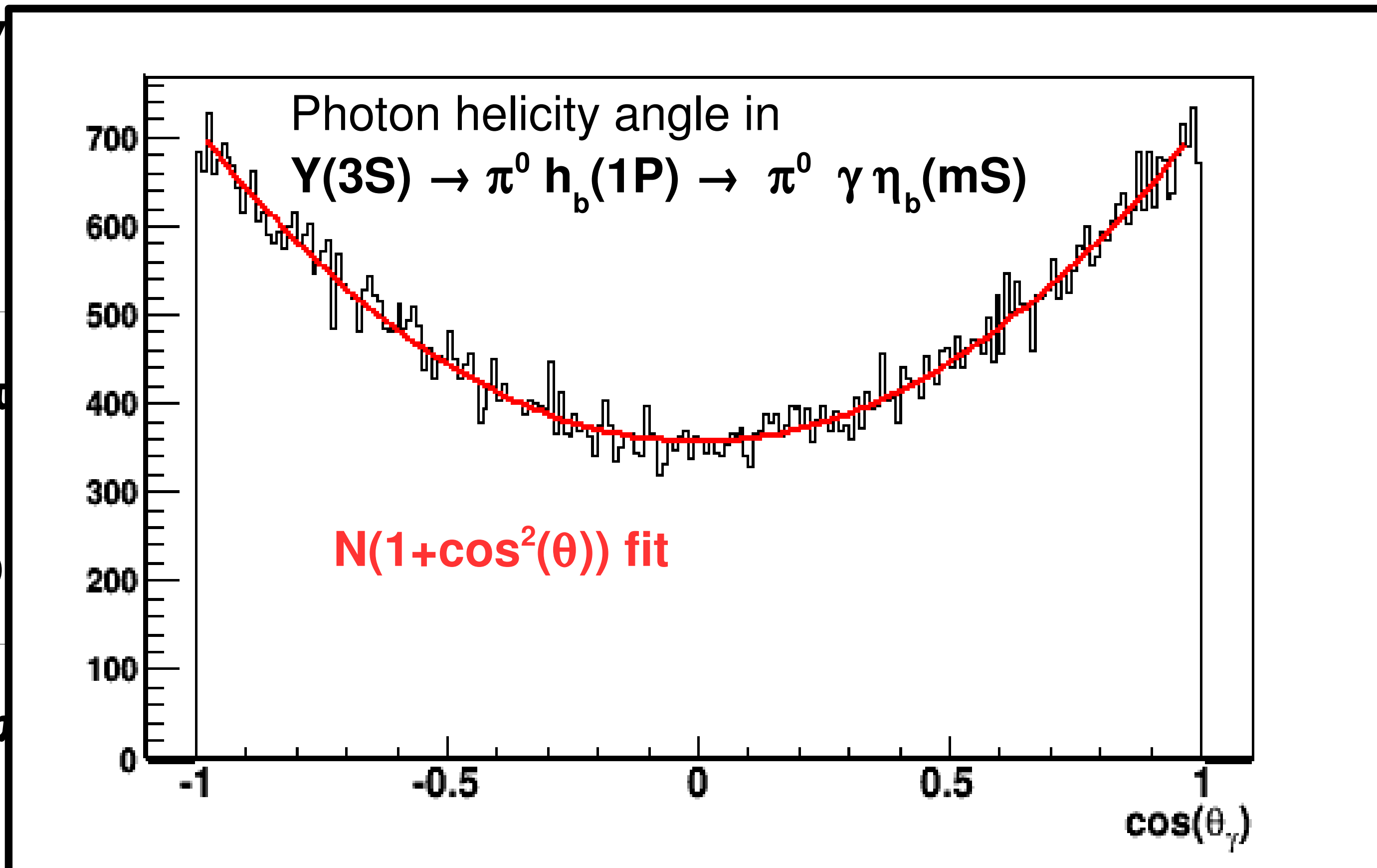
Correct model:
HELAMP 1.0 0.0 1.0 0.0

$\Upsilon(nS) \to \gamma$

1^{-}

P

.0 -1.0 0.0



$\Upsilon(nS) \to \pi$

1^{-}

D

. 0. 1. 0. 0. 0.

$\Upsilon(nS) \to$

1^{-}

Dominnt S-wave

PHSP

PARTWAVE 1. 0. 0. 0. 0. 0.

χ_{bJ}(nP) annihilations

Decay chi_b0

Partons

….

0.949650000 rndmflav anti-rndmflav PYTHIA 12;

….

Enddecay

"A random **u, d, or s** flavour; possible decay product"

"Matrix element code"
Reweighting of the matrix element in order to modulate the PHSP distribution

Charm has been proved to be produced by bottomonium annihilations
Phys.Rev. D78 (2008) 092007

χ_{bJ}(nP) annihilations

Decay chi_b0
....
0.949650000 rndmflav anti-rndmflav PYTHIA 12;
....
Enddecay

Partons

"A random **u, d, or s** flavour; possible decay product"

"Matrix element code"
Reweighting of the matrix element in order to modulate the PHSP distribution

Charm has been proved to be produced by bottomonium annihilations
Phys.Rev. D78 (2008) 092007

χ_{b0}(nP)

$J^{PC} = 0^{++}$
Dominant: $\chi_{b0}(nP) \rightarrow g\,g$

Official model:
rndmflav anti-rndmflav PYTHIA 12

Correct model:
g g PYTHIA 32

χ_{b2}(nP)

$J^{PC} = 2^{++}$
Dominant: $\chi_{b2}(nP) \rightarrow g\,g$

Official model:
g g PYTHIA 32

Correct model:
g g PYTHIA 32

χ_{b1}(nP)

$J^{PC} = 1^{++}$
Dominant: $\chi_{b1}(nP) \rightarrow \mathbf{q\bar{q}g}$

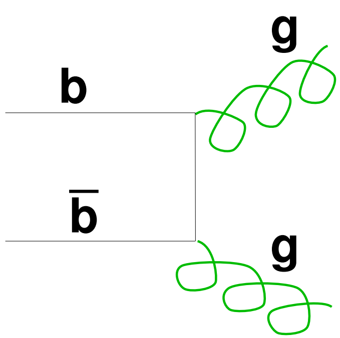
Official model:
g g PYTHIA 32

Correct model:
?

The $\chi_{b1}(nP)$ case

Official DECAY.DEC

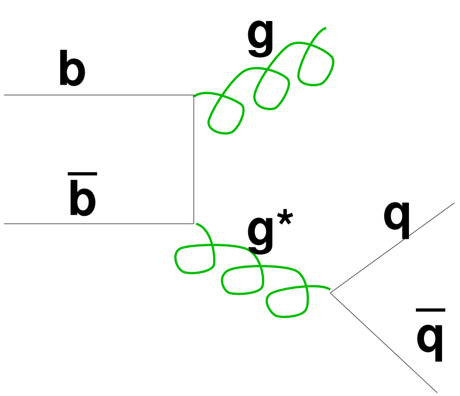
Decay chi_b1
. . .
0.643080000 g g PYTHIA 32;
. . .
Enddecay



Impossible.
Violates Yang-Landau theorem

Correct Physics

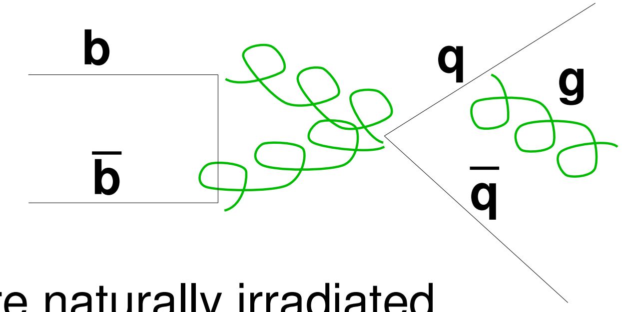
0.16275 d anti-d g PYTHIA (?);
0.16275 u anti-u g PYTHIA (?);
0.16275 s anti-s g PYTHIA (?);
0.16275 c anti-c g PYTHIA (?);



Not implementable in Pythia.
Missing matrix element for q q g final state

Possible Workaround

0.16275 d anti-d PYTHIA 32;
0.16275 u anti-u PYTHIA 32;
0.16275 s anti-s PYTHIA 32;
0.16275 c anti-c PYTHIA 32;



Gluons are naturally irradiated during the fragmentation process

Correct final state
Recovers charm production rate

Soft gluon only
Continuum-like event

Charmonium radiative transitions

Charmonium transitions a are also mainly modeled using PHSP:

$\psi(2S) \rightarrow \gamma\, \chi_{cJ}(1P)$

$1^{--} \rightarrow 1^{--}\ 0,1,2^{++}$

Official model:
PHSP

Better model: same as $Y(2S) \rightarrow \gamma\, \chi_{bJ}(1P)$

J = 0: HELAMP 1. 0.+1. 0.;
J = 1: HELAMP 1. 0. 1. 0. -1. 0. -1. 0.;
J = 2: HELAMP 2.4494897 0.
1.7320508 0.
1. 0.
1. 0.
1.7320508 0.
2.4494897 0.;

Actually, a small M2 contribution is known to be present in these transitions

For a discussion of the $\chi_{c1,2}(1P)$ angular distribution, see, for example:
M. Ambrogiani et al.
Phys. Rev. D 65, 052002 (2002)

$\chi_{cJ}(1P) \rightarrow \gamma\, J/\psi$

$0,1,2^{++} \rightarrow 1^{--}\ 1^{--}$

Official model for J=0,2:
PHSP

Official model for J=1:
VVG (vector-to-vector-gamma)

Correct model:
As in bottomonium

To be tested?

Higher order multipoles

Actually, a small M2 contribution is known to be present in these transitions (also E3 is possible!)

For a discussion of the $\chi_{c1,2}(1P)$ angular distribution, see:
Phys. Rev. D 65, 052002 (2002)
Phys. Rev. D 80, 112003 (2009)

E1 | M2 | E3

J=1
$$\begin{pmatrix} A_0 = \frac{1}{\sqrt{2}}a_1 - \frac{1}{\sqrt{2}}a_2 \\ A_1 = \frac{1}{\sqrt{2}}a_1 + \frac{1}{\sqrt{2}}a_2 \end{pmatrix}_{J=1}$$

J=2
$$\begin{pmatrix} A_0 = \sqrt{\frac{1}{10}}a_1 + \sqrt{\frac{1}{2}}a_2 + \sqrt{\frac{6}{15}}a_3 \\ A_1 = \sqrt{\frac{3}{10}}a_1 + \sqrt{\frac{1}{6}}a_2 - \sqrt{\frac{8}{15}}a_3 \\ A_2 = \sqrt{\frac{6}{10}}a_1 - \sqrt{\frac{1}{3}}a_2 + \sqrt{\frac{1}{15}}a_3 \end{pmatrix}_{J=2}$$

$\chi_{cJ}(1P) \rightarrow \gamma J/\psi$

	E1 only		E1 + M2	
	χ_{c1}	χ_{c2}	χ_{c1}	χ_{c2}
A0	0.7071	0.3162	**0.7443**	**0.2540**
A1	0.7071	0.5477	**0.6679**	**0.4924**
A2	none	0.7745		**0.8328**

$\psi(2S) \rightarrow \gamma \chi_{cJ}(1P)$

	E1 only		E1 + M2	
	χ_{c1}	χ_{c2}	χ_{c1}	χ_{c2}
A0	0.7071	0.3162	**0.6863**	**0.3336**
A1	0.7071	0.5477	**0.7273**	**0.5543**
A2	none	0.7745		**0.7625**

Other issues with EvtGen

All the Hyperon decays are modeled using PHSP

Decay Lambda0
0.638719992 p+ pi- PHSP; #[Reconstructed PDG2011]
0.357719992 n0 pi0 PHSP; #[Reconstructed PDG2011]

Decay Xi-
0.998870000 Lambda0 pi- PHSP; #[Reconstructed PDG2011]

Decay Xi0
0.995242400 Lambda0 pi0 PHSP; #[Reconstructed PDG2011]
0.001162400 Lambda0 gamma PHSP;

Large P-violating effects neglected!

Baryon angular distribution

Asymmetry parameter

Polarization vector

$$\frac{dN}{d\Omega} = \frac{N}{4\pi}\left(1 + \alpha_\gamma\, \mathbf{P}_i \cdot \hat{\mathbf{p}}\right)$$

Spin quantization axis

EvtGen model:
EvtHyNonLepton

Tests so far:
→ With unpolarized Lambda reproduces the PHSP results
→ Model to produce polarized Lambda to be written

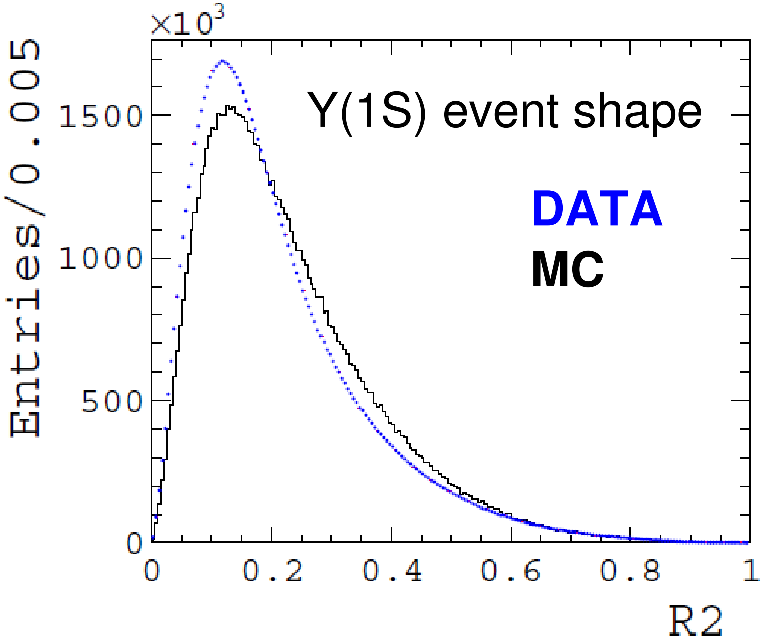
Pythia fragmentation tuning

Fragmentation is dominant in the simulation of bottomonium annihilation

→ Pythia (6 or 8) is not really meant to deal with low energy processes

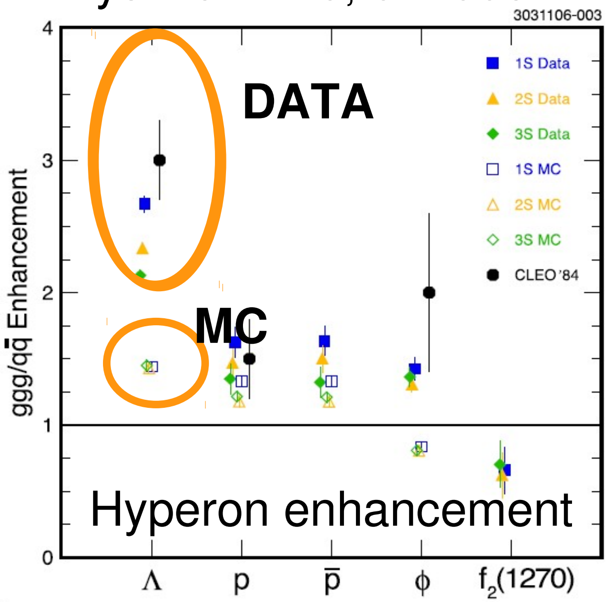
→ **Major source of systematic uncertainties**

- → 3-5% for the mismodelling of the event shape
- → 3-5% for the mismodelling of the low multiplicity events not passing the hadronic selection



→ **Also interesting for physics!**

Phys.Rev.D76, 012005

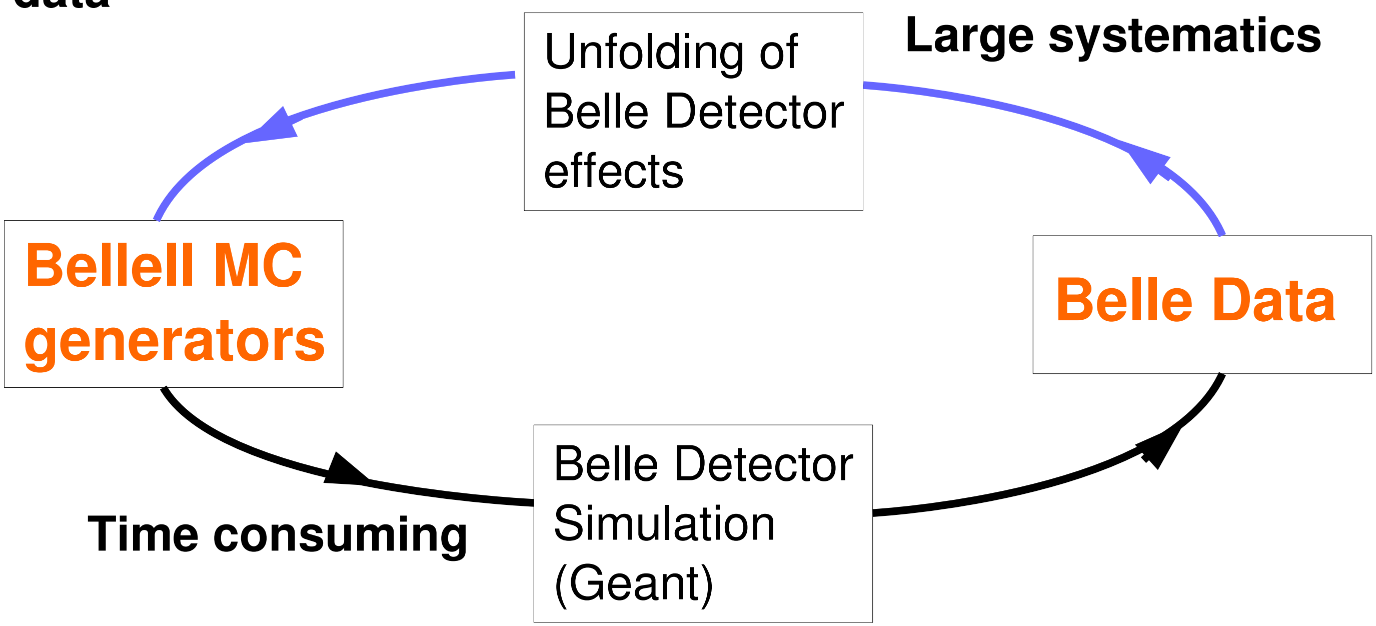


Deuteron production: Phys. Rev. D 89, 111102 (2014)

Process	
$\mathcal{B}(\Upsilon(3S) \to \bar{d}X)$	$(2.33 \pm 0.15^{+0.31}_{-0.28}) \times 10^{-5}$
$\mathcal{B}(\Upsilon(2S) \to \bar{d}X)$	$(2.64 \pm 0.11^{+0.26}_{-0.21}) \times 10^{-5}$
$\mathcal{B}(\Upsilon(1S) \to \bar{d}X)$	$(2.81 \pm 0.49^{+0.20}_{-0.24}) \times 10^{-5}$
$\sigma(e^+e^- \to \bar{d}X)$ $[\sqrt{s} \approx 10.58\,\mathrm{GeV}]$	$(9.63 \pm 0.41^{+1.17}_{-1.01})$ fb
$\dfrac{\sigma(e^+e^- \to \bar{d}X)}{\sigma(e^+e^- \to \mathrm{Hadrons})}$	$(3.01 \pm 0.13^{+0.37}_{-0.31}) \times 10^{-6}$

Tuning overview

How to tune the fragmentation process?
→ **use Belle data**



Which Datasets?
→ Y(1S) for ggg events
→ Y(4S)-30 MeV continuum for $q\bar{q}$

Do we need different sets of tunes?
→ Yes (No?)

Do we need two different approaches?
→ **NO**

Goal:
Prepare a software tool tha can be used on **any dataset from Belle** to extract the optimal puthia tunig

Pythia8 tuning task force
Hulya Atmacan,
Torben Ferber,
Ami Rostomyan,
U.T.

Pythia tuning: Belle VS BelleII

Belle used Pythia 6 with custom tunings

JetSetPar PARJ(21)=0.28	Default 0.36
JetSetPar PARJ(25)=0.27	Default 1
JetSetPar PARJ(26)=0.12	Default 0.4
JetSetPar PARJ(33)=0.3	Default 0.8
JetSetPar PARJ(35)=1.0	Default = PARJ(33)
JetSetPar PARJ(41)=0.32	Default 0.3
JetSetPar PARJ(42)=0.62	Default 0.58
JetSetPar PARJ(82)=0.38	Default 0.29
JetSetPar PARJ(82)=0.76	Default 1

JetSetPar PARP(2)=4.0	Default 10
JetSetPar MSTP(141)=1	Default 0
JetSetPar MSTP(171)=1	Default 0
JetSetPar MSTJ(104)=4	Default 5

Continuum $q\bar{q}$ was generated using the evtgen model PYCONT

```
Decay vpho
         # d u s c b t   e   mu  tau
1.0 PYCONT 0 0 0 1 0 0   0 0 0 0 0 0;
Enddecay
```

Pythia tuning: Belle VS BelleII

Belle used Pythia 6 with cu

JetSetPar PARJ(21)=0.28
JetSetPar PARJ(25)=0.27
JetSetPar PARJ(26)=0.12
JetSetPar PARJ(33)=0.3
JetSetPar PARJ(35)=1.0
JetSetPar PARJ(41)=0.32
JetSetPar PARJ(42)=0.62
JetSetPar PARJ(82)=0.38
JetSetPar PARJ(82)=0.76

JetSetPar PARP(2)=4.0
JetSetPar MSTP(141)=1
JetSetPar MSTP(171)=1
JetSetPar MSTJ(104)=4

BelleII uses Pythia 8
→ **First challenge is to translate the Belle tunings from Pythia 6 to Pythia 8**

Current Proposal (by Hulya Atmacan)**:**
PythiaBothParam StringFlav:etaSup=0.27
PythiaBothParam StringFlav:etaPrimeSup=0.12
PythiaBothParam StringFragmentation:stopMass=1.1
PythiaBothParam StringZ:aLund=0.32
PythiaBothParam StringZ:bLund=0.62
PythiaBothParam StringZ:usePetersonC=off
PythiaBothParam StringZ:usePetersonB=off
PythiaBothParam StringZ:usePetersonH=off
PythiaBothParam StringZ:rFactC=1.0
PythiaBothParam StringPT:sigma = 0.4
PythiaBothParam TimeShower:pTmin = 0.38

Continuum $q\bar{q}$ was generat

```
Decay vpho

      # d u s c b t   e

1.0 PYCONT 0 0 0 1 0 0   0 0

Enddecay
```

Continuum can be generated now using KKMC + Pythia8
→ better treatment of ISR/FSR
→ more accurate description of the initial partonic state
Great effort by Ami Rostomyan and Torben Ferber

Tuning and validation observables

Guidelines

→ General obervables (easy to compute)
→ Solid physical meaning
→ Independent
→ Sensitive to different tuning parameters
→ $\sqrt{s}$-independent (or almost independent)

Energy spectra
→ **$E^*/\sqrt{s}$** for photons and charged
→ **$\Sigma(E^*)/\sqrt{s}$** for photons and charged

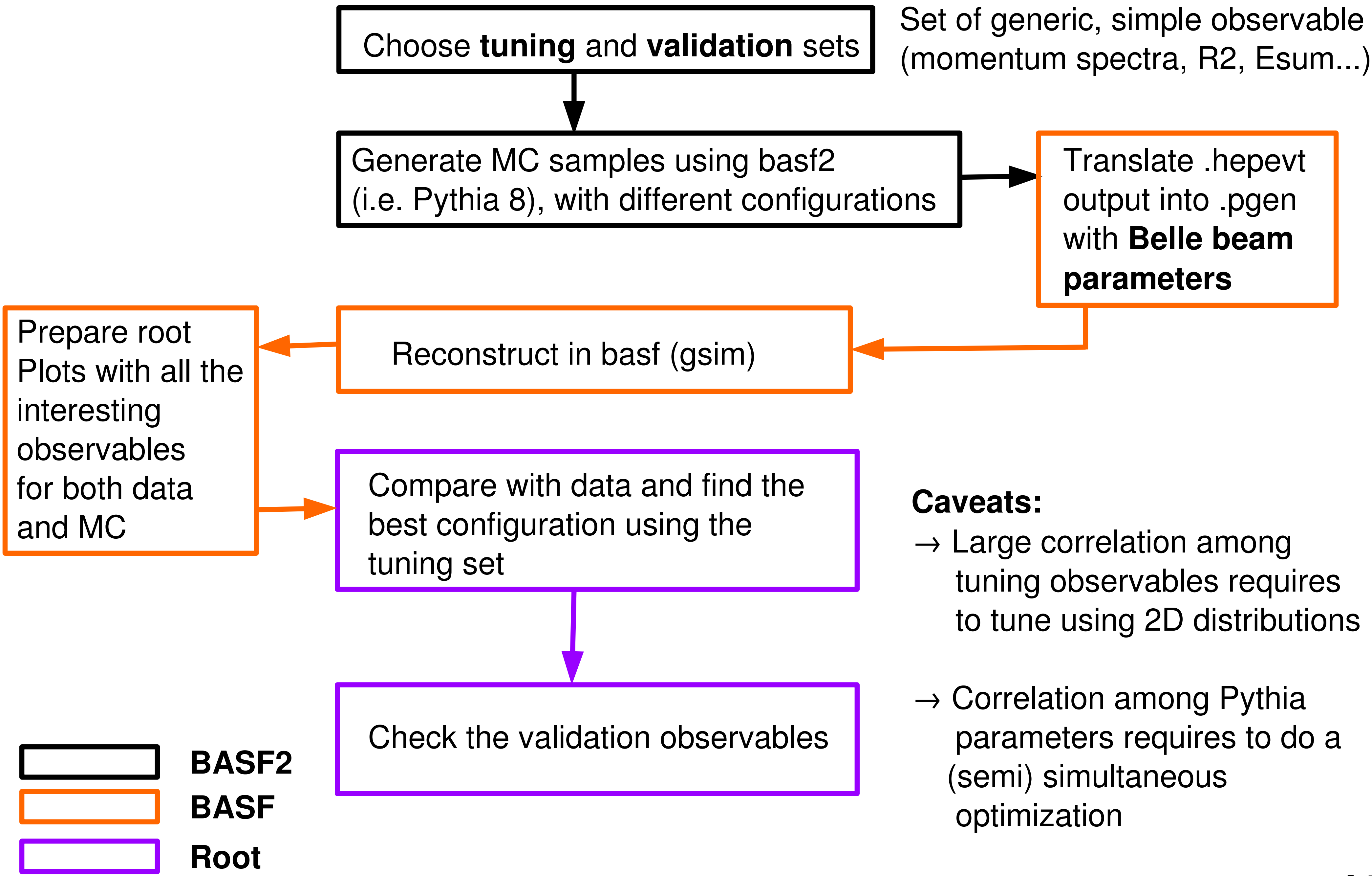
Multiplicities
→ photon multiplicity (full and reduced acceptance)
→ charged multiplicity

Event shape
→ R2 fox wolfram moment

Single particle spectra
→ D^0, η, π, K, γ

Correlations are crucial!
→ 2D comparisons are mandatory

Workflow proposal



Caveats:

→ Large correlation among tuning observables requires to tune using 2D distributions

→ Correlation among Pythia parameters requires to do a (semi) simultaneous optimization

Status in May 2015

	New Analysis ?	Theoretical work needed?	EvtGen methods to be written?	Timescale	Priority	Contacts	Status
Fix DECAY.DEC	No	No	No	Short	HIGH	B. Fulsom T. Pedlar U. Tamponi	**Done (?)**
Pythia tune	Yes	No	No	Long	HIGH	H. Atmacan T. Ferber A. Rostomyan U. Tamponi	Ongoing
ππ transitions Υ(5S)	No	No	Yes	Medium	HIGH	R. Mizuk	
Soft ISR	Sugg.	No	Maybe	Medium	**MED**	U. Tamponi	Ongoing
ππ transitions Υ(4S)	Yes	No (?)	No (?)	Medium - Long	LOW	?	?
ππ transitions among Υ(nS)	Sugg.	No	**Maybe**	Medium	HIGH	B. Fulsom T. Pedlar U. Tamponi	**Done**
Υ(nS) → γ ηb	Yes	Yes	Yes	Long	LOW	?	?

Conclusions

Pythia8 tuning

→ **The Belle tuning was succesfully translated into Pythia8**
→ **BelleII generators output has been succesfully reconstructed using the Belle Detector simulation**
→ **Minimization strategy has to be choosen:**
  → Brute force scan
  → Recoursive scan
  → Functional parameterization (PROFESSOR: https://professor.hepforge.org/)

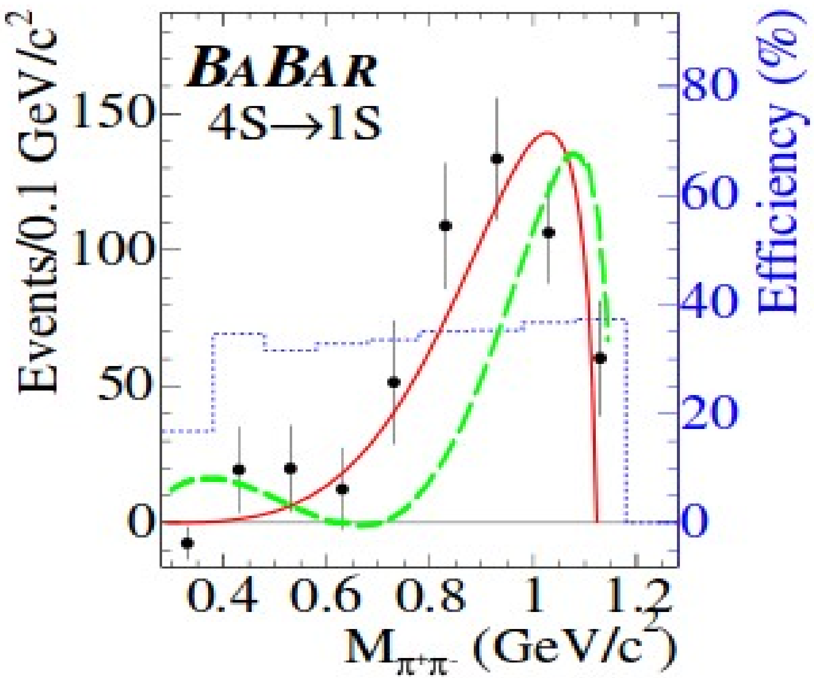
EvtGen validation

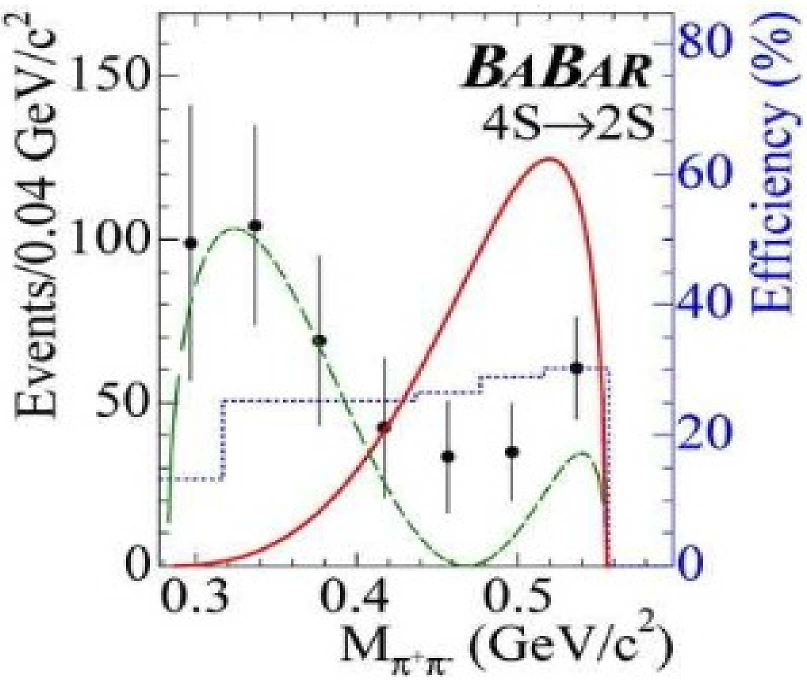
→ **DECAY.dec for bottomonium has been updated**
  → bug in the $\pi\pi$ transition model has been discovered and fixed.
  → χ_{b1}(nP) hadronization is still puzzle
  → Final test is ongoing
→ **First look into charmonium: χ_{cJ}(1P) transitions fixed**
→ **Mismodellings in the hyperon sector**
  → How to test EvtHypNonLepton?

Backup

Dipion transitions from Y(4S)

Babar study: Phys. Rev. Lett.96 (2006) 23200





Solid fit: Phys. Rev. D24, 2874(1981)

Dashed fit: Phys. Rev. D79 (2009)03402

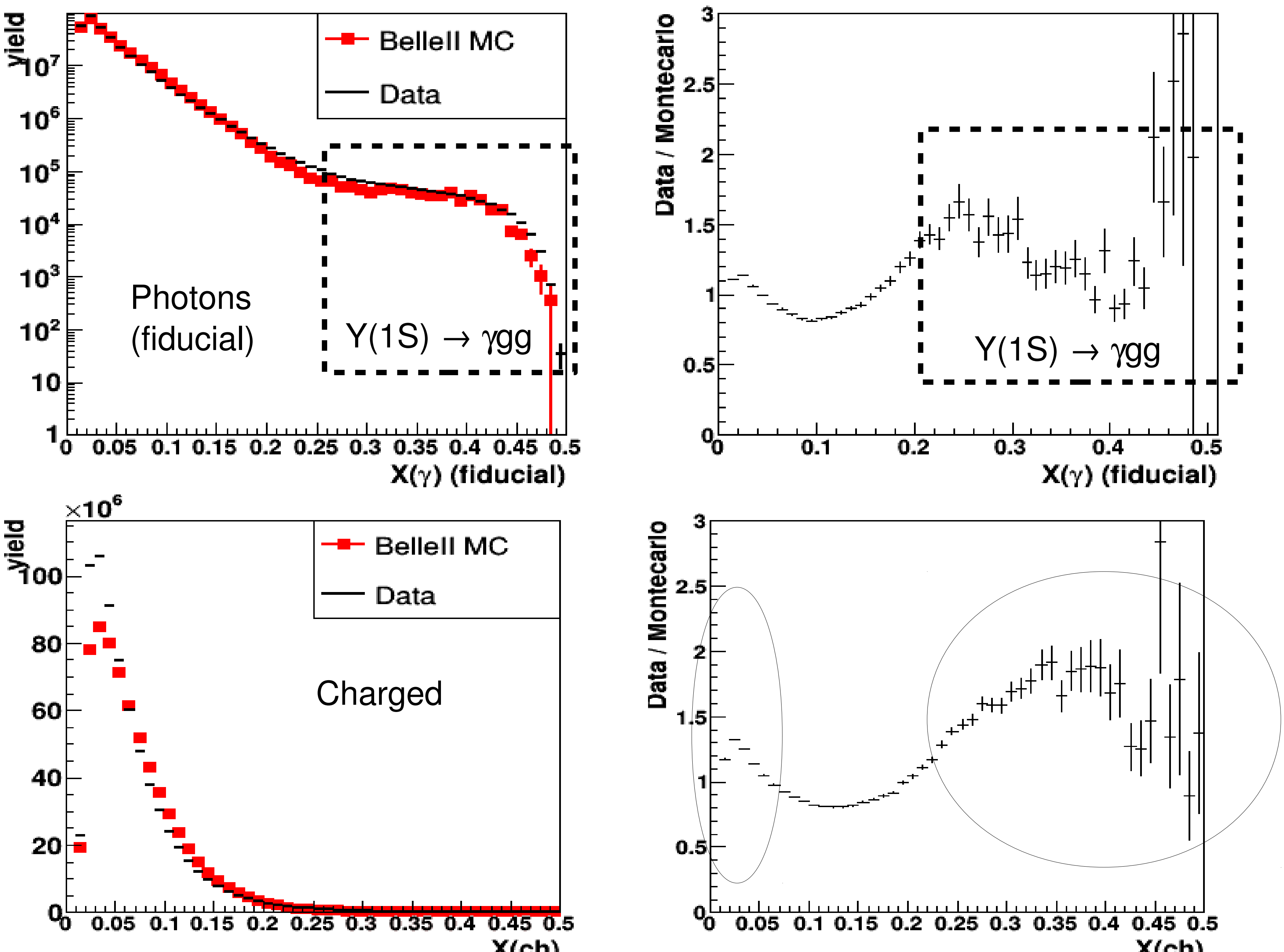
What for BelleII?

Minimal solution: write a new EvtGen model the Dalitz analysis

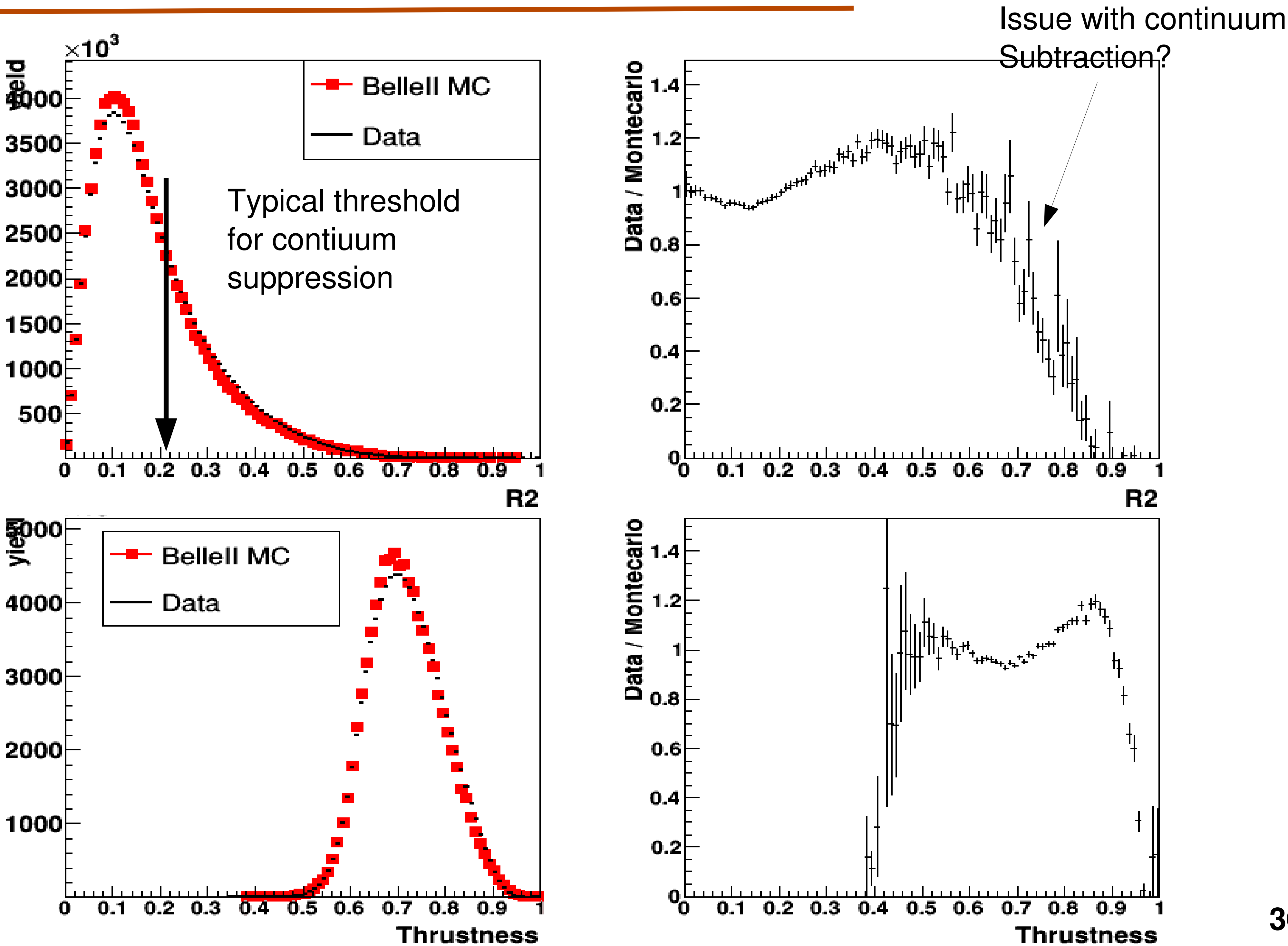
Best solution: Validate BaBar's analysis with Belle's dataset and write a new EvtGen model the Dalitz analysis

Stable particles' spectra

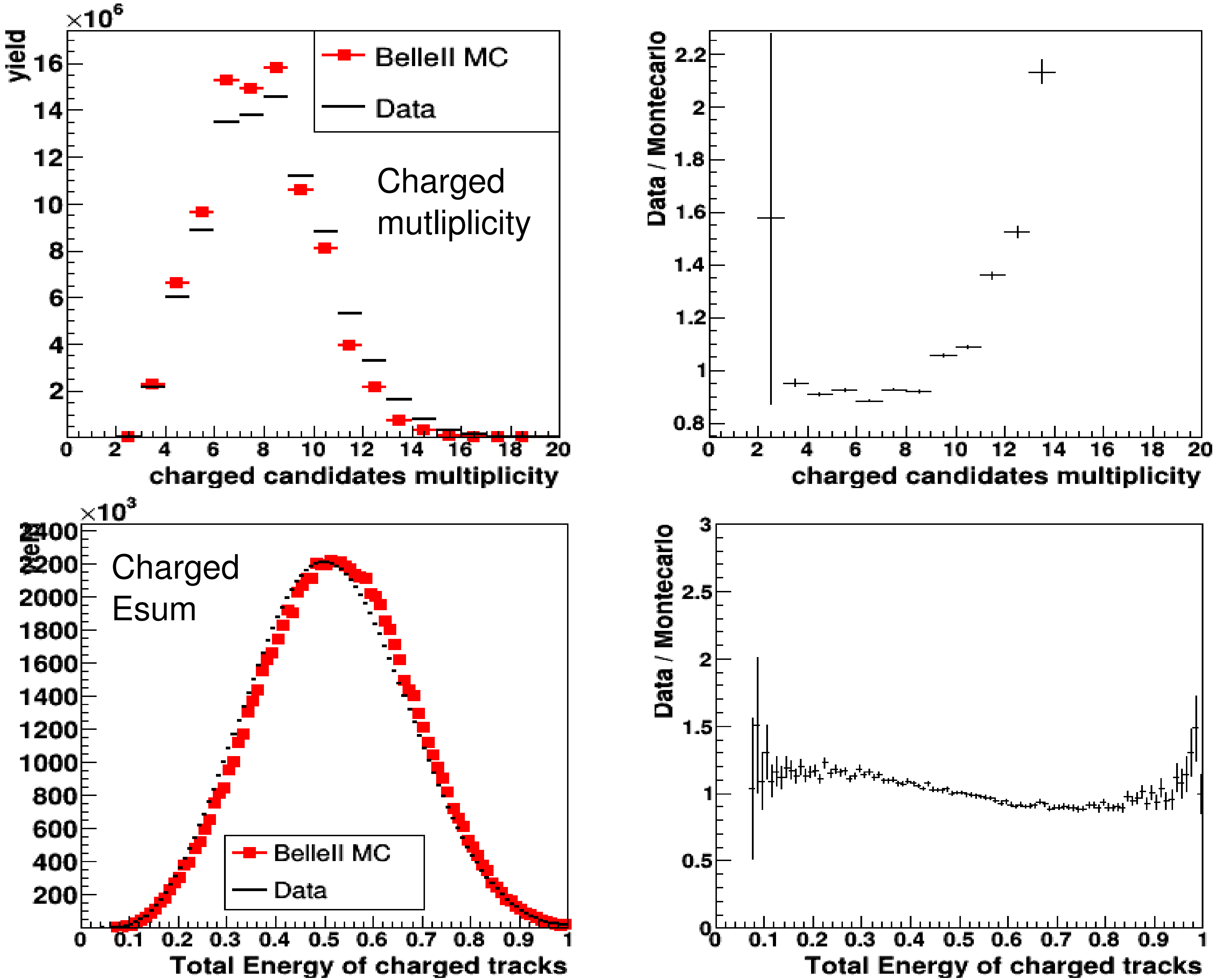
MC predicts less, more energetic tracks



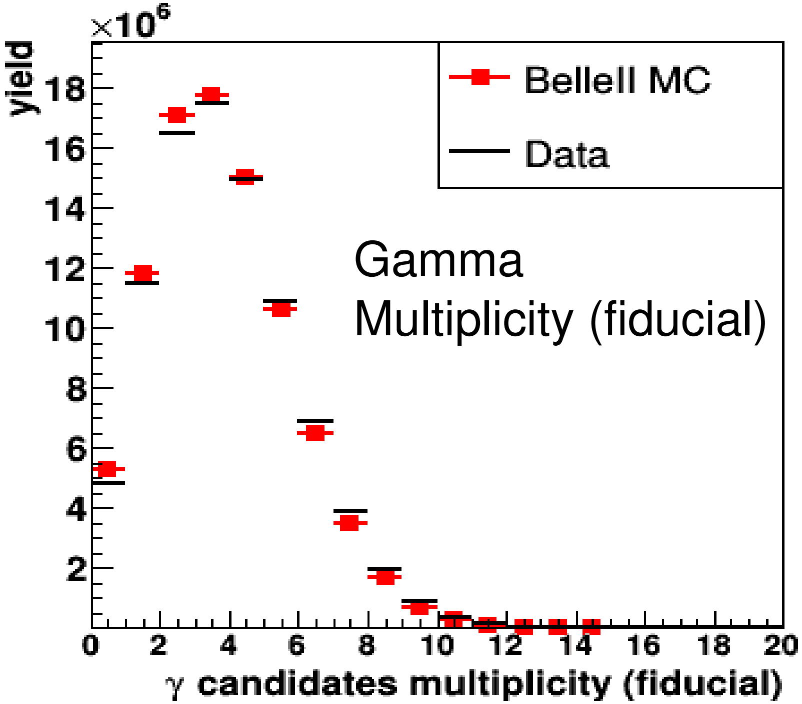
Event shape

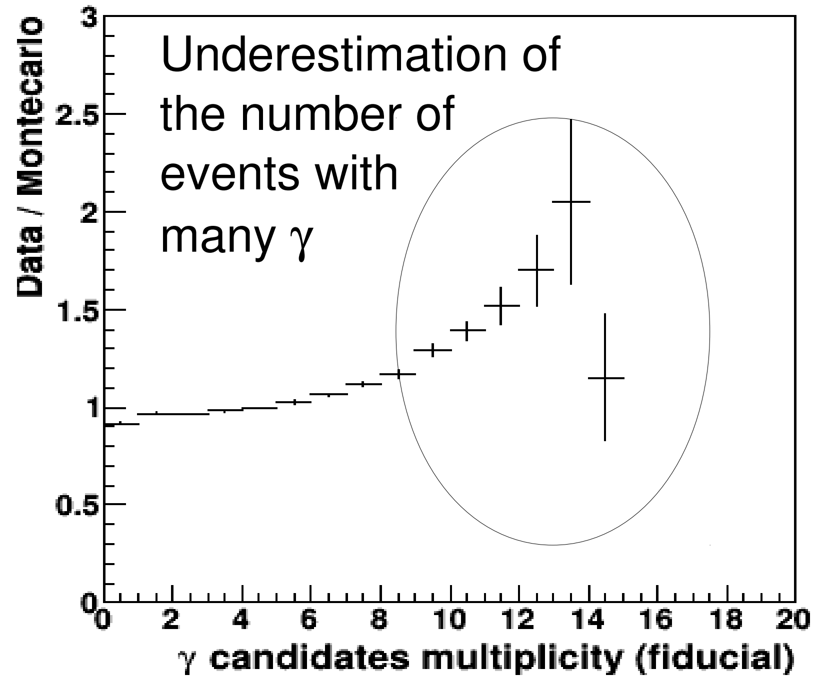

Issue with continuum Subtraction?
Typical threshold for contiuum suppression
×10³
yield
BelleII MC
Data
R2
Data / Montecarlo
yield
BelleII MC
Data
Thrustness
Data / Montecarlo
Thrustness

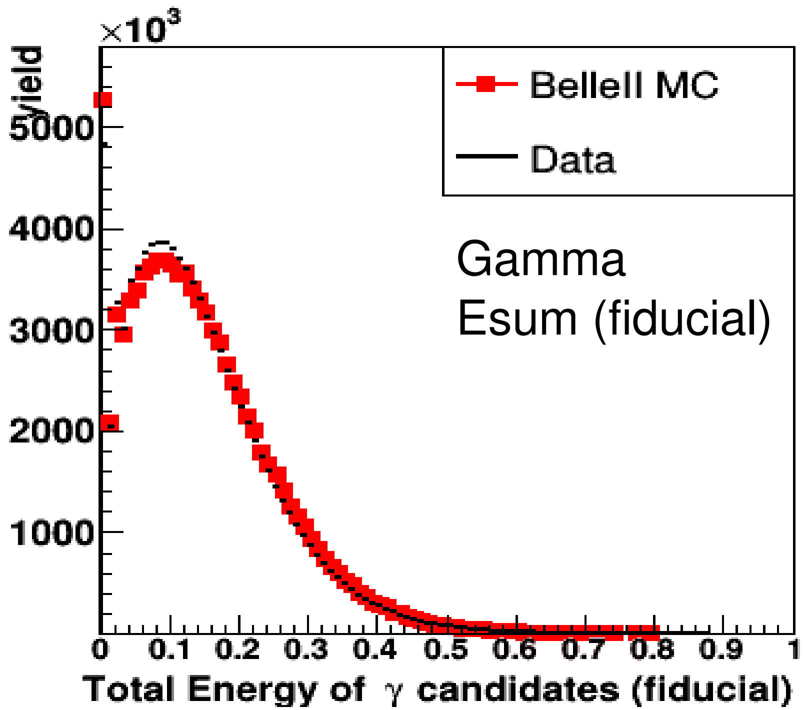
Data/MC comparison: charged

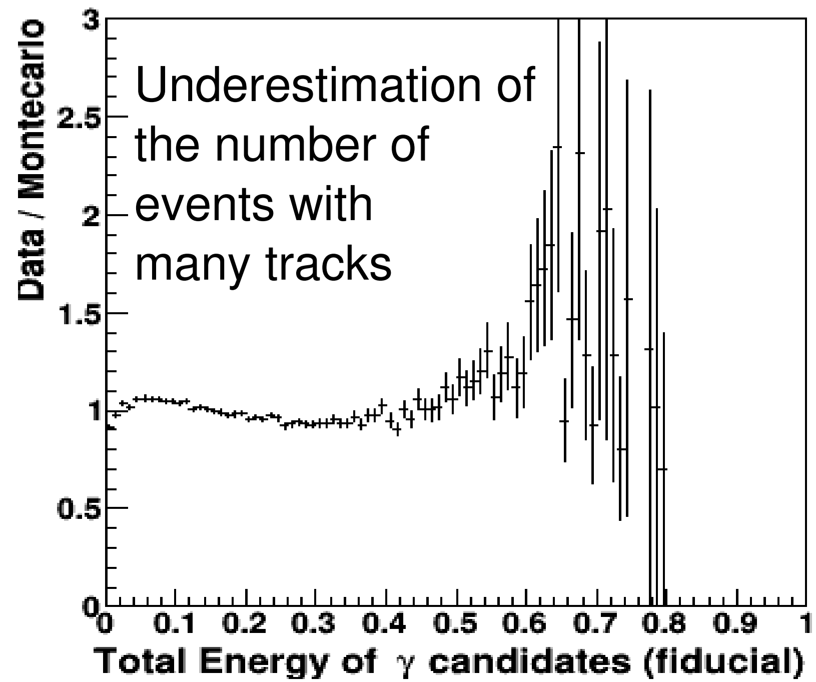


Data/MC comparison: neutral





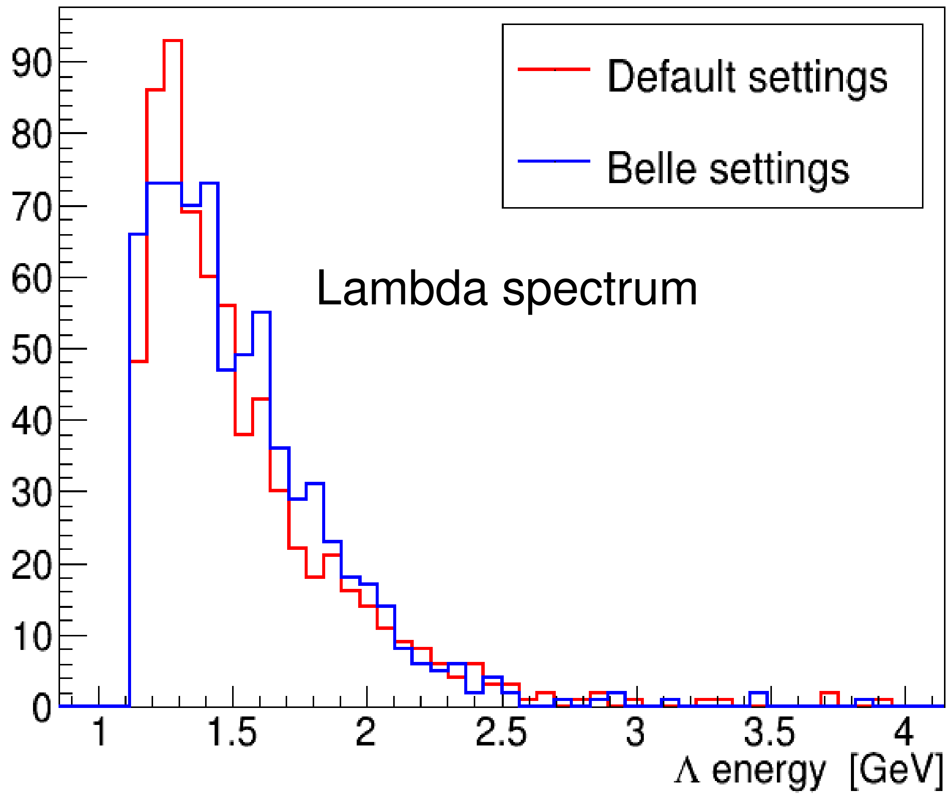


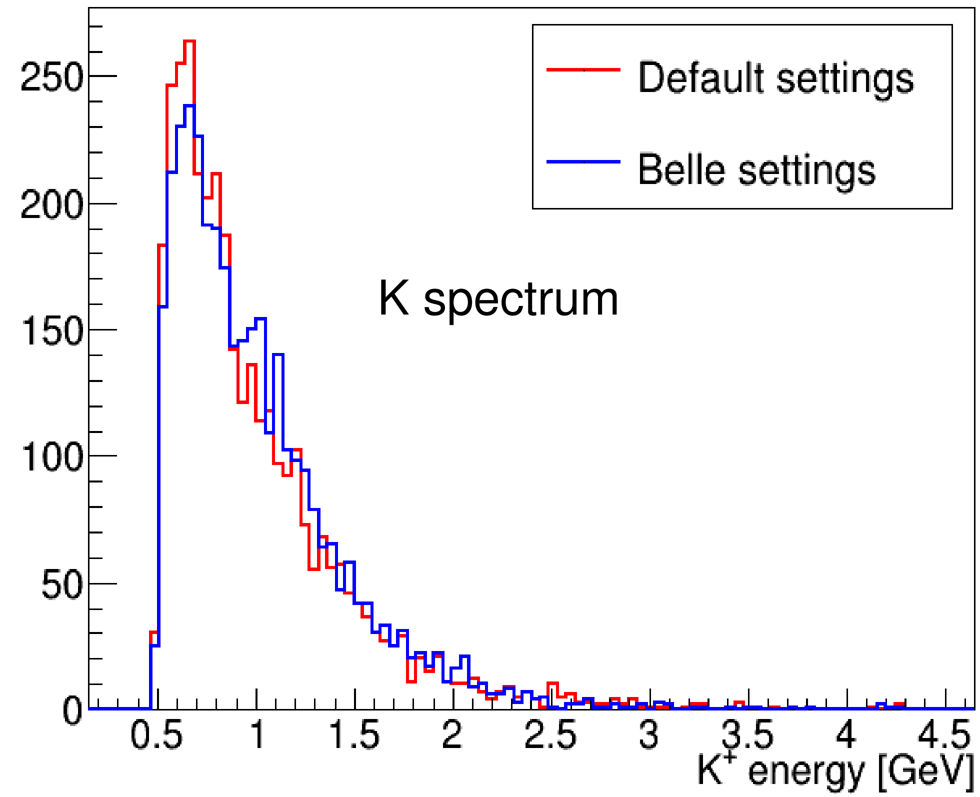


Tuning comparison with Pythia8

Process Υ(4S) → ππ Υ(1S) → hadrons

~tamponi/public/Pythia8Validation/





Pythia parameters

Which parameters should we change and in which range?

Generate sample changing ONE parameter at time

→ No reconstruction, generatore level only

→ Check how much our distributions change

Tested parameters:

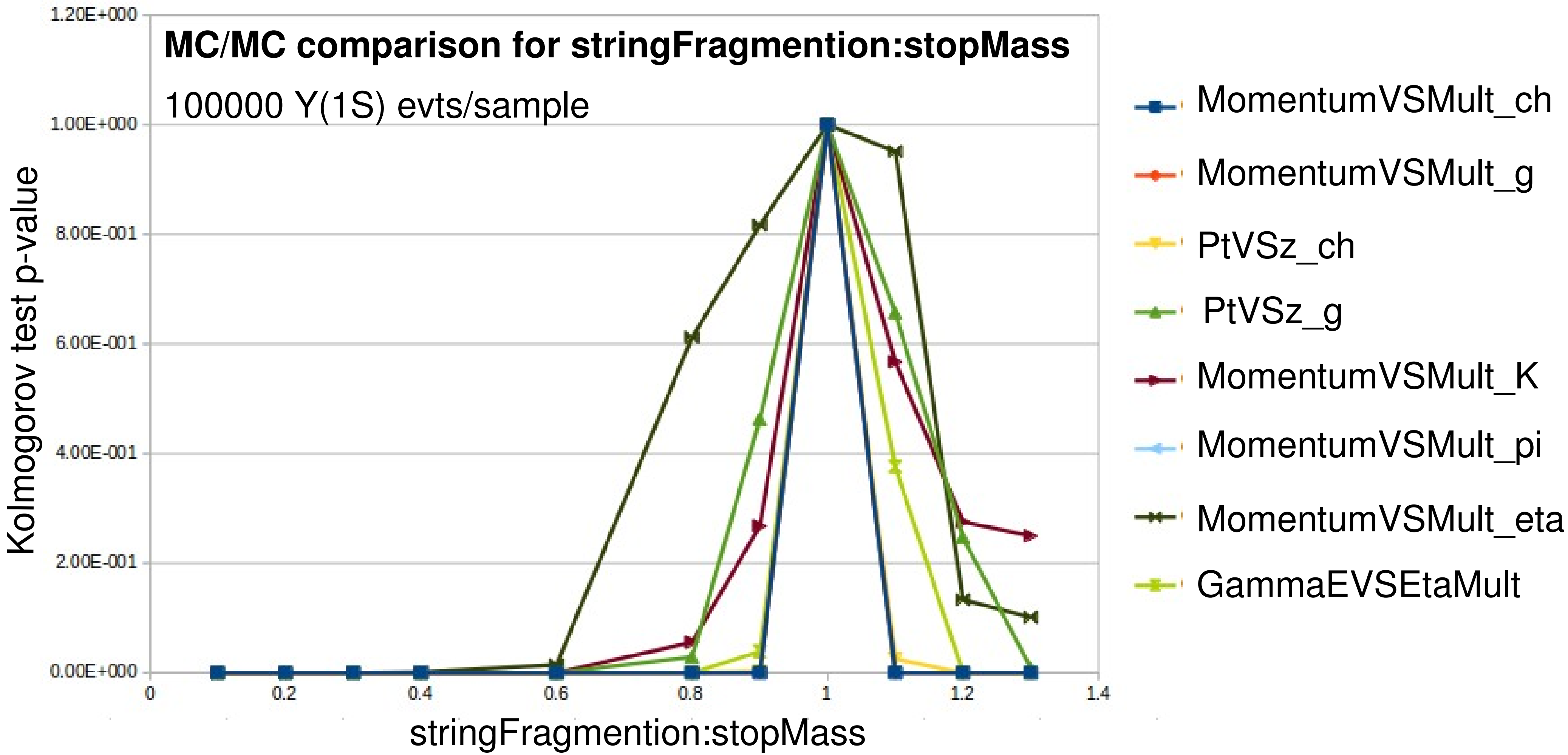
stopMass

aLund

bLund

sigma

pTmin



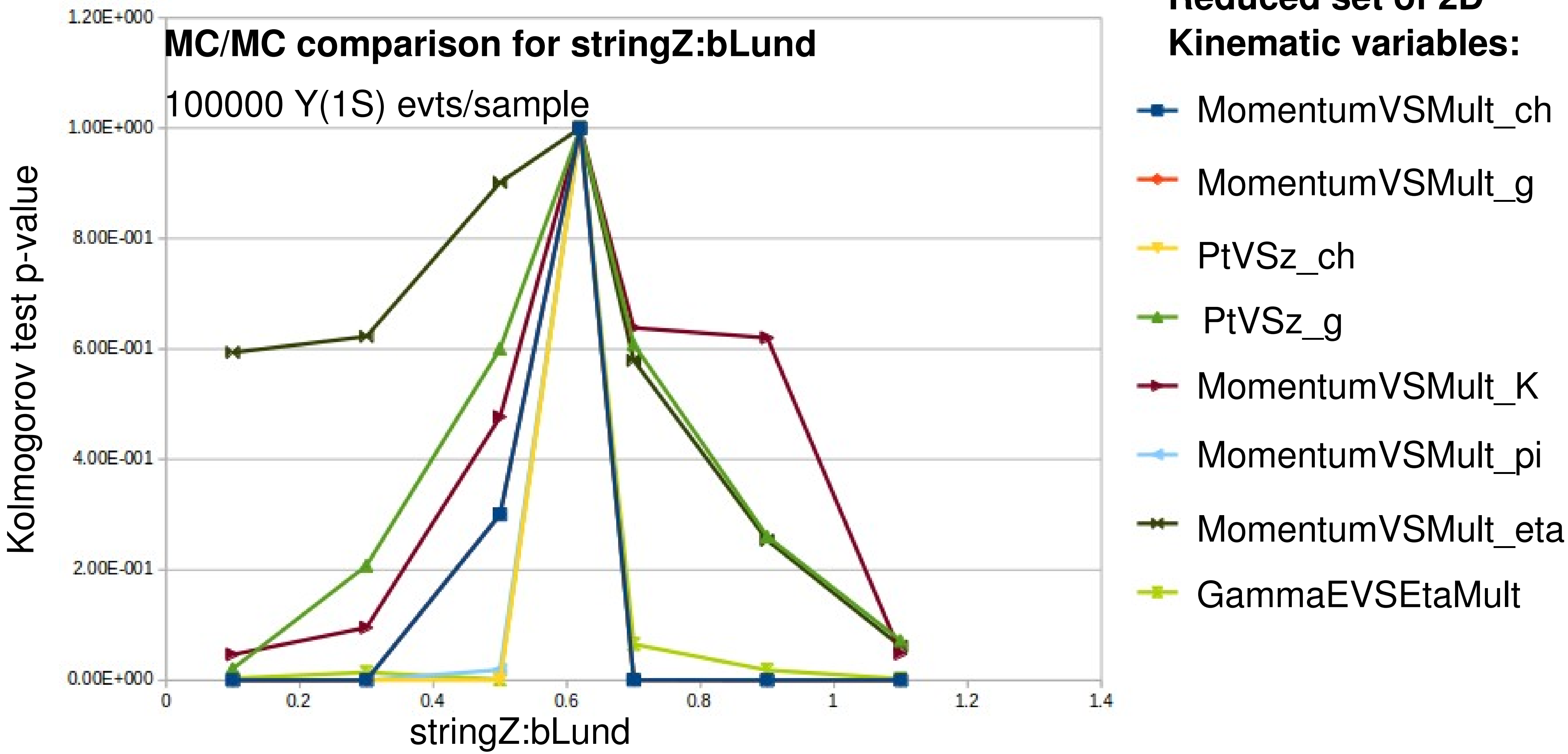
Pythia parameters

Which parameters should we change and in which range?

Generate sample changing ONE parameter at time

→ No reconstruction, generatore level only

→ Check how much our distributions change



Tested parameters:

stopMass

aLund

bLund

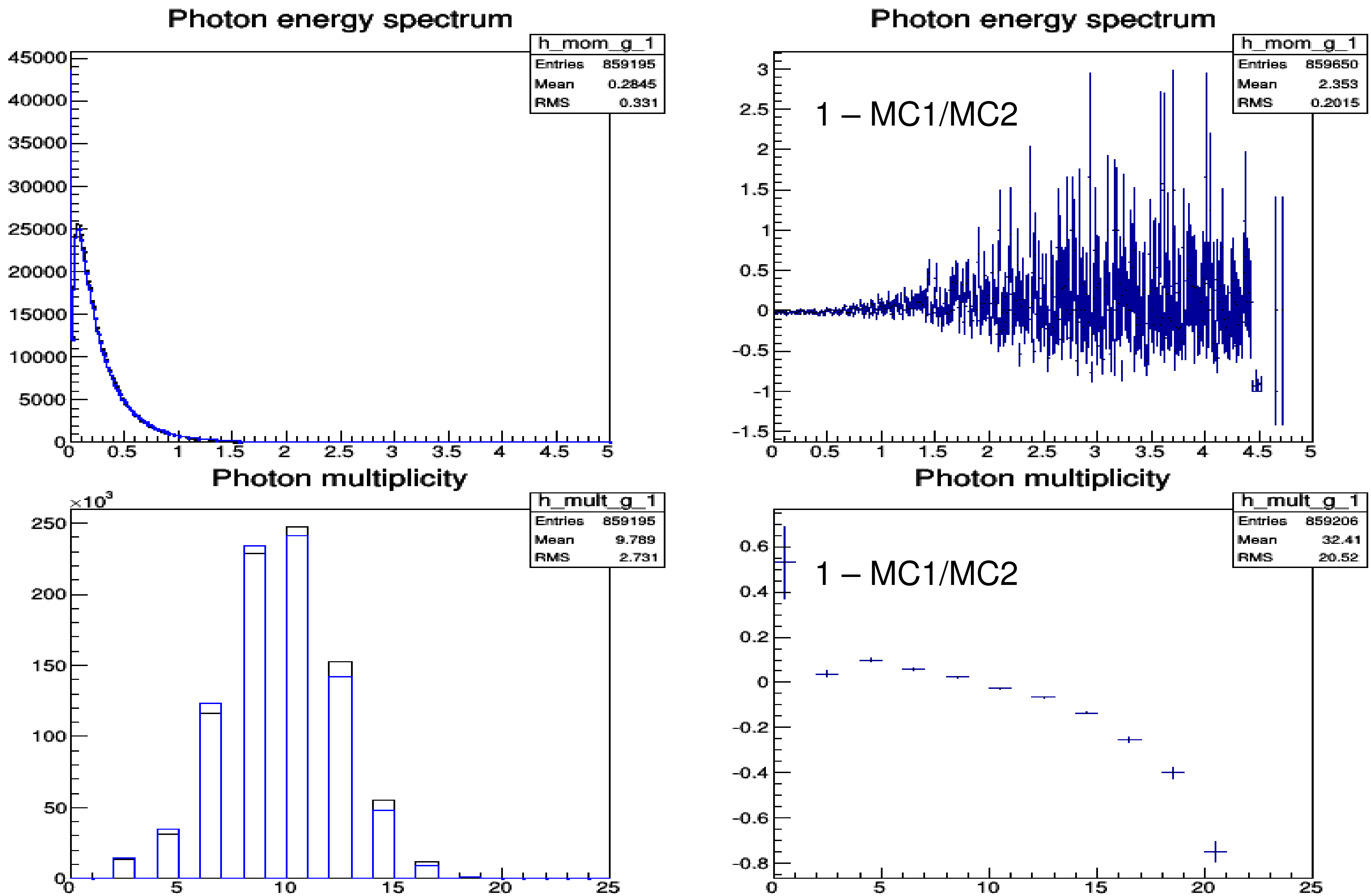
sigma

pTmin

Reduced set of 2D Kinematic variables:

Example of 1D comparison

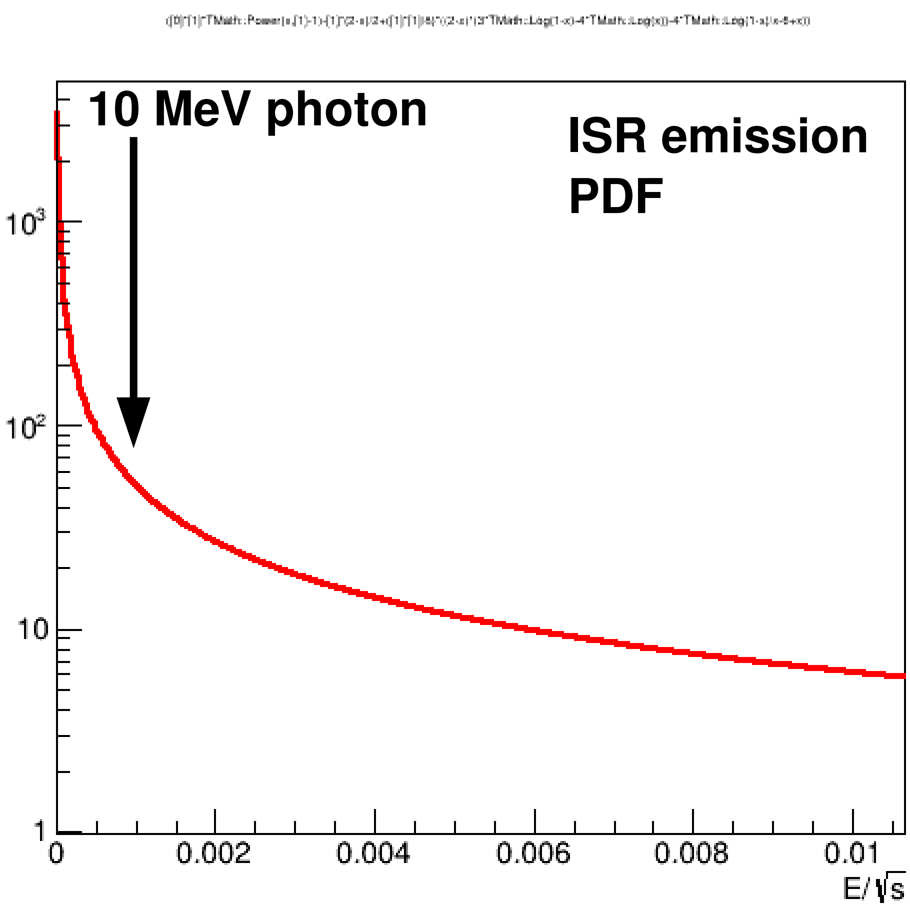
StopMass= 1.0 (MC 1) VS stopMass= 1.2 (MC 2)

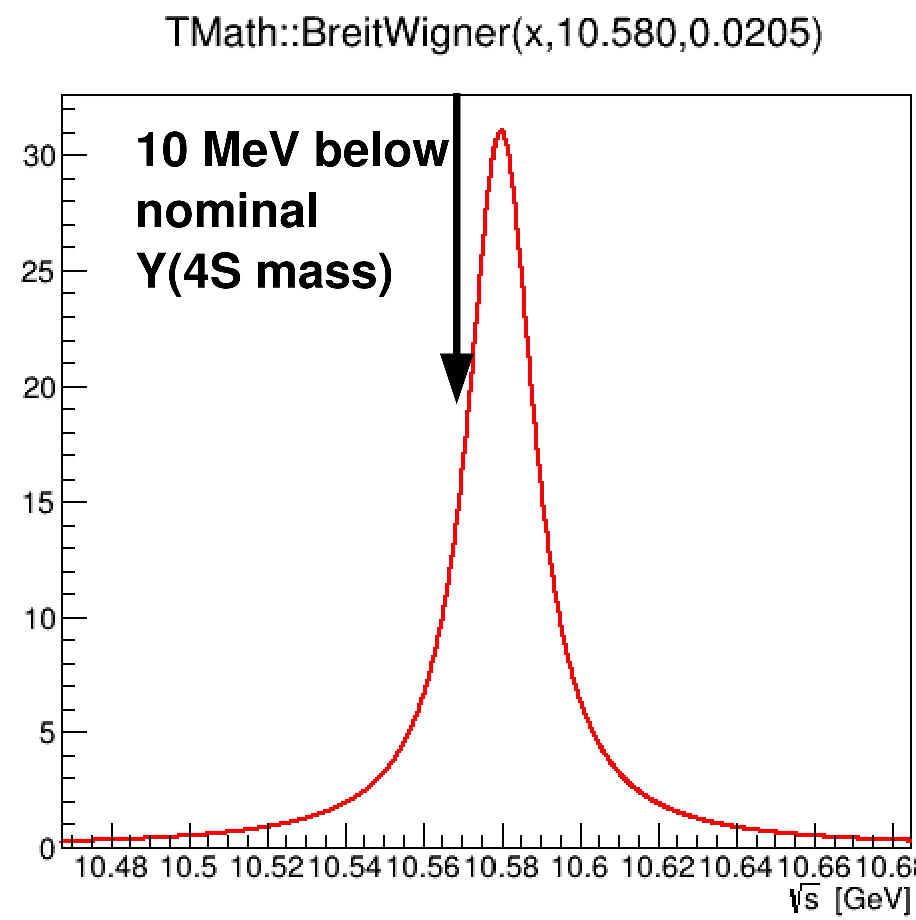


Soft ISR at Y(4,5S)

Y(4,5S) have non negligible width. Soft ISR emission may occur:

$e^+e^- \rightarrow \gamma_{SOFT}\ Y(4S) \rightarrow \gamma_{SOFT} + X$



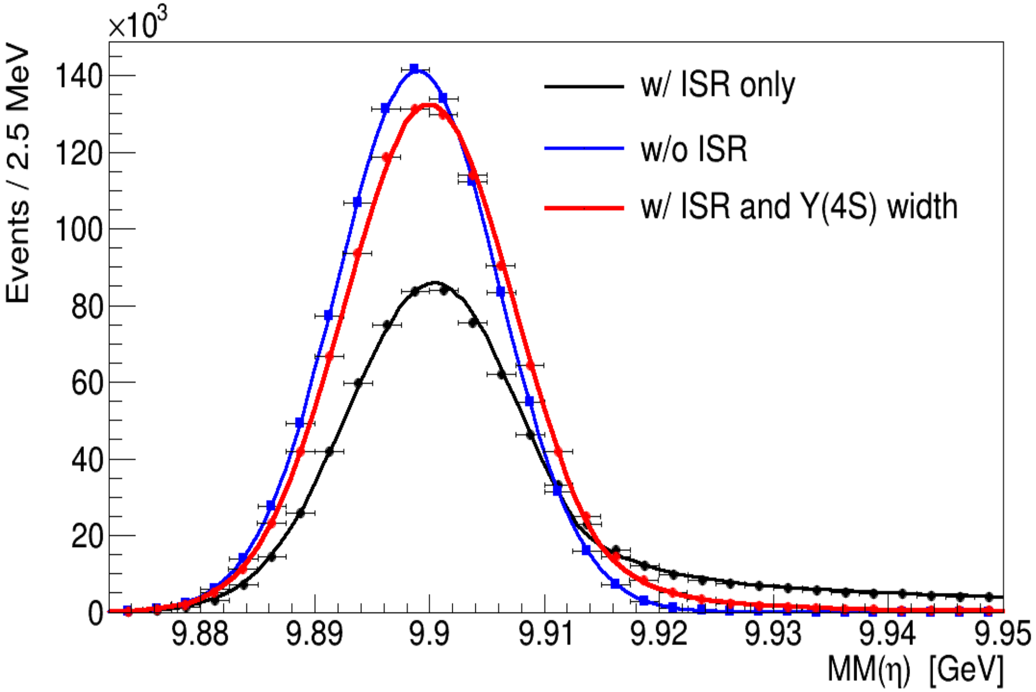


Lower Ecm but still an Y(4S) → Asimmetric tails in the recoil mass of two body decays

[Y(4S) → η hb(1P) as example]

Soft ISR at Υ(4,5S)

Example: Υ(4S) → η hb in η recoil mass



Blue:
MC simulation with Υ(4S) → η hb(1P)

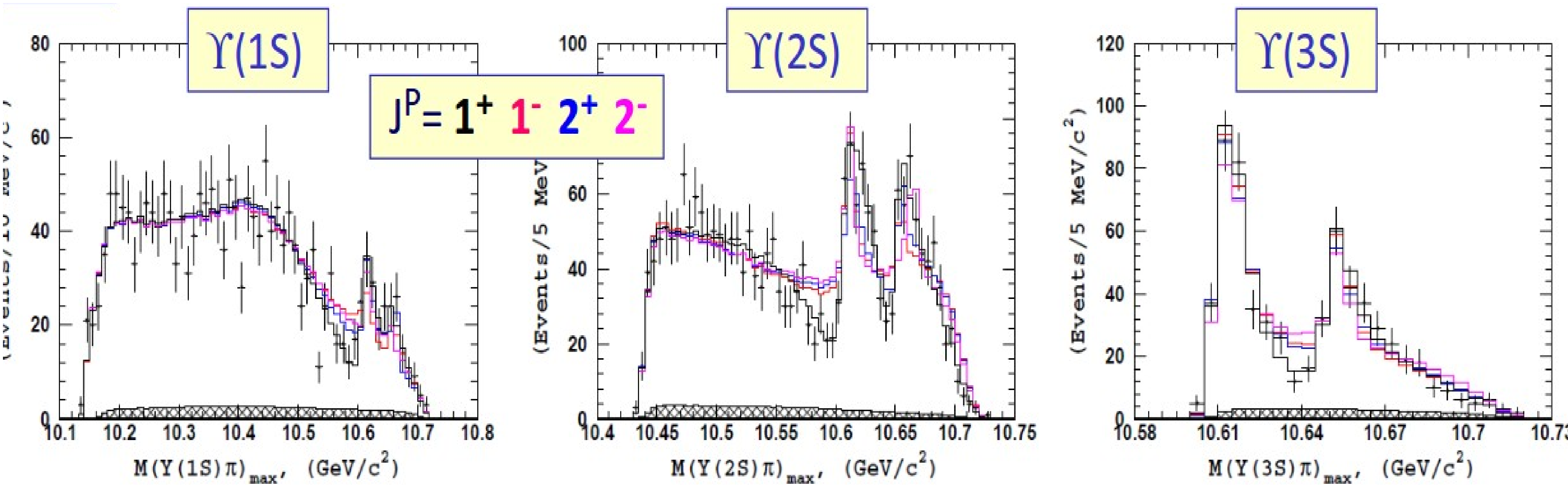
Red:
Convolution with ISR emission PDF and Υ(4S) lineshape

Currently done in two ways:
→ Numerical convolution
→ MC simulation with VectorISR

Vector ISR is originally mean for $e^+e^- \to \gamma\,\phi$
→ No low energy validation available
→ LO radiator formula

Validation is ongoing

Dipion transitions from Υ(5S)



Zb and Zb' should be listed in the evt.pdl file,
but can we **write to separate models?**

```
Decay Upsilon(5S)
1.0000  pi+ Zb  Model1;
Enddecay

Decay Zb
1.0000  pi-  Upsion  Model2;
Enddecay
```

→

Dalitz Model:

$\mathbf{S = A(Z_b) + A(Z'_b)}$ **+**	Breit-Wigner
$\mathbf{A(f_0(980))}$ **+**	Flatte
$\mathbf{A(f_2(1275))}$ **+**	Breit-Wigner
A(NR)+	$c_1 + c_2 M^2(\pi\pi)$
$\mathbf{A(\sigma)}$	Breit-Wigner