Update on $\psi(2S)/J/\psi(1S)$ ratio in photoproduction: t dependence

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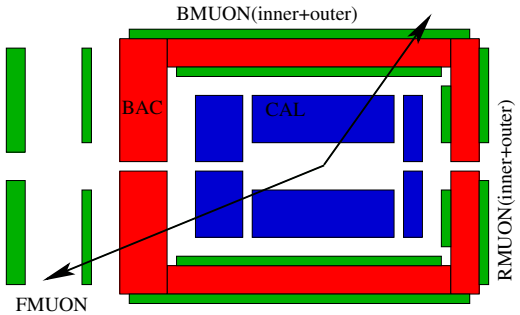
ZEUS Analysis Forum, DESY/Vidyo meeting, 10-Jun-2020

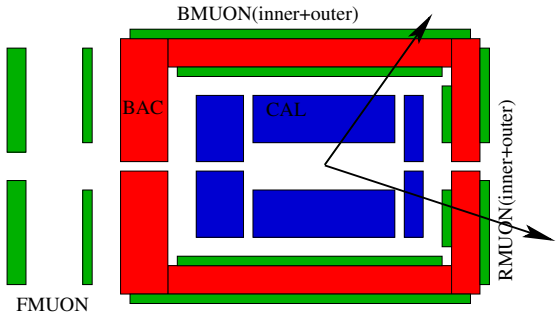
Outlook:

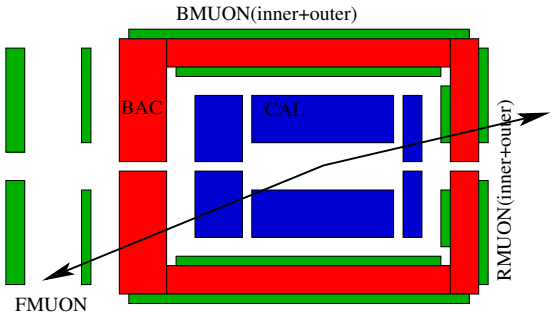
- muon corrections once again, treatment of empty bins
- $|t|$ distribution, definition of $|t|$ bins
- control plots
- efficiency and acceptance corrections in $|t|$ bins
- R in $|t|$ bins
- Conclusions/Plans

TAG and PROBE: di-muon configurations

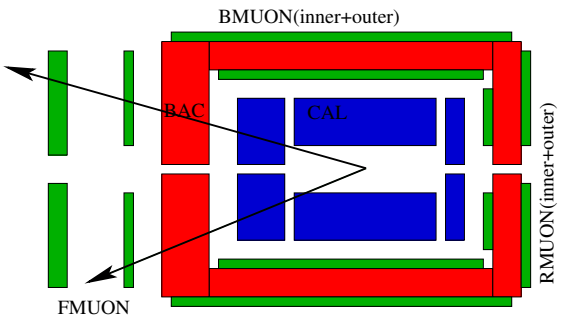
- (almost) non ambiguous: 1F1B, 1B1R, 1F1R (used)

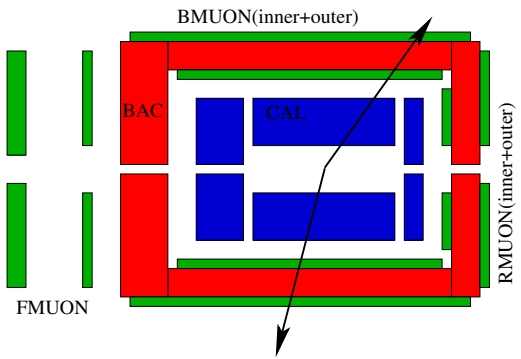


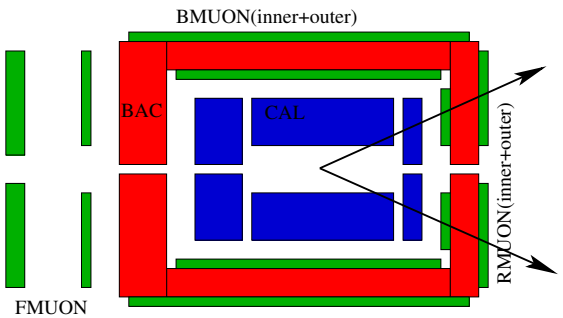




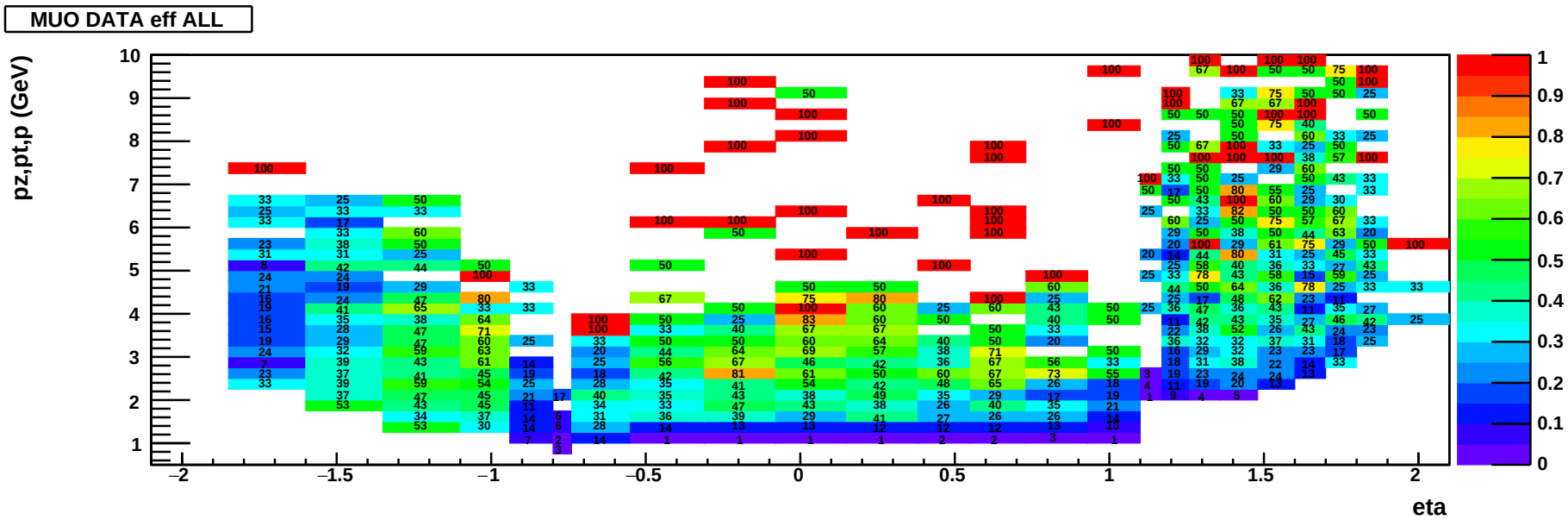
- ambiguous: 2F, 2B, 2R (not used)





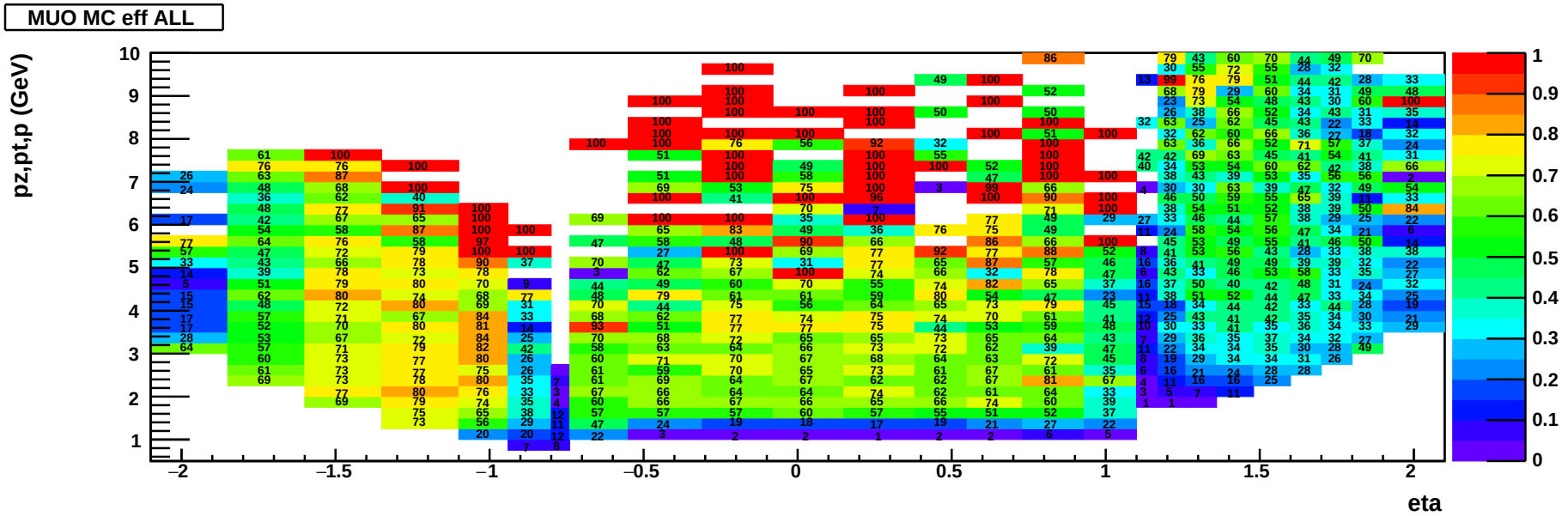


Muon correction maps: (p_z, p_t, p *vs.* η) - DATA



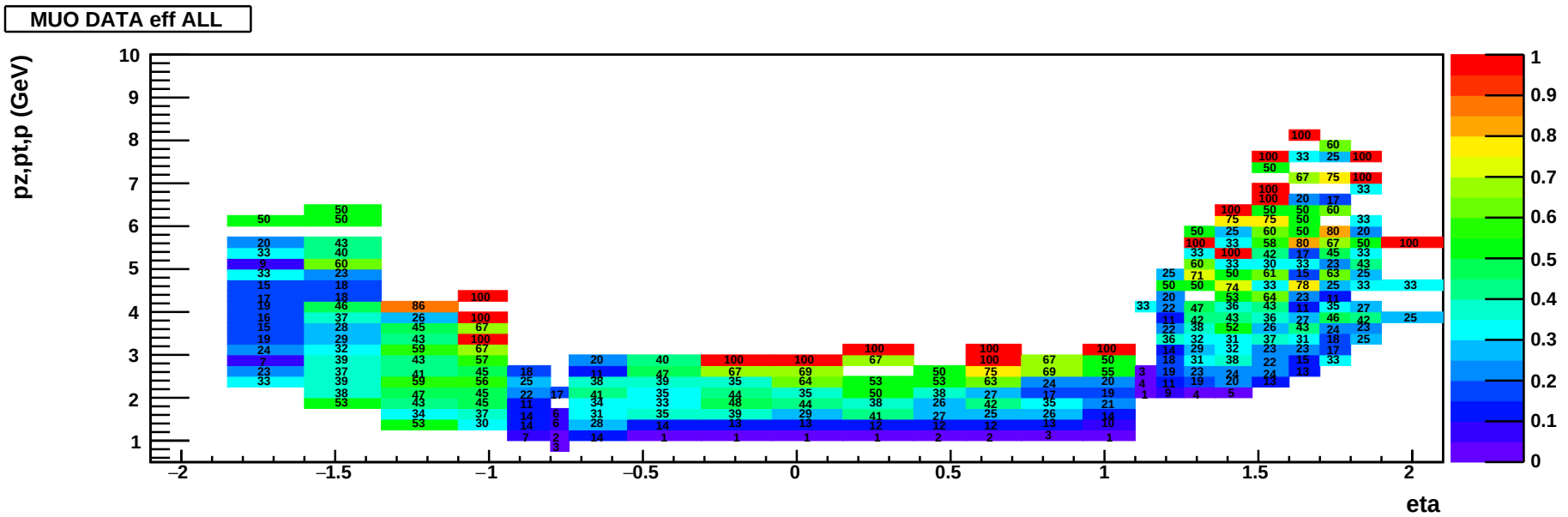
- probability (%) to fire FLT-SLT-TLT-REC by muon on ($p_z, p_t, p; \eta$) grid
- X-axis: RMUO-BMUO-FMUON (along eta)
- RMUO-BMUO: $\eta = -0.74$, BMUO-FMUON: $\eta = 1.1$
- parameterization for RMUO: p_z, BMUO: p_t, FMUON: p
- current choice for p_z, p_t, p grid: 250 MeV per bin
- size of the grid is subject to systematics

Muon correction maps: (p_z, p_t, p *vs.* η) - MC



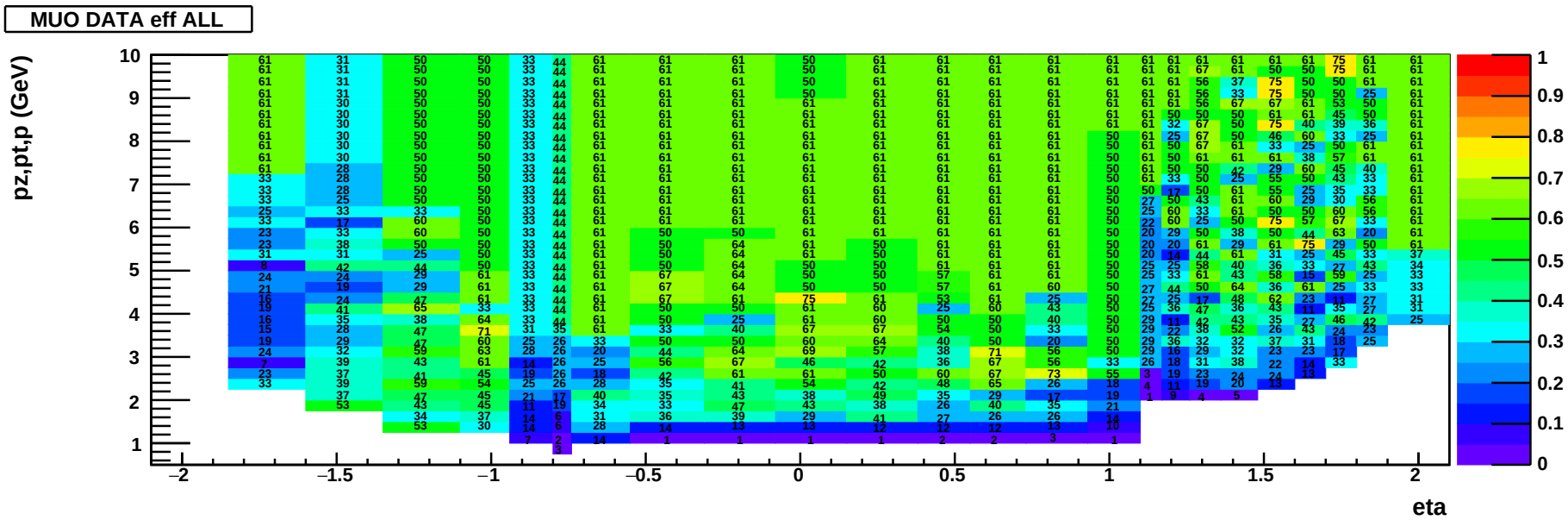
- probability (%) to fire FLT-SLT-TLT-REC by muon on ($p_z, p_t, p; \eta$) grid
- MC: bigger statistic $\rightarrow$ less empty bins
- Using mixture of MC samples: DIFFVM - J/ψ, ψ' (elastic and p.diss) and GRAPE (Bethe-Heitler) in proportion as extracted from data
- MC : not 100% efficient for high momentum muons in FMUON

Muon correction maps: (p_z, p_t, p *vs.* η) - DATA



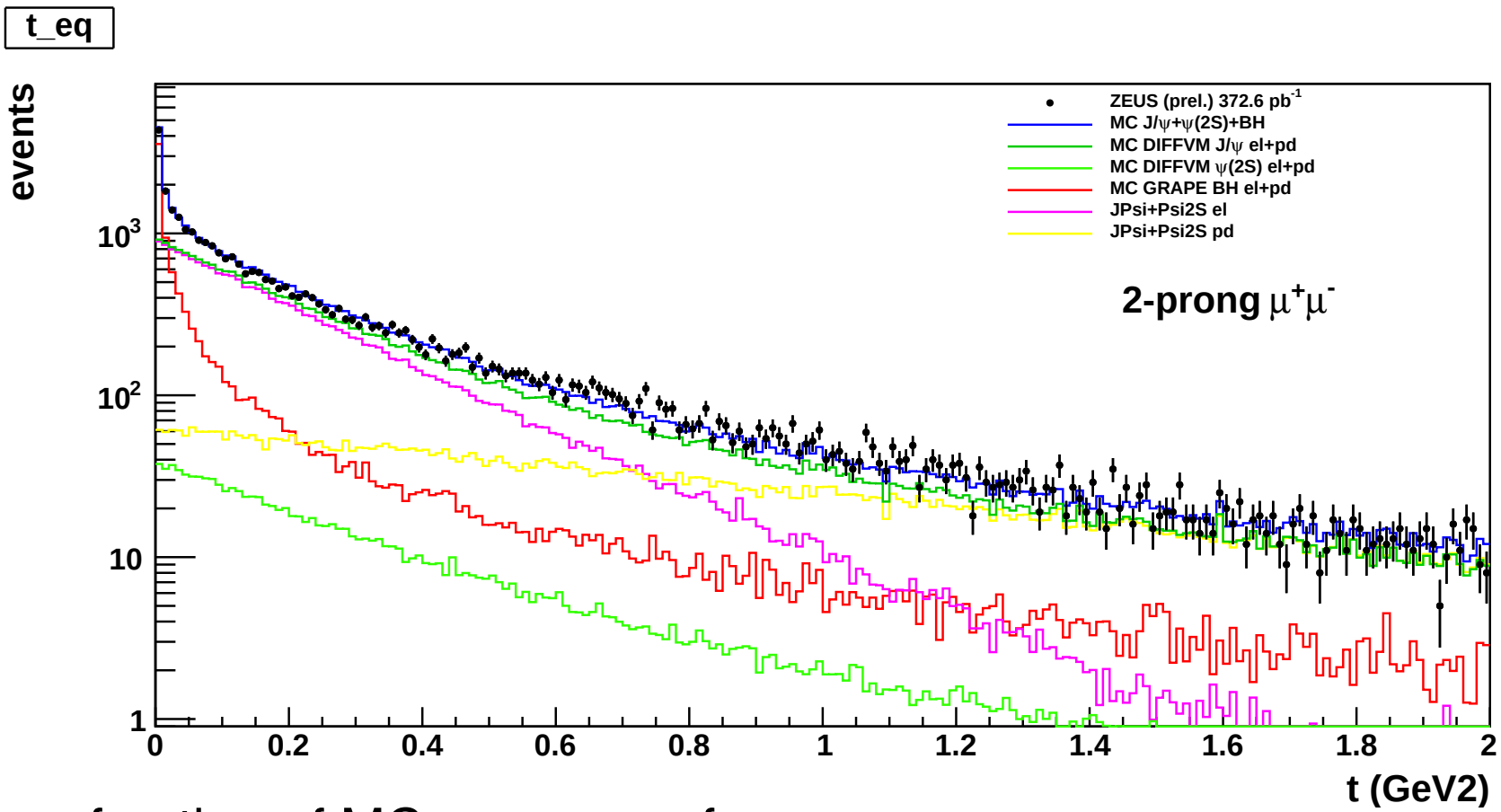
- probability (%) to fire FLT-SLT-TLT-REC by muon on ($p_z, p_t, p; \eta$) grid
- X-axis: RMUO-BMUO-FMUON (along eta)
- only events with $M(\mu^+, \mu^-) < 6$ GeV
  (ie. in the phase space range of di-muon mass fits)
- not big amount of empty bins in relevant phase space
- but low statistic at the upper half of the “banana” shape

Muon correction maps: (p_z, p_t, p *vs.* η) - DATA



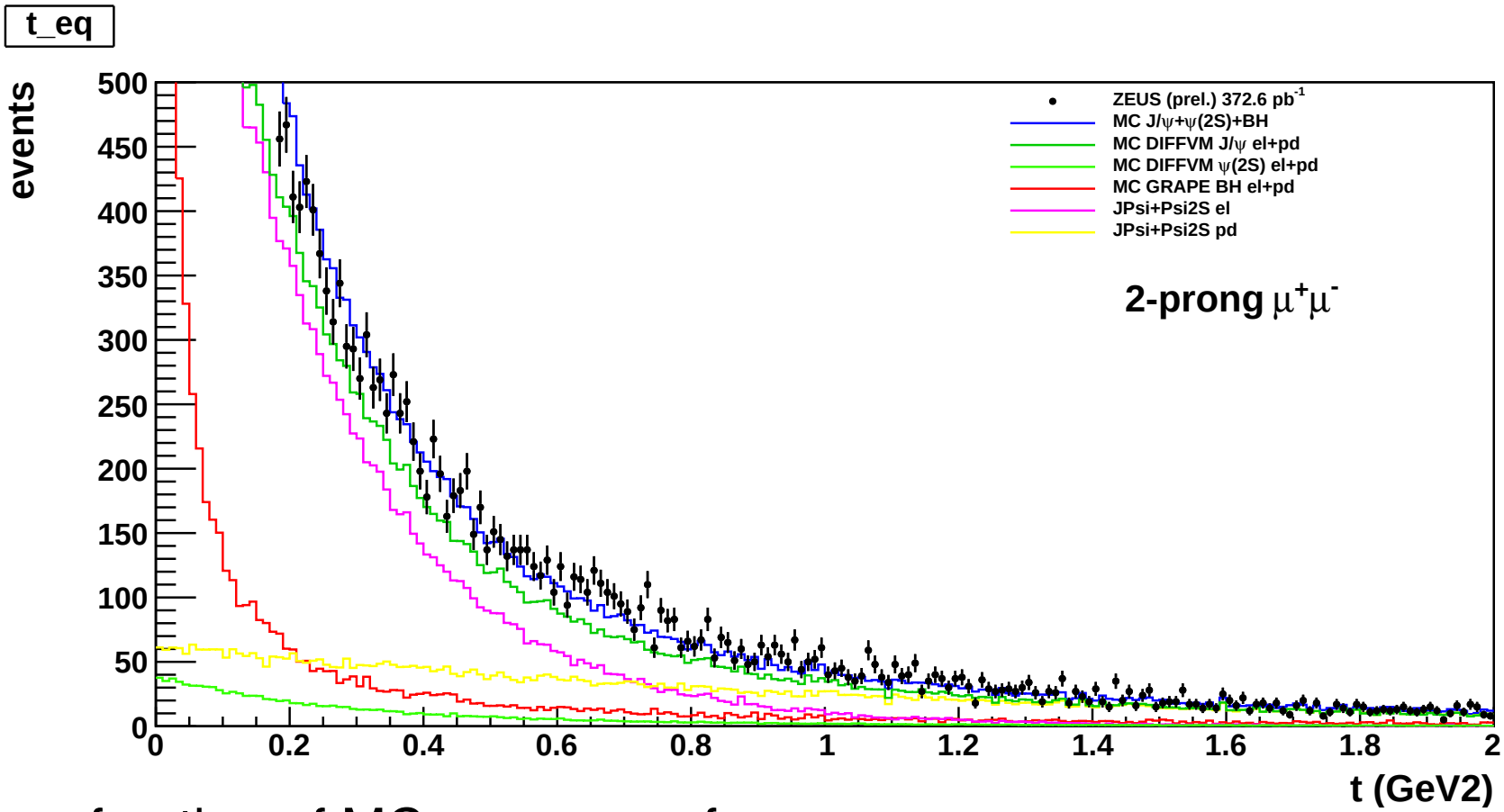
- probability (%) to fire FLT-SLT-TLT-REC by muon on ($p_z, p_t, p; \eta$) grid
- X-axis: RMUO-BMUO-FMUON (along eta)
- after correction for empty and “hot” bins:
  filled with mean value on neighbor bins and extrapolated upwards
- the same for MC...
- the final correction weight is the DATA/MC ratio for a given bin

$|t|$ distribution: all 2-prong events



- fraction of MC processes from `TFracFitter` to di-muon mass spectrum
- assuming $f_{p.diss} = 0.25$ (for J/ψ and ψ')
- $d\sigma/d|t| \sim \exp(-b|t|)$: $b_{el} = 5.0$ (J/ψ), $b_{el} = 4.0$ (ψ'), $b_{pd} = 1.0$ GeV^{-2} (both)

$|t|$ distribution: all 2-prong events (zoom)



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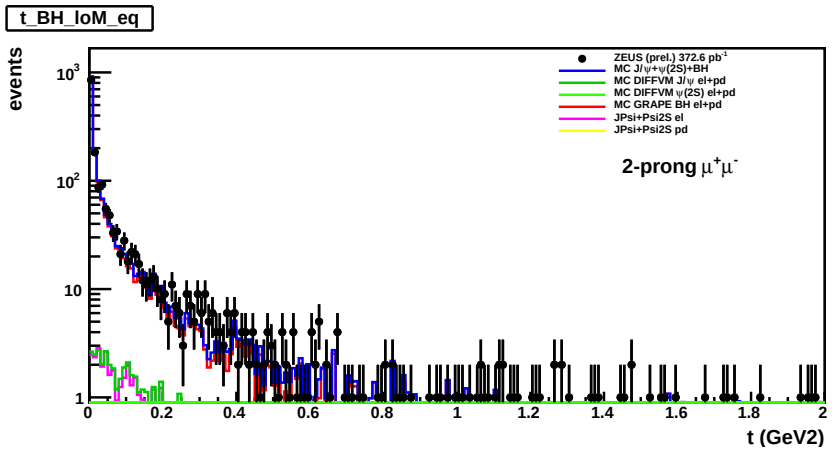
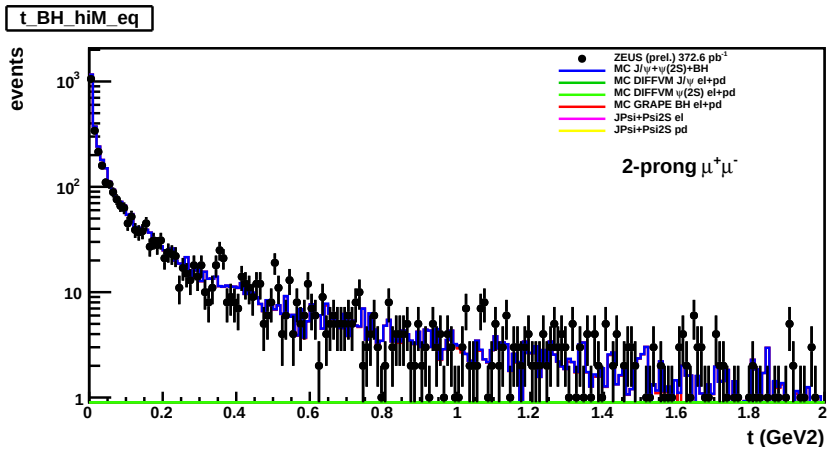
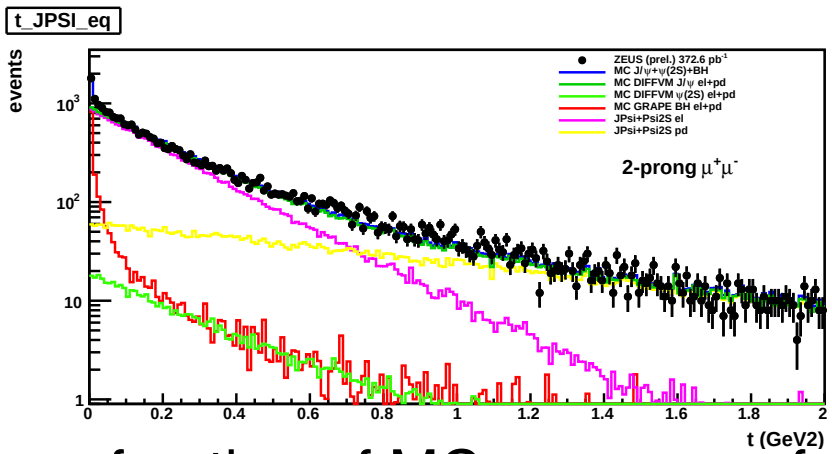
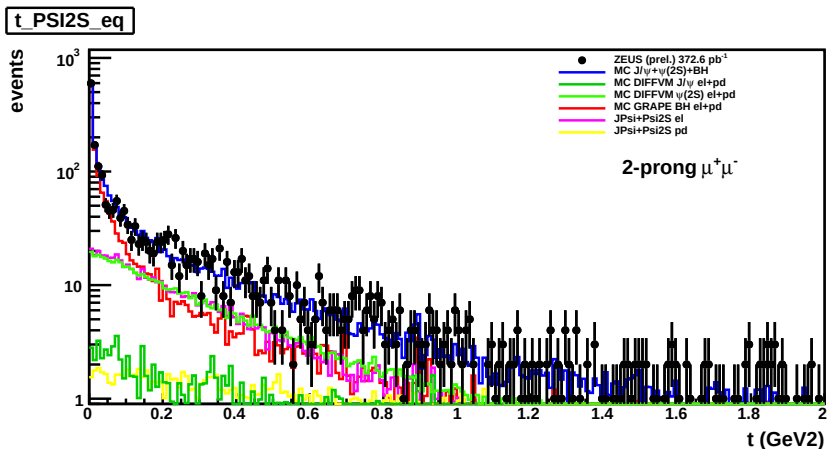
$|t|$ distribution: 2-prong in mass bins



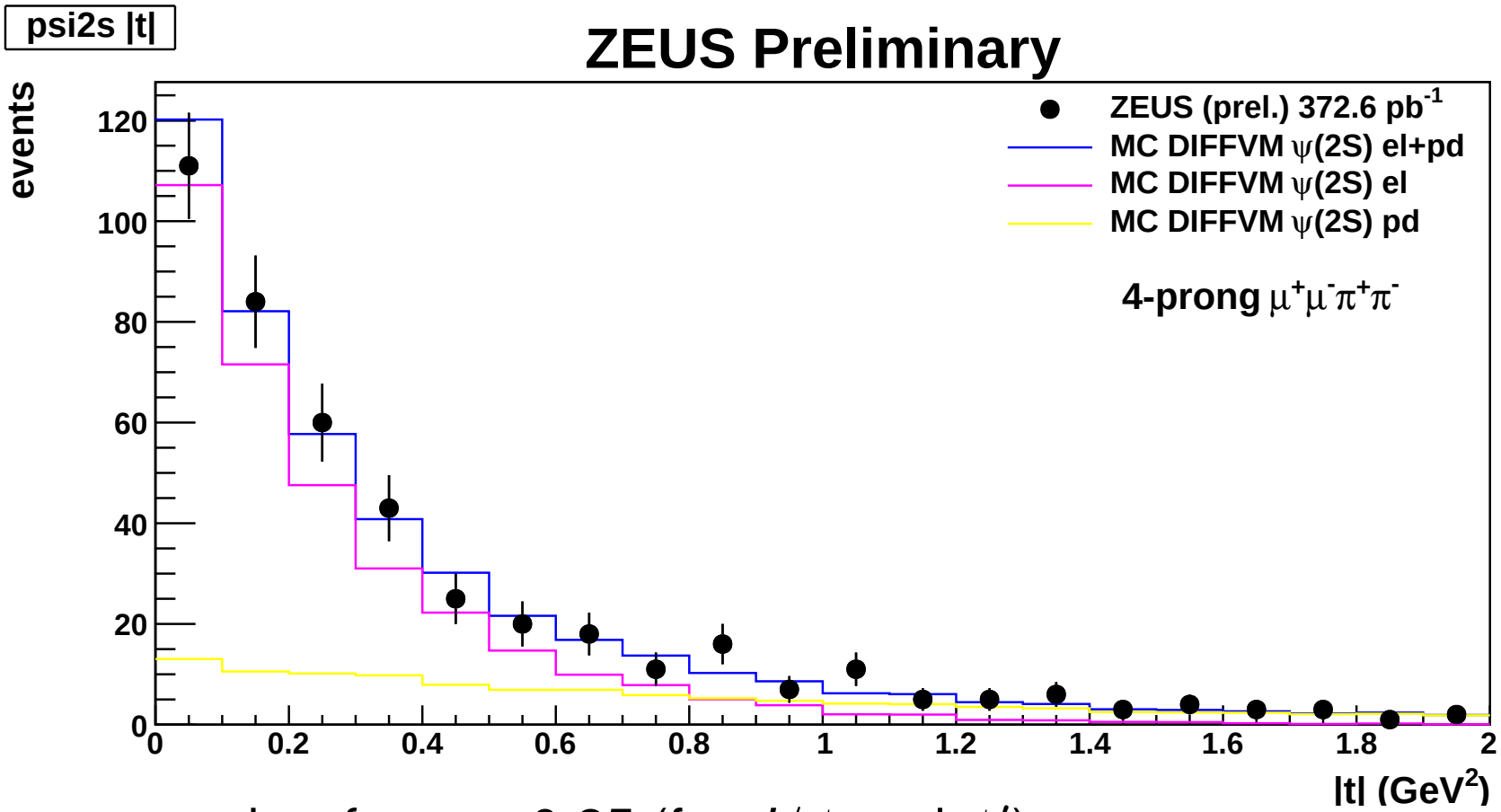






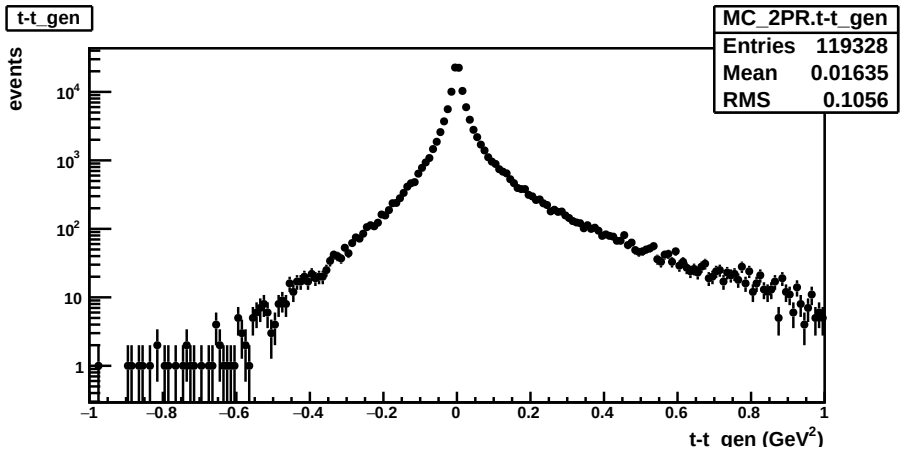
- fraction of MC processes from `TFracFitter` to di-muon mass spectrum
- BH-loM, BH-hiM, JPSI, PSI2S

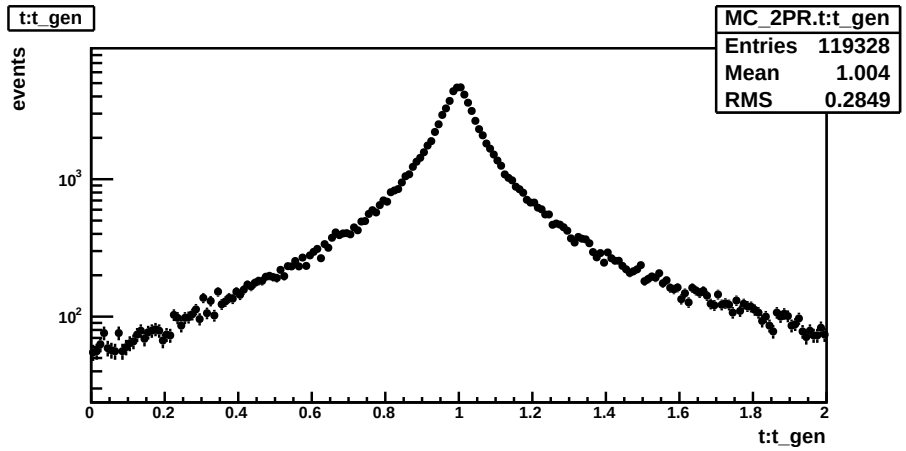
$|t|$ distribution: all 4-prong events

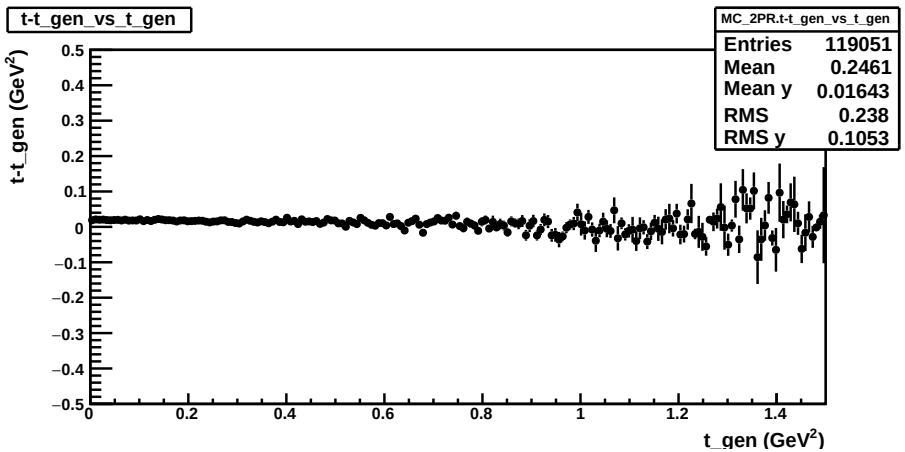


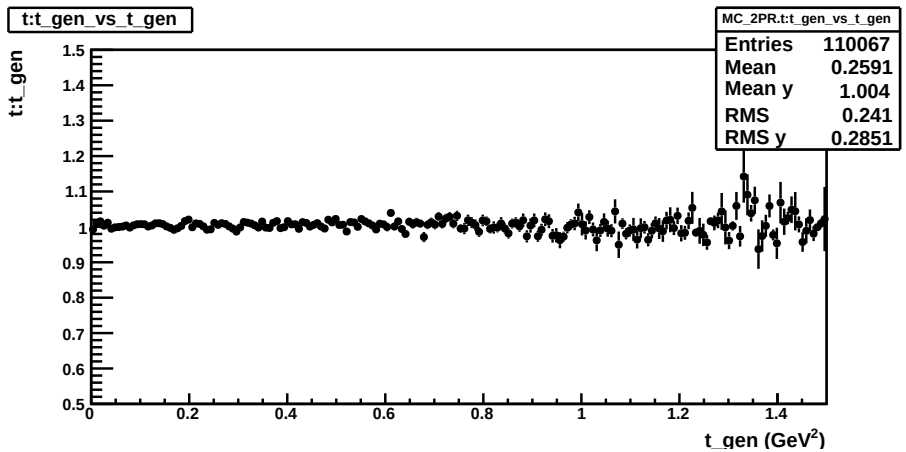
- assuming $f_{p.diss} = 0.25$ (for J/ψ and ψ')
- definition of $|t|$ bins: **t1**: (0.0-0.2), **t2**: (0.2-0.6), **t3**: (0.6-2.0) GeV^2

$|t|$ resolution: 2-prong



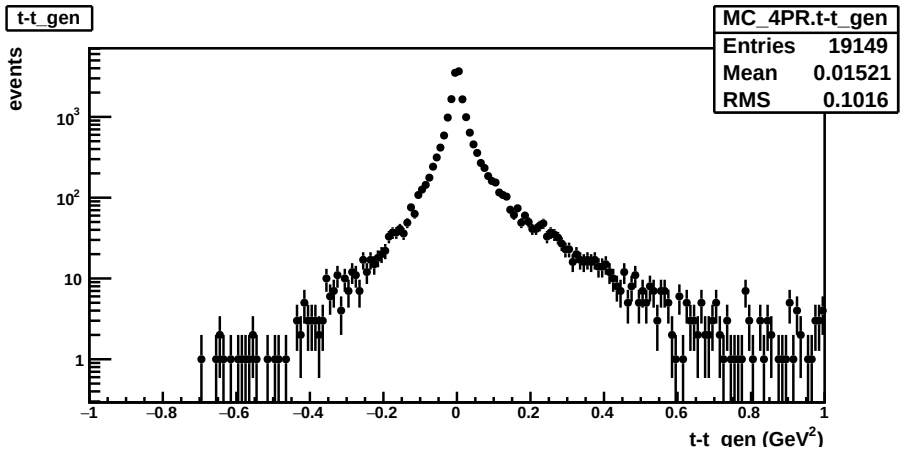


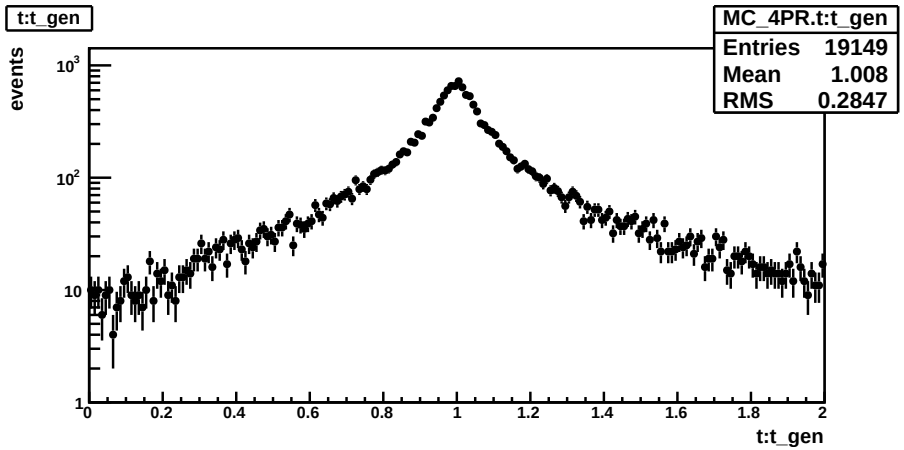


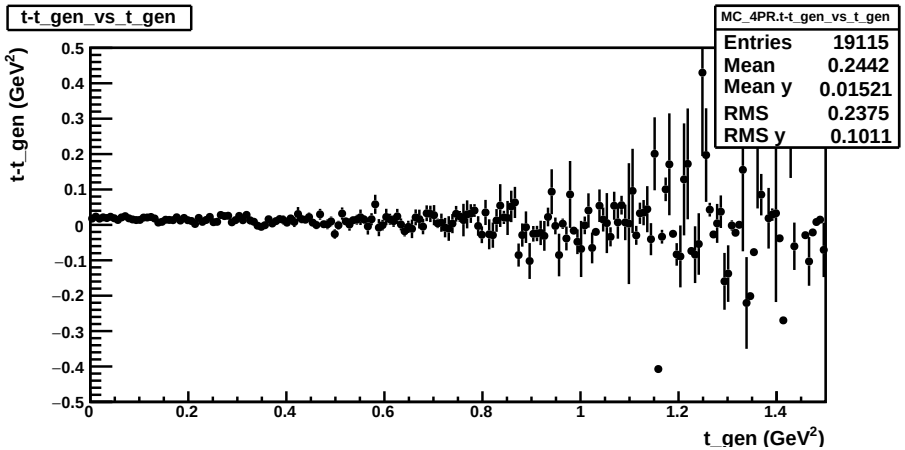


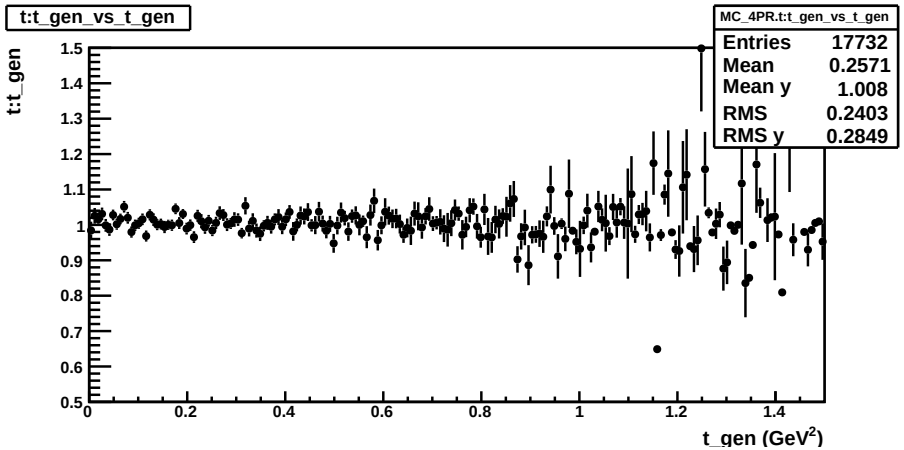
- upper row: $t_{rec} - t_{gen}$ and t_{rec}/t_{gen}
- lower row: profile plots: $t_{rec} - t_{gen}$ and t_{rec}/t_{gen} vs. true t_{gen}

$|t|$ resolution: 4-prong



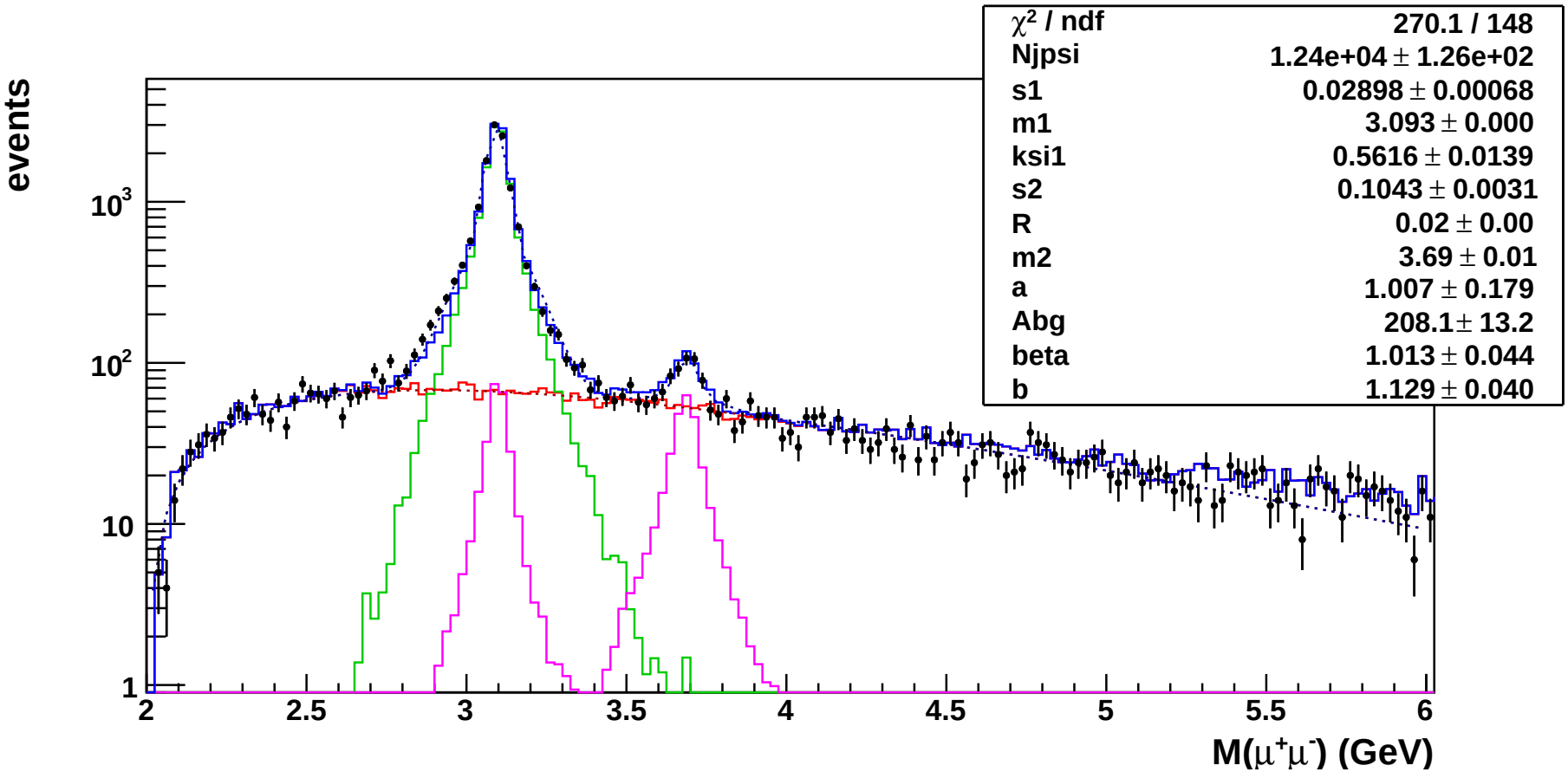






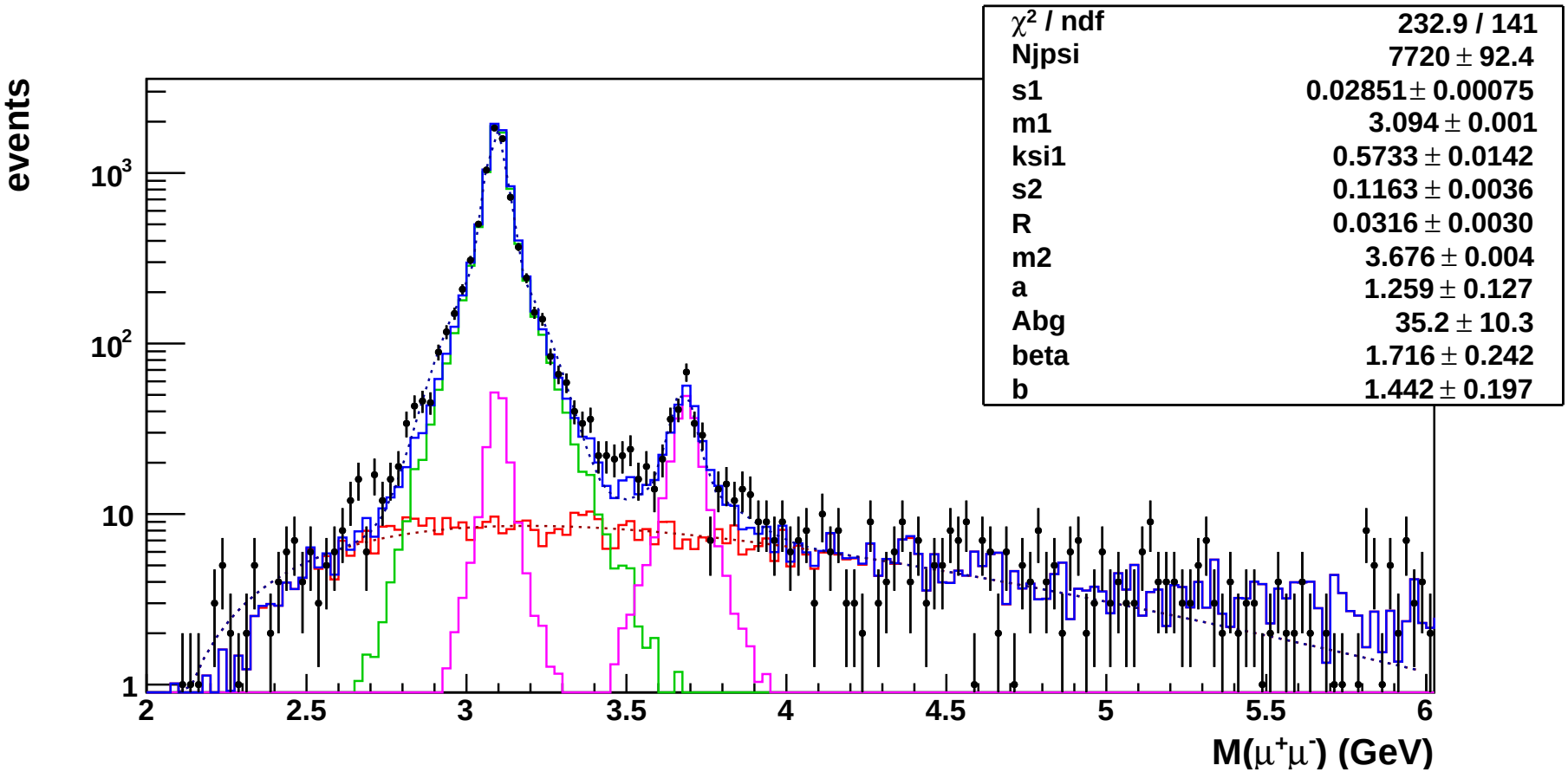
- upper row: $t_{rec} - t_{gen}$ and t_{rec}/t_{gen}
- lower row: profile plots: $t_{rec} - t_{gen}$ and t_{rec}/t_{gen} vs. true t_{gen}

2-prong: di-muon mass distribution: **t1** bin



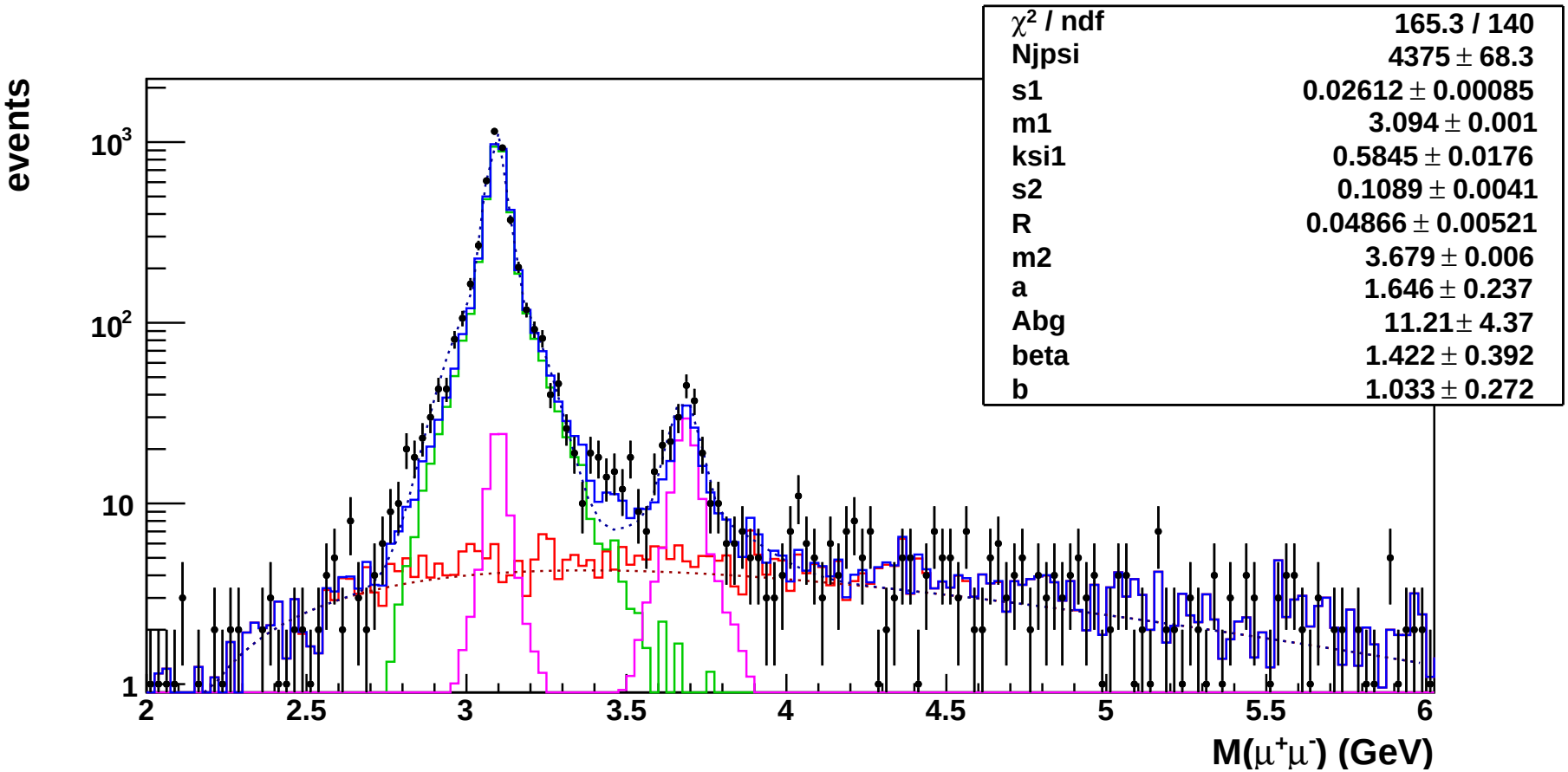
- low $|t|$ values $(0.0 - 0.2)$ GeV^2
- most contaminated by Bethe-Heitler background

2-prong: di-muon mass distribution: **t2** bin



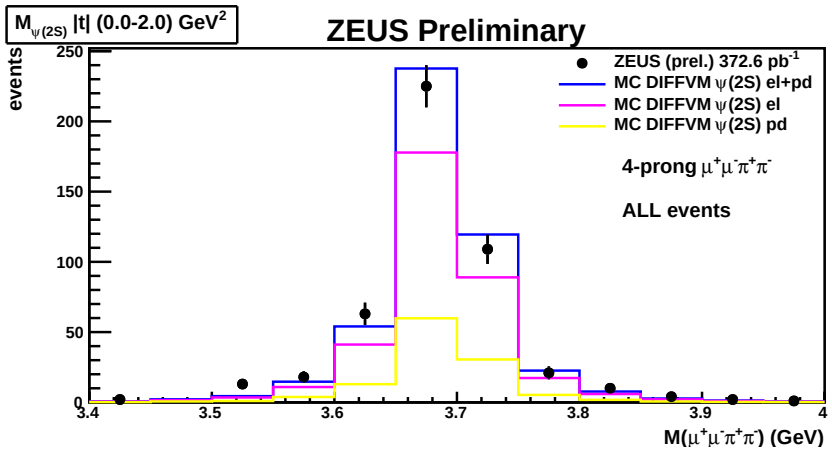
- middle $|t|$ values $(0.2 - 0.6)$ GeV^2
- some fluctuation between the peaks (?)

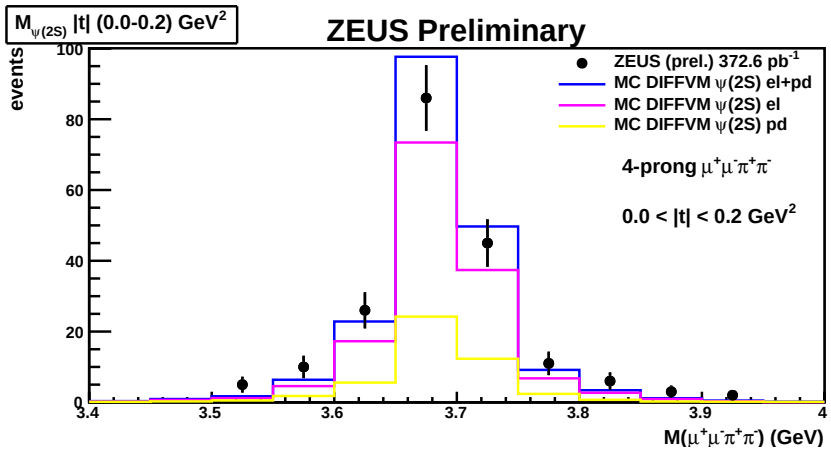
2-prong: di-muon mass distribution: **t3** bin

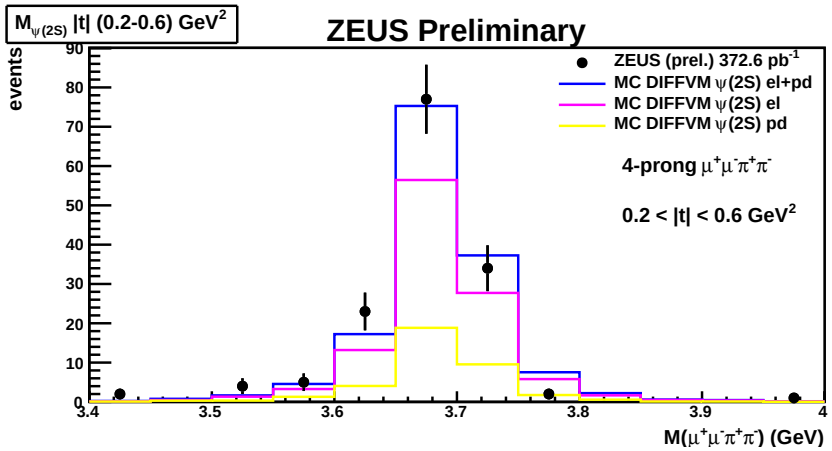


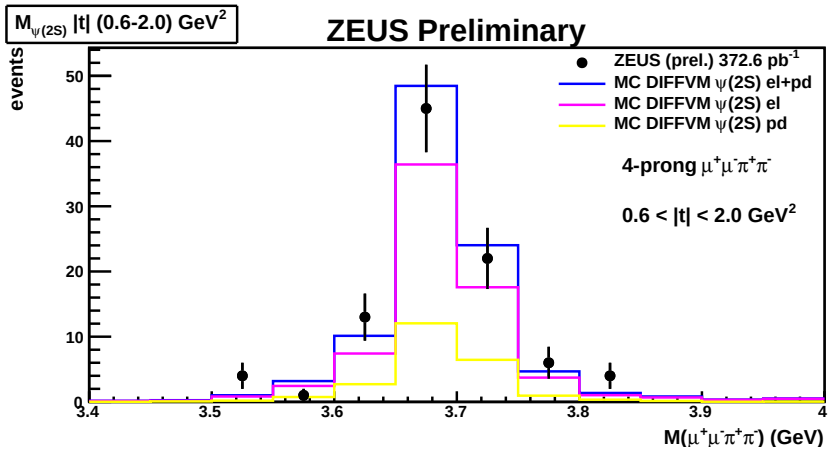
- high $|t|$ values $(0.6 - 2.0)$ GeV^2
- best χ^2 value
- very low BH background

4-prong: di-muon mass distribution in $|t|$ bins



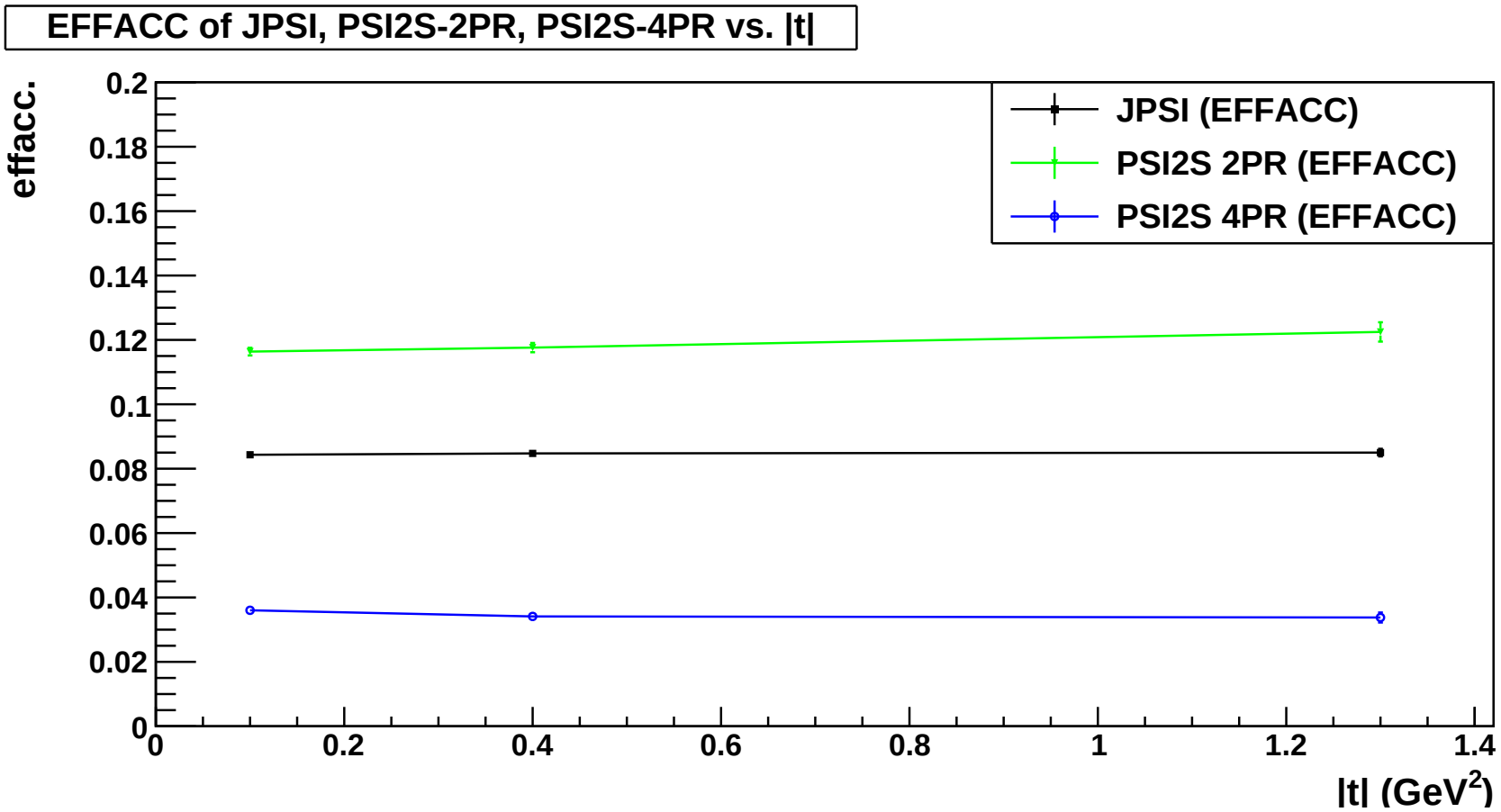






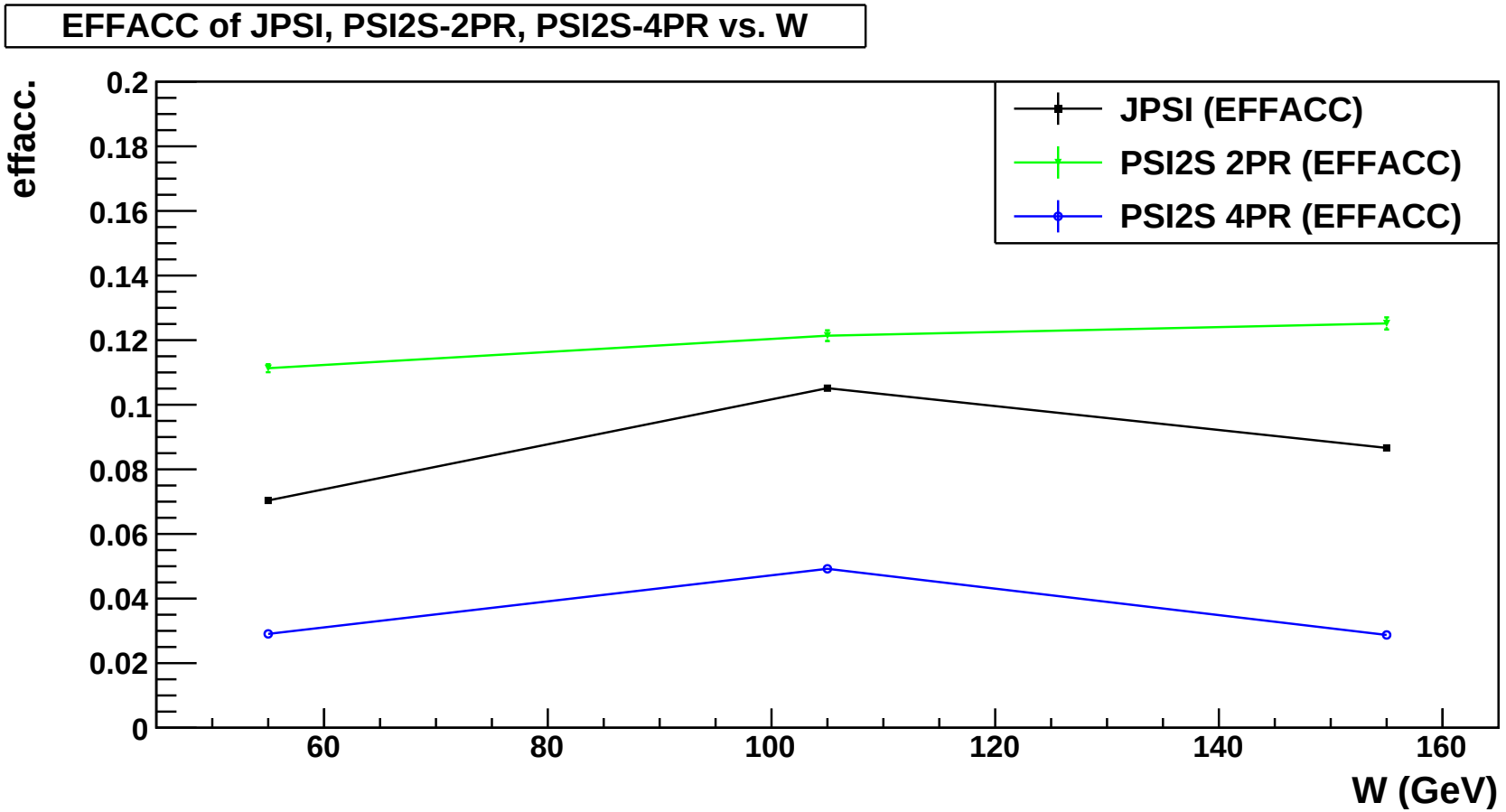
- all events and in **t1, t2, t3** bins
- assuming $f_{p.diss} = 0.25$

Efficiency*acceptance in $|t|$ bins



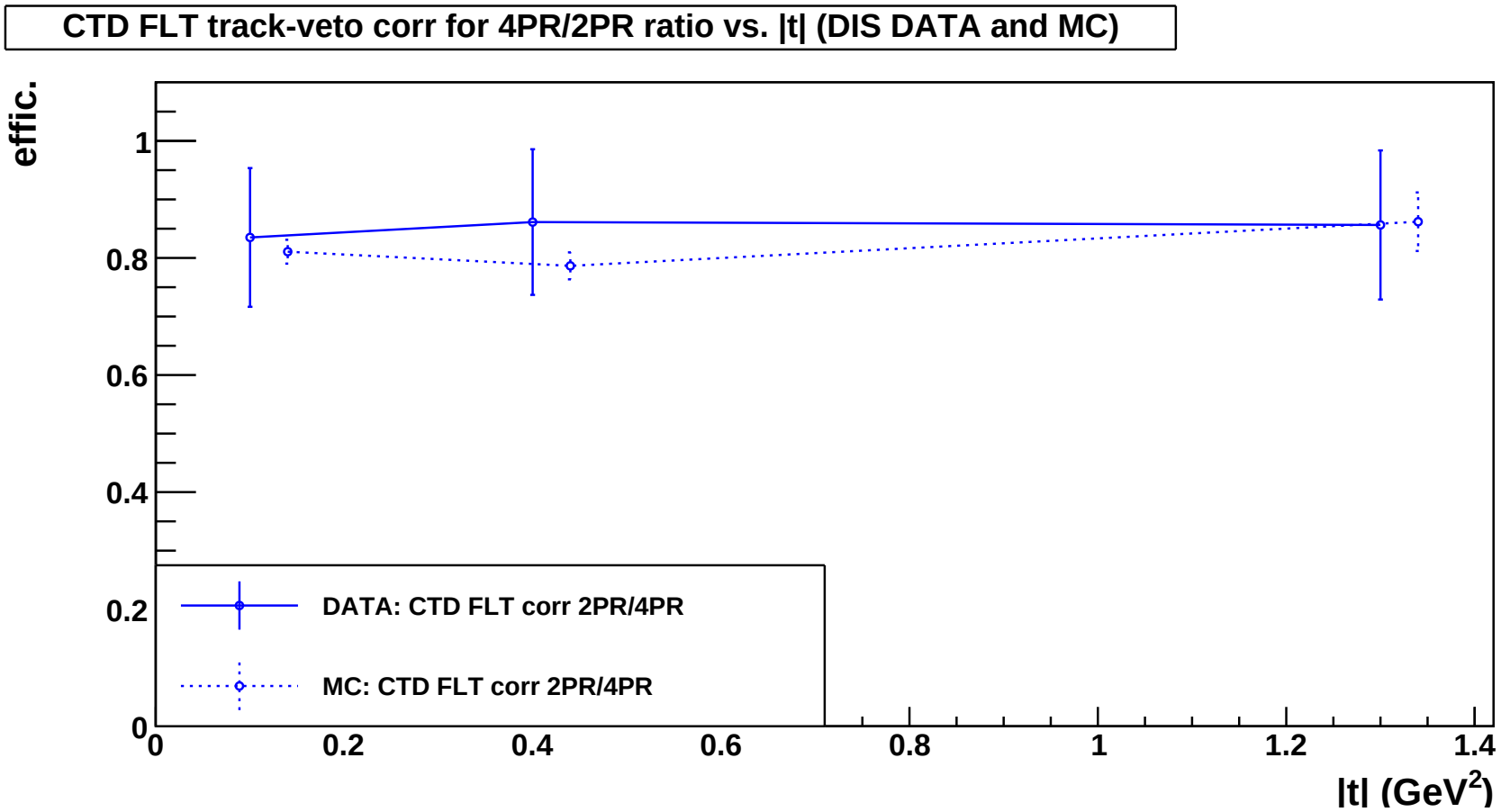
- Green: direct $\psi' \to \mu^+\mu^-$
- Black: $J/\psi \to \mu^+\mu^-$
- Blue: 4-prong $\psi' \to \mu^+\mu^- + \pi^+\pi^-$

Efficiency*acceptance in W bins



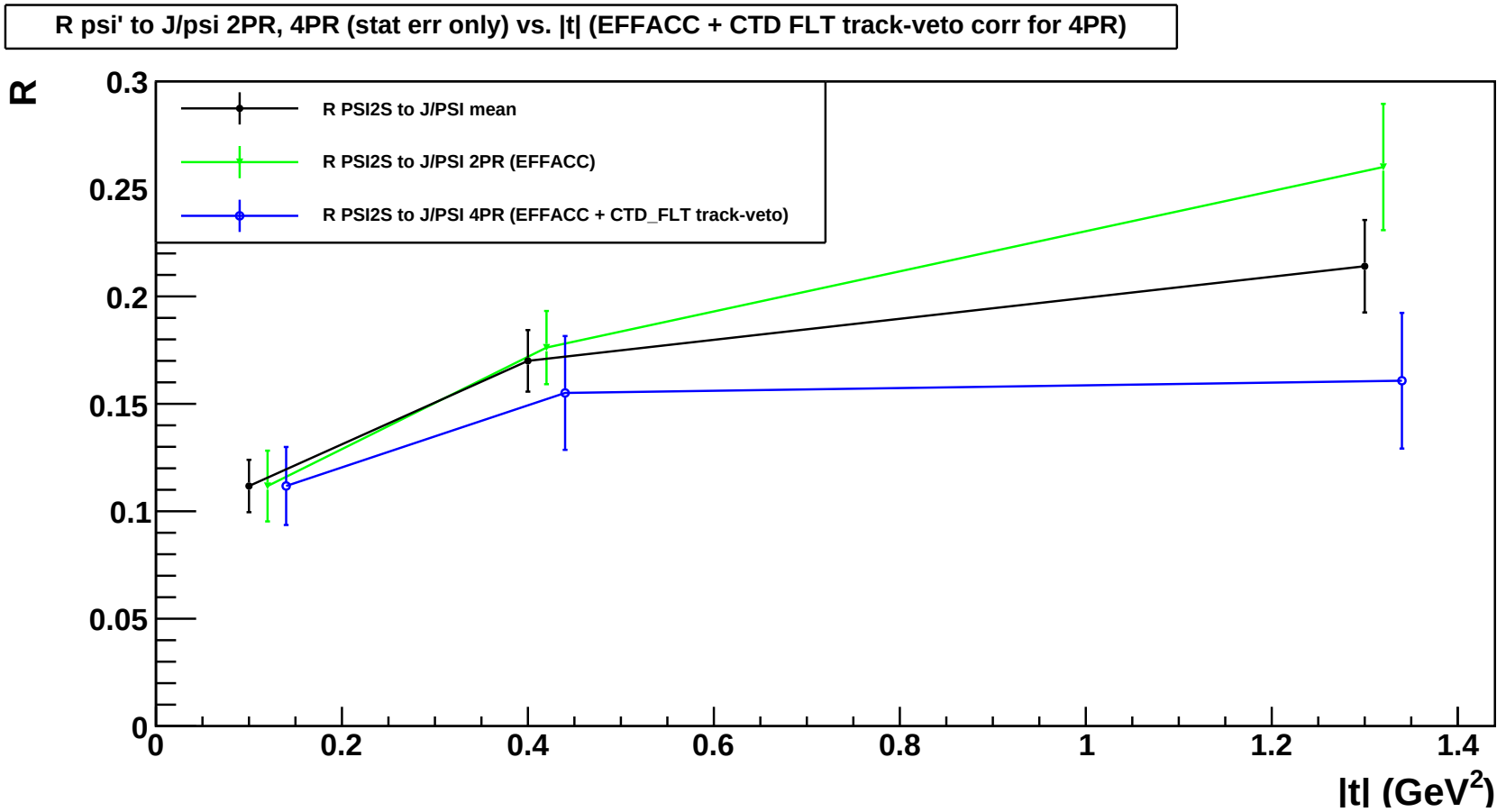
- Green: direct $\psi' \to \mu^+\mu^-$
- Black: $J/\psi \to \mu^+\mu^-$
- Blue: 4-prong $\psi' \to \mu^+\mu^- + \pi^+\pi^-$

CTD FLT track-veto correction in $|t|$ bins



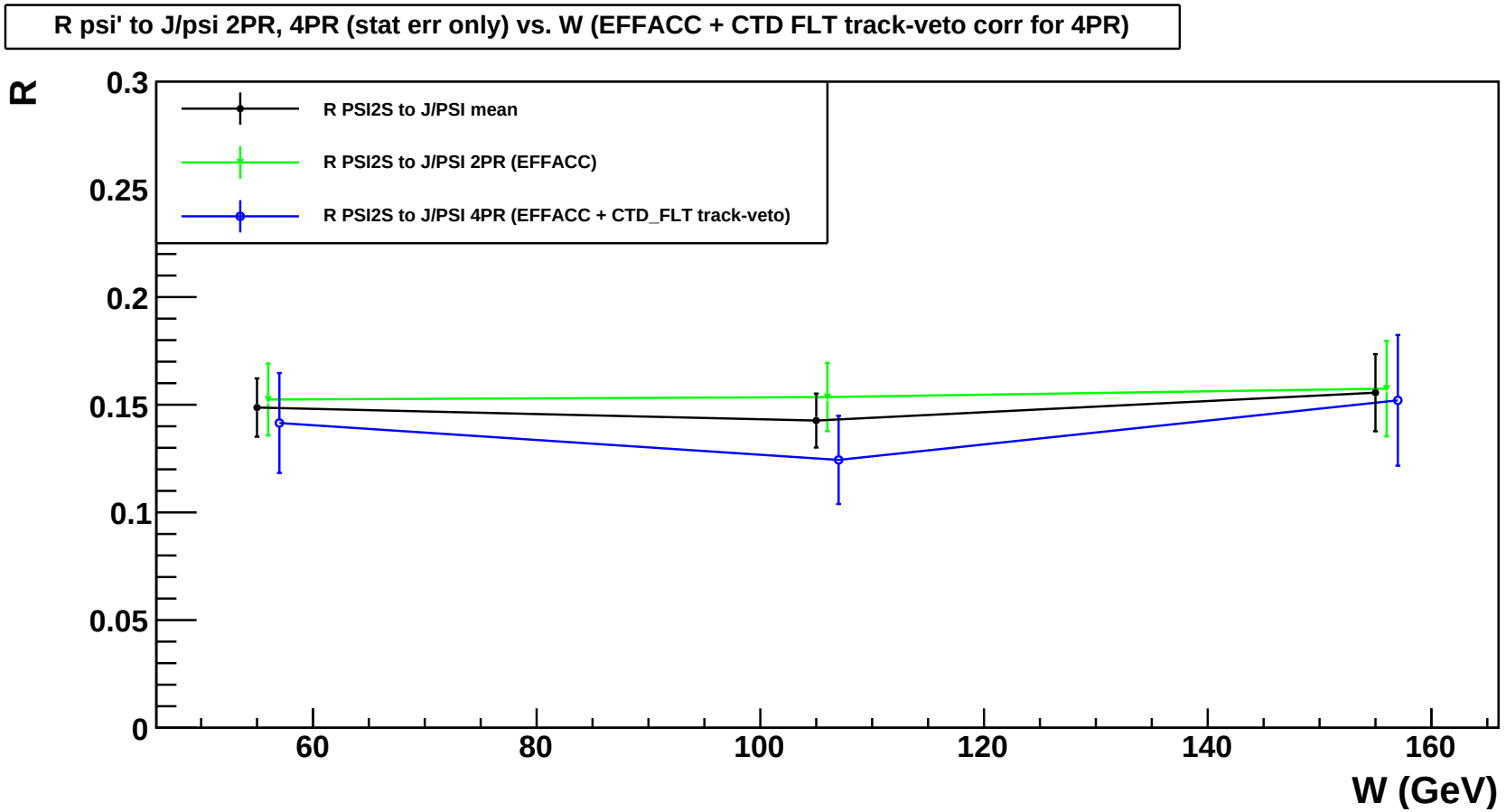
- extracted from DIS data and MC w.r.t. the FLT30 slot (no track to e' electron !)
- the actual correction is DATA/MC double ratio $\rightarrow$ consistent with 1.0
- big errors (limited DIS statistic...)

R: ψ' to J/ψ ratio in $|t|$ bins



- events corrected for effic*acceptance and CDT FLT track veto
- number of events corrected for BR (ratio of xsec.)
- Green: 2-prong, Blue: 4-prong, Black: weighted mean value
- some tension in high $|t|$ bin... ($\chi^2/NDF = 5.8/3$)

R: ψ' to J/ψ ratio in W bins



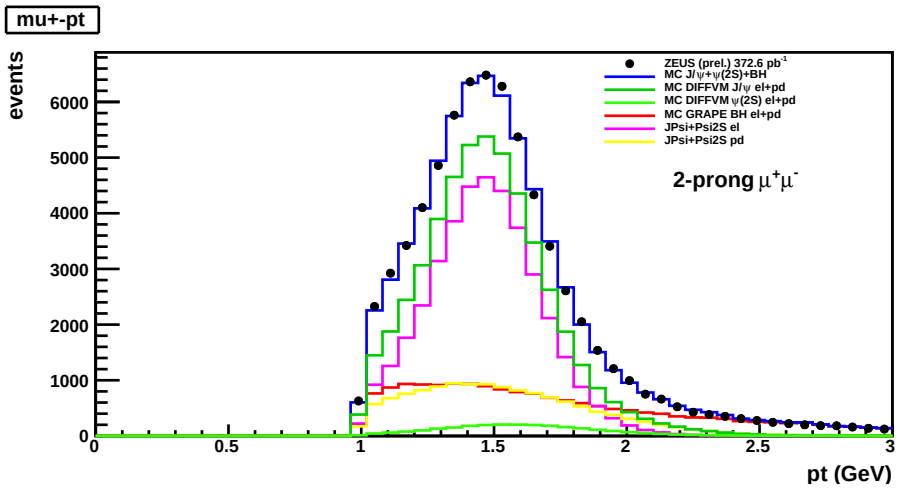
- events corrected for effic*acceptance and CDT FLT track veto
- number of events corrected for BR (ratio of xsec.)
- Green: 2-prong, Blue: 4-prong, Black: weighted mean value

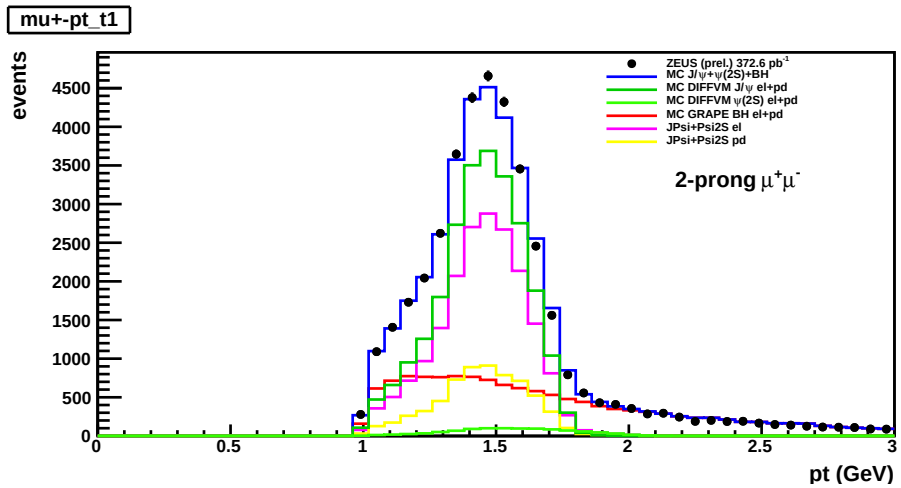
R: ψ' to J/ψ tension in last $|t|$ bin

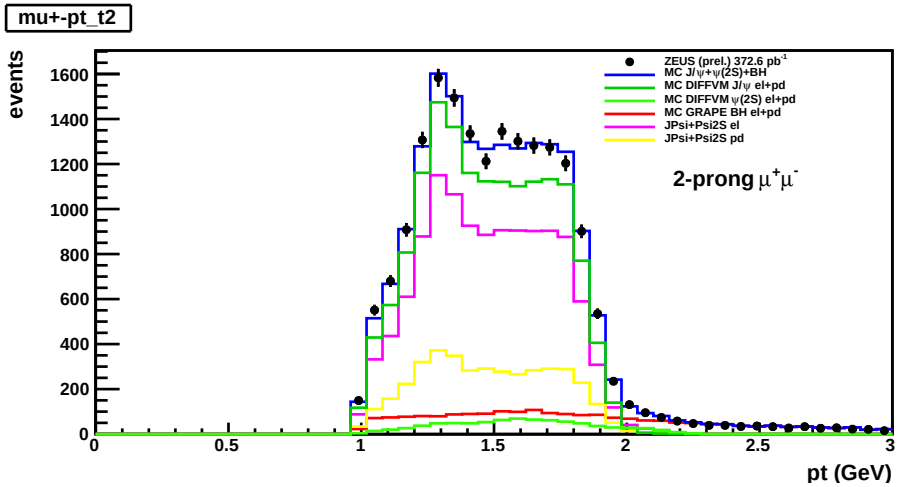
- effect is very stable, persisted after several checks:
- MC composition used to extract the efficiency maps (elastic, elastic + p.diss)
- different muon momentum parameterization (p, pz) in FORWARD muon
- different grid size: (pt, eta, ... bins)
- different reweighting of $|t|$-slopes ($\exp(-b|t|)$) in MC
- (modifications of phase space for muon efficiency calculation)

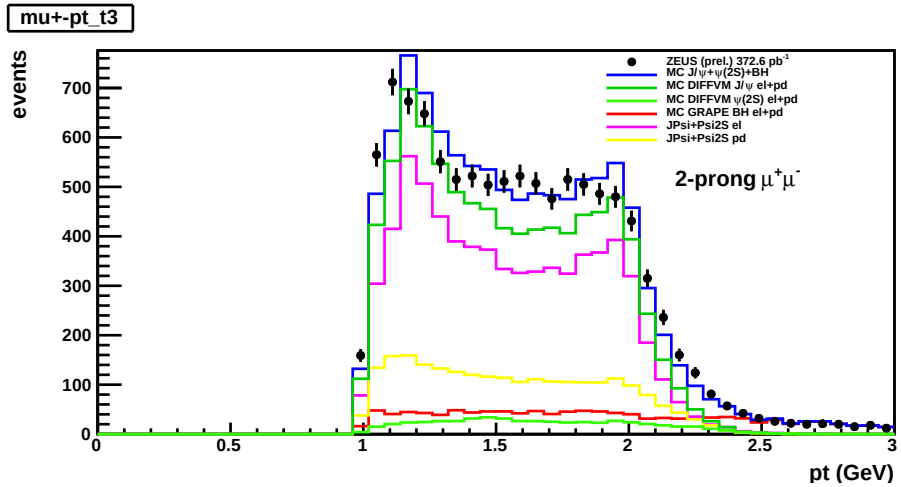
- possible explanation : not sufficient statistic for muons from direct $\psi' \to \mu^+\mu^-$ decay (upper half of "banana" shape)
- MC (after muon corrections) underestimates the efficiency for hard muons $\to$ to high corrected number of events for 2-prong ψ' (?)

Muon ($\mu^{\pm}$) p_t in t bins (all 2-prong events)



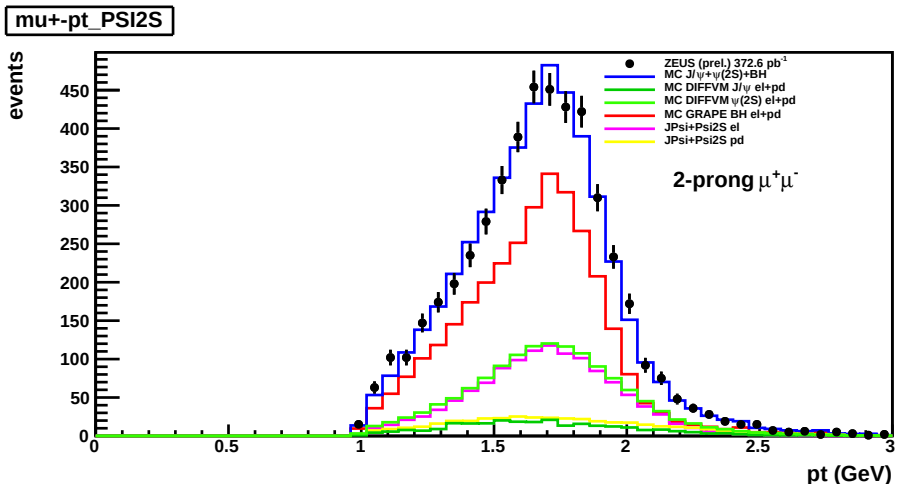


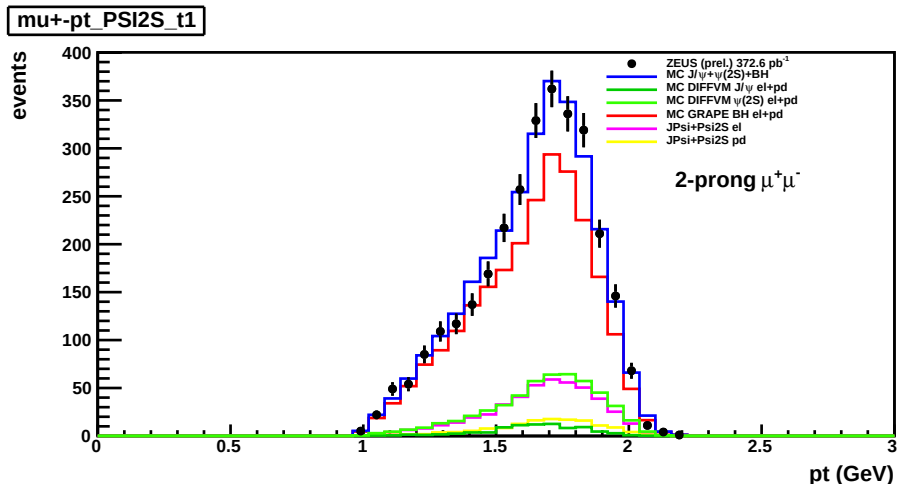


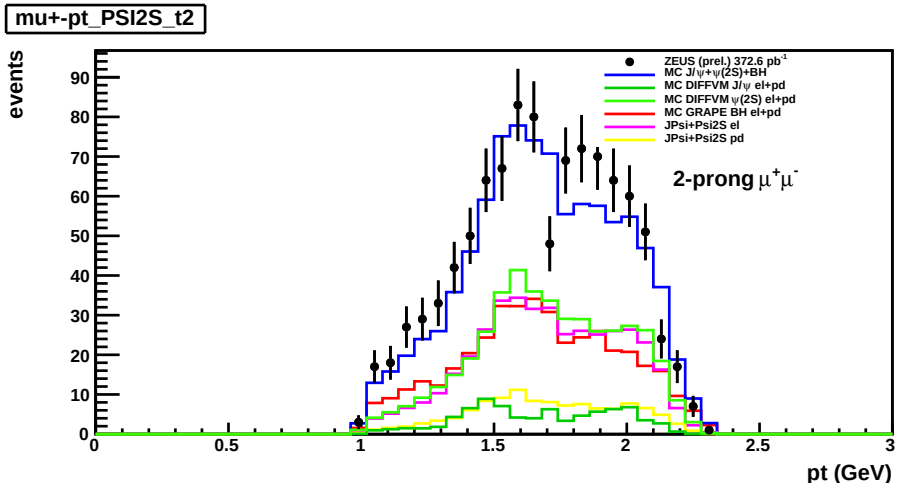


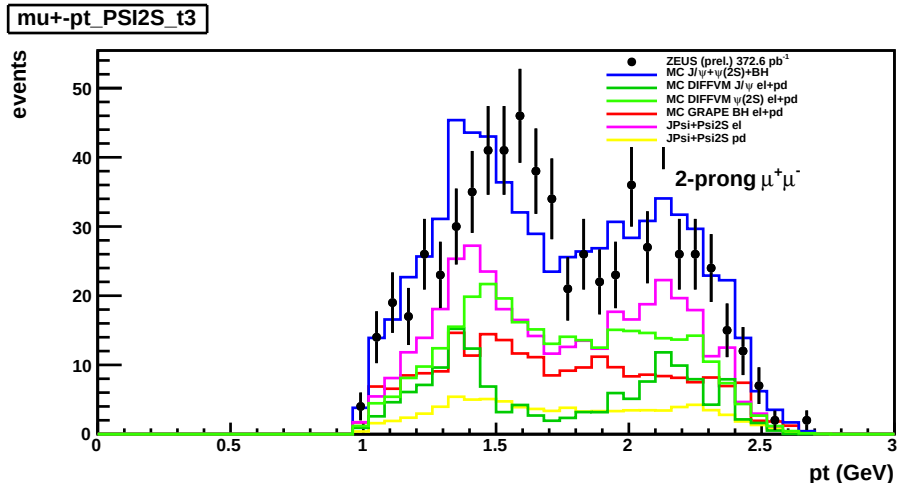
- all events and in **t1, t2, t3** bins
- (MC normalized to no. of events from mass `TFractionalFitter`)
- some discrepancy in last $|t|$ bin

Muon ($\mu^{\pm}$) p_t in t bins (ψ' 2-prong events)



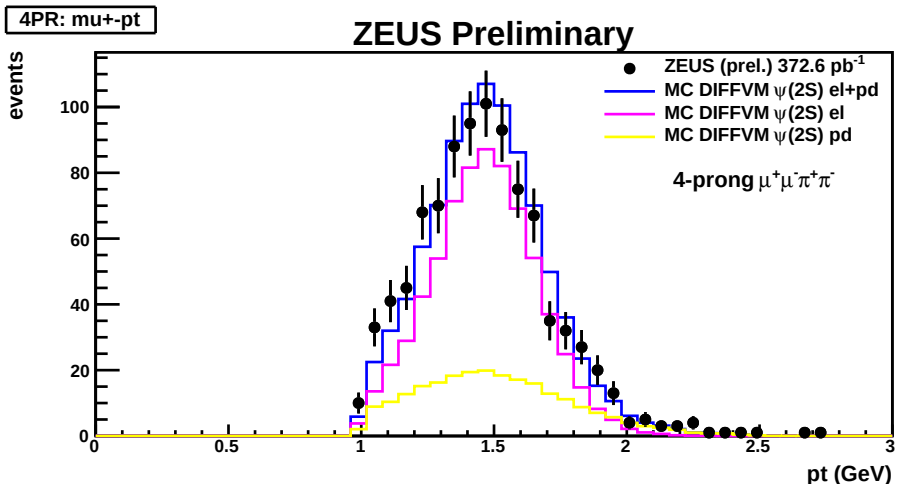


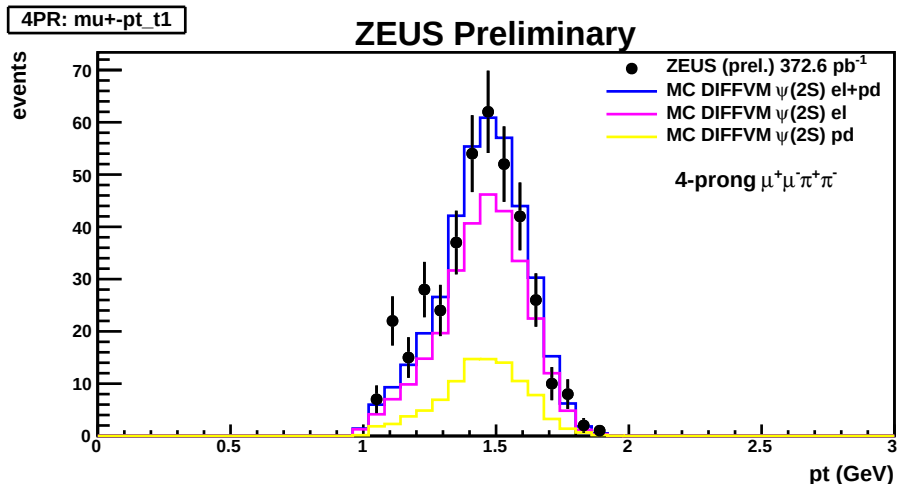


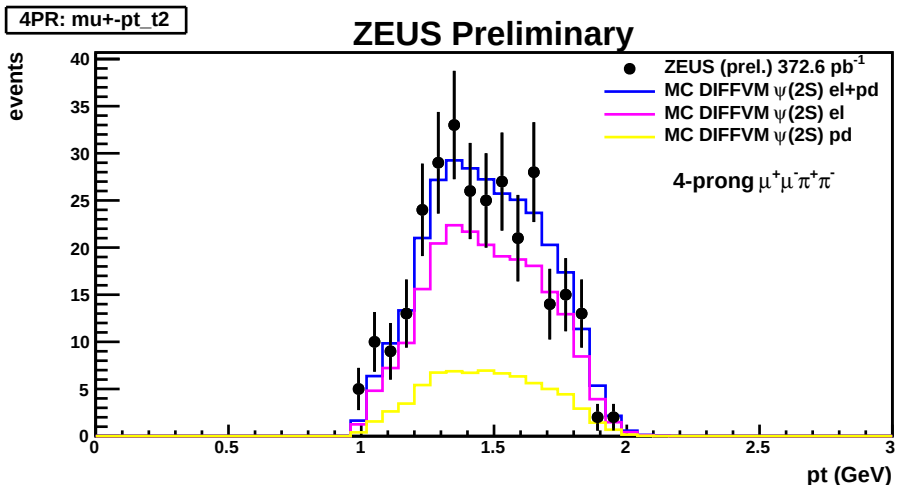


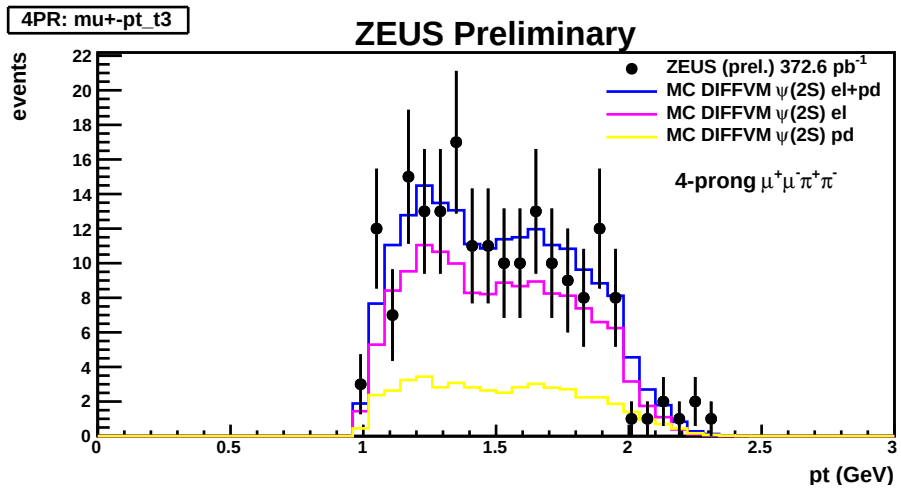
- ψ' 2-prong events: all events and in **t1, t2, t3** bins
- muons from direct decay: $\psi' \to \mu^+\mu^-$
- some discrepancy in last $|t|$ bin

Muon ($\mu^{\pm}$) p_t in t bins (ψ' 4-prong events)



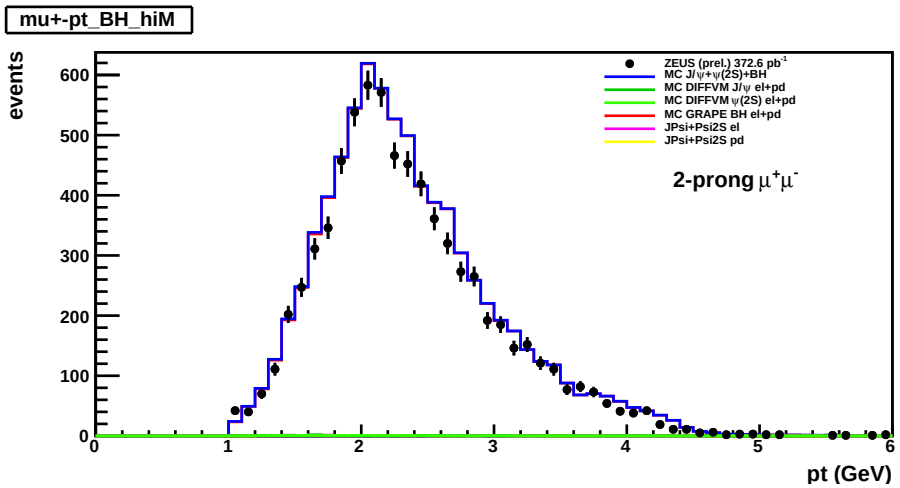


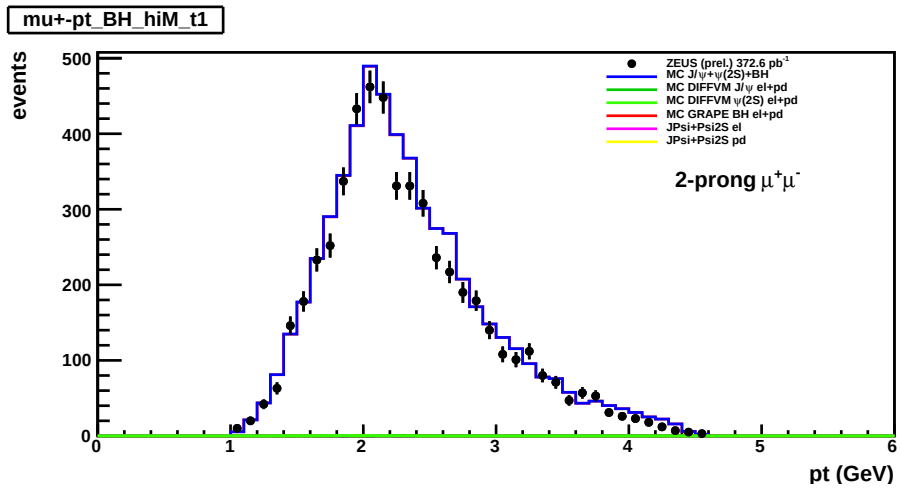


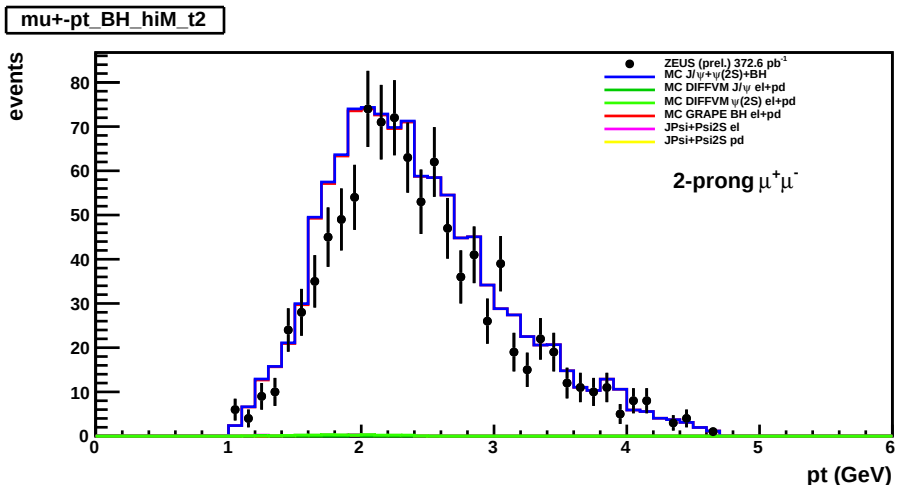


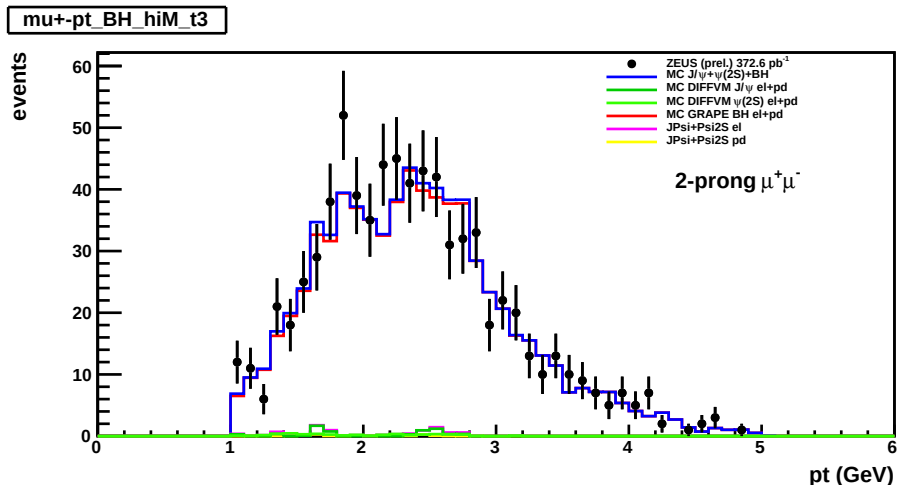
- ψ' 4-prong events: all events and in **t1, t2, t3** bins
- muons from cascade decay: via $J/\psi \to \mu^+\mu^-$ (softer)
- agreement in all $|t|$ bins

Muon ($\mu^{\pm}$) p_t in t bins (BH-hiM events)









- Bethe-Heitler high-Mass: all events and in **t1, t2, t3** bins
- BUT: BH populates a bit different phase space... (smaller θ angles)

Conclusions/Plans

- ψ' to J/ψ ratio was studied in $|t|$ bins
- some tension between 2- and 4-prong channel for high-t bin
- effect is very stable against many systematics checks
- still under investigation...

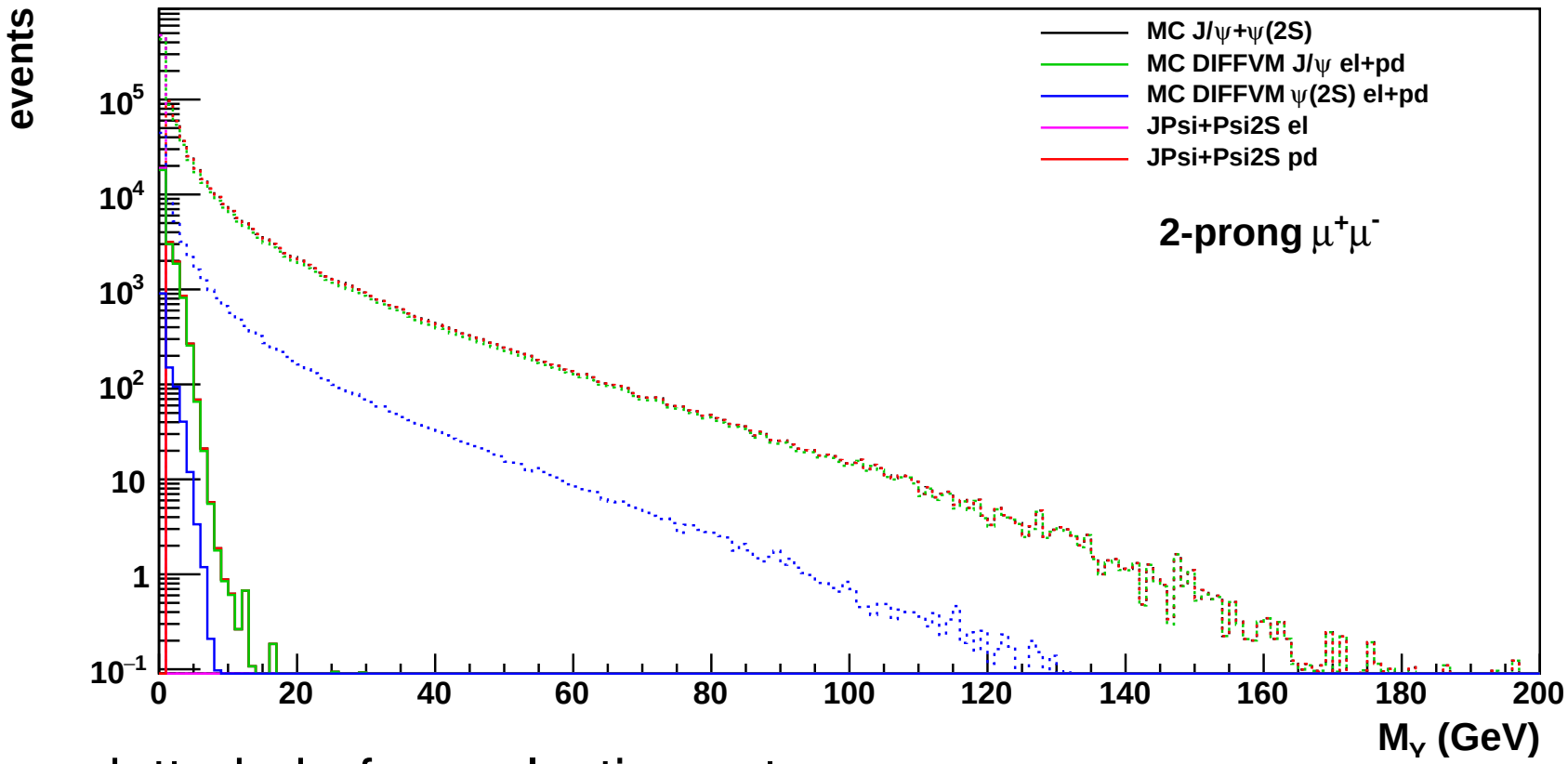
- next steps:
- systematics
- theory predictions on top of R plots

BACKUP PLOTS

- see next pages...

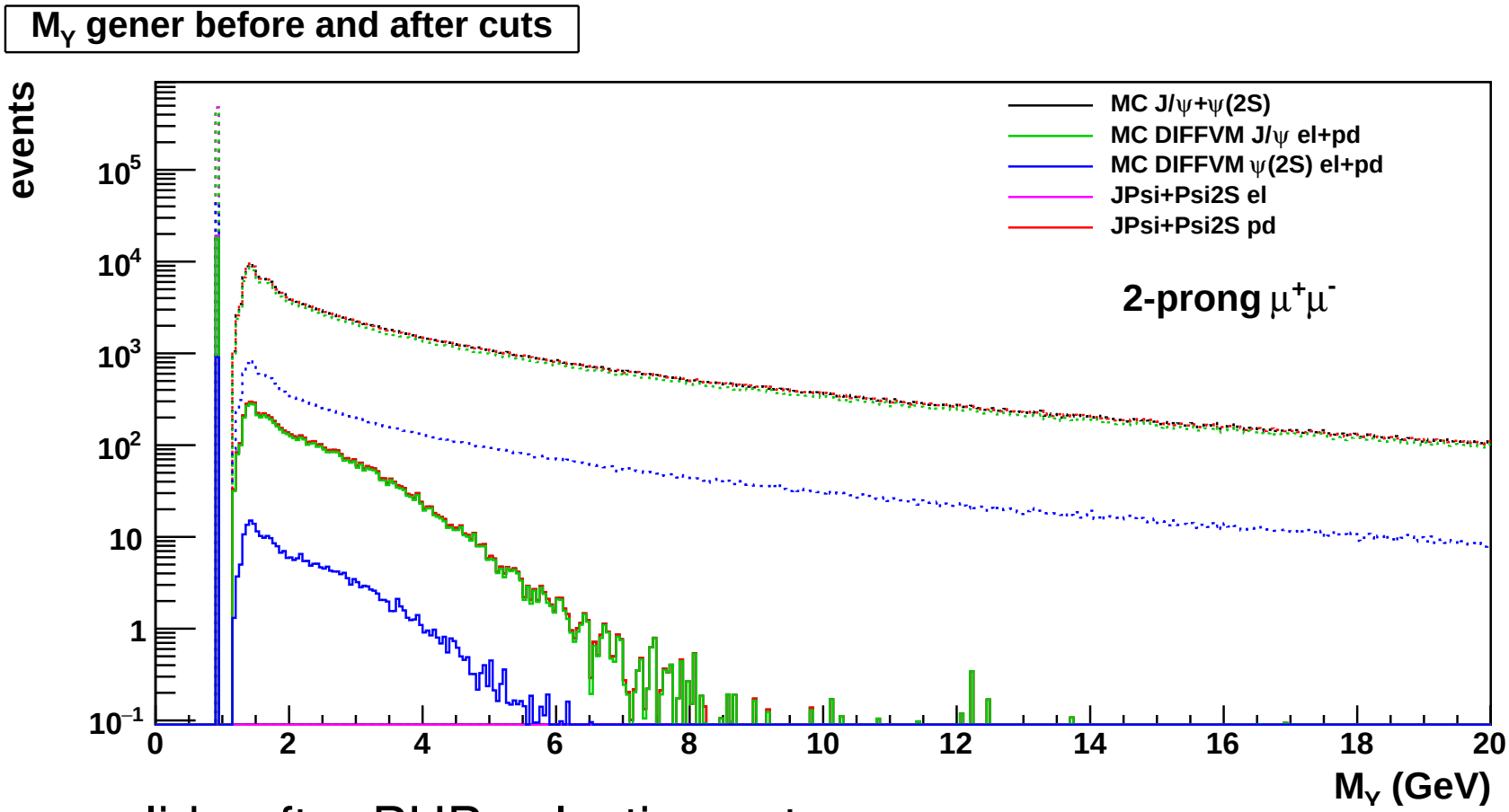
M_Y distribution: full kinematic range

M_Y gener before and after cuts



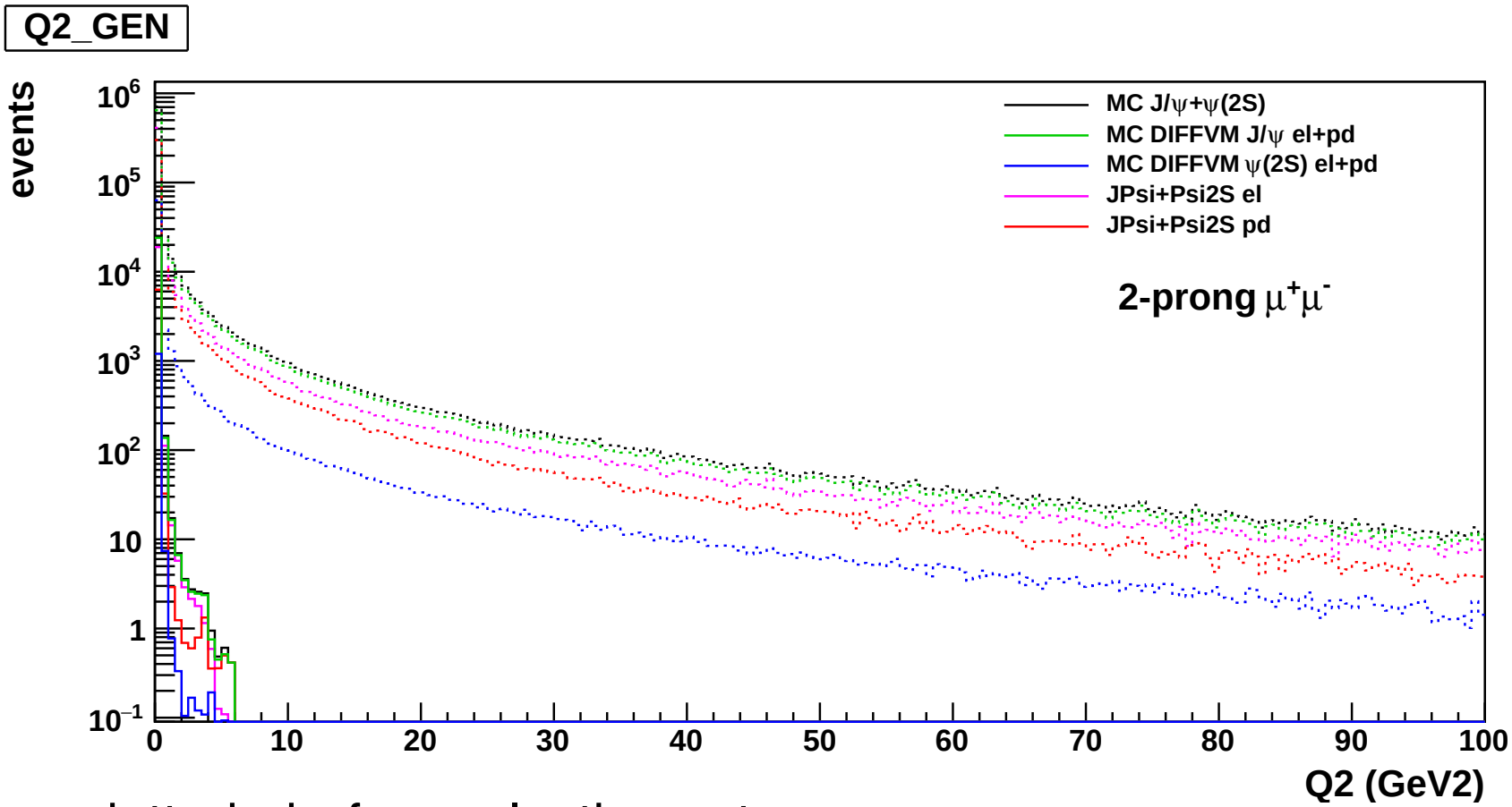
- dotted : before selection cuts
- solid : after selection cuts

M_Y distribution: zoom for low-M_Y



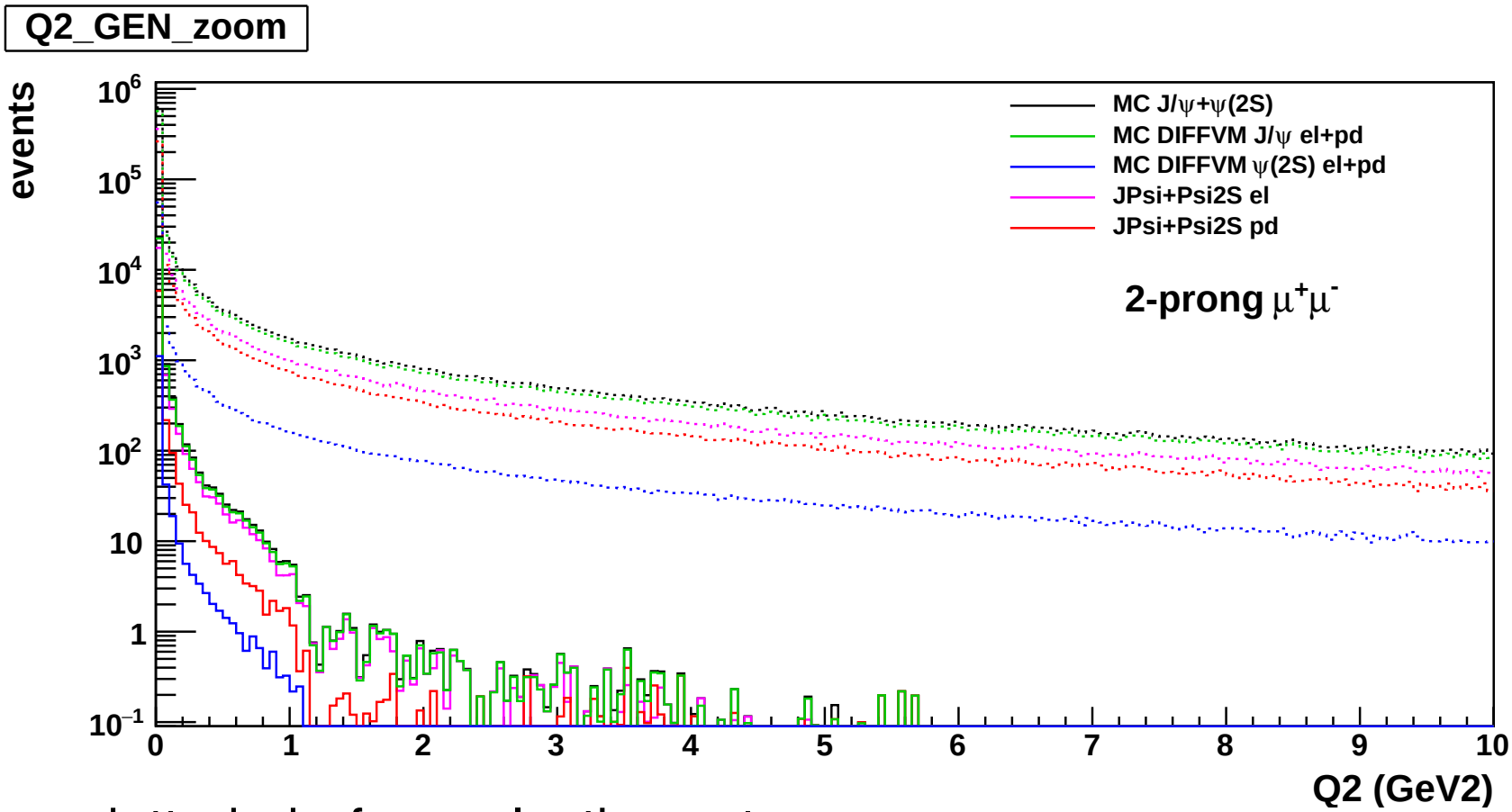
- solid : after PHP selection cuts
- mean M_Y : 2.28 GeV (for p.diss processes: J/ψ plus ψ')
- median M_Y : 2.00 GeV
- Quantiles: 90%, 95%, 99% : (3.57, 4.12, 5.36) GeV

Q^2 distribution: full kinematic range



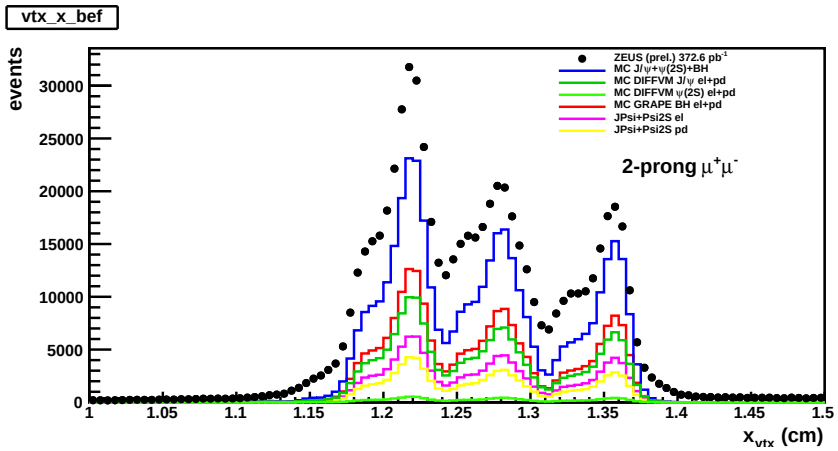
- dotted : before selection cuts
- solid : after PHP selection cuts

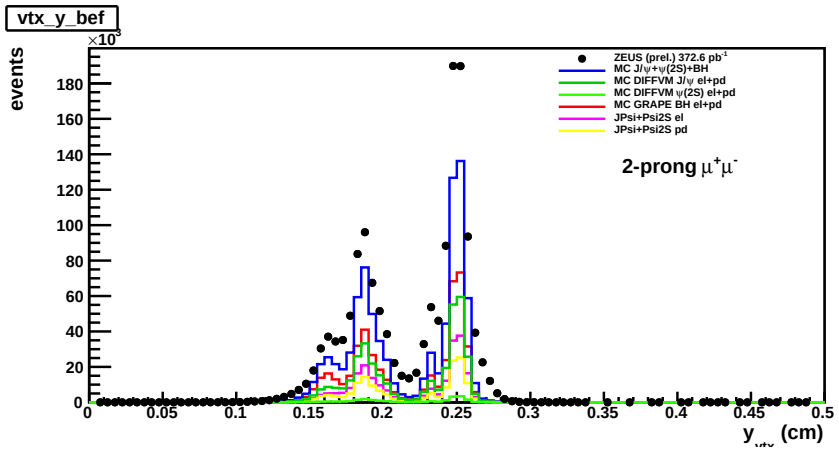
Q^2 distribution: zoom for low-Q^2

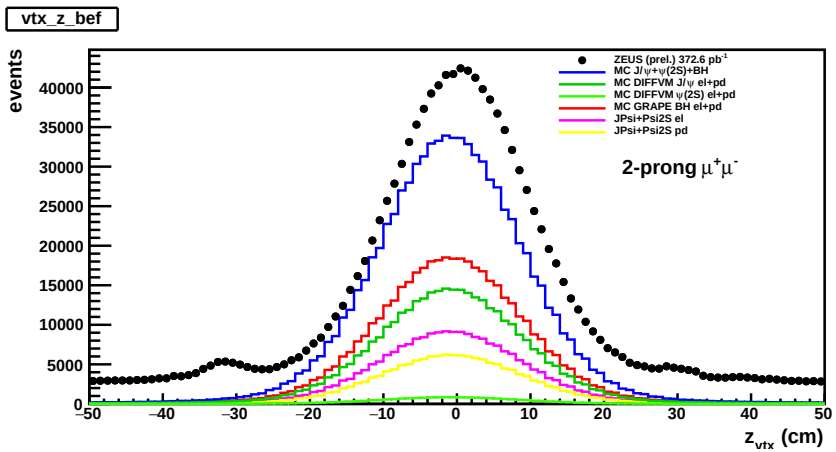


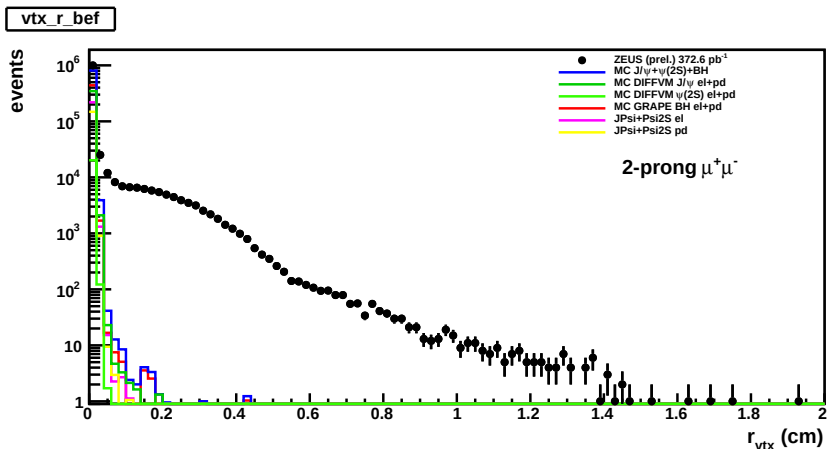
- dotted : before selection cuts
- solid : after PHP selection cuts
- mean Q^2 : 0.02 GeV^2 (for elastic VM)
- median Q^2 : 3.2×10^{-5} GeV^2 (for elastic VM)

2-PRONG: Vertex distribution before clean-up cuts



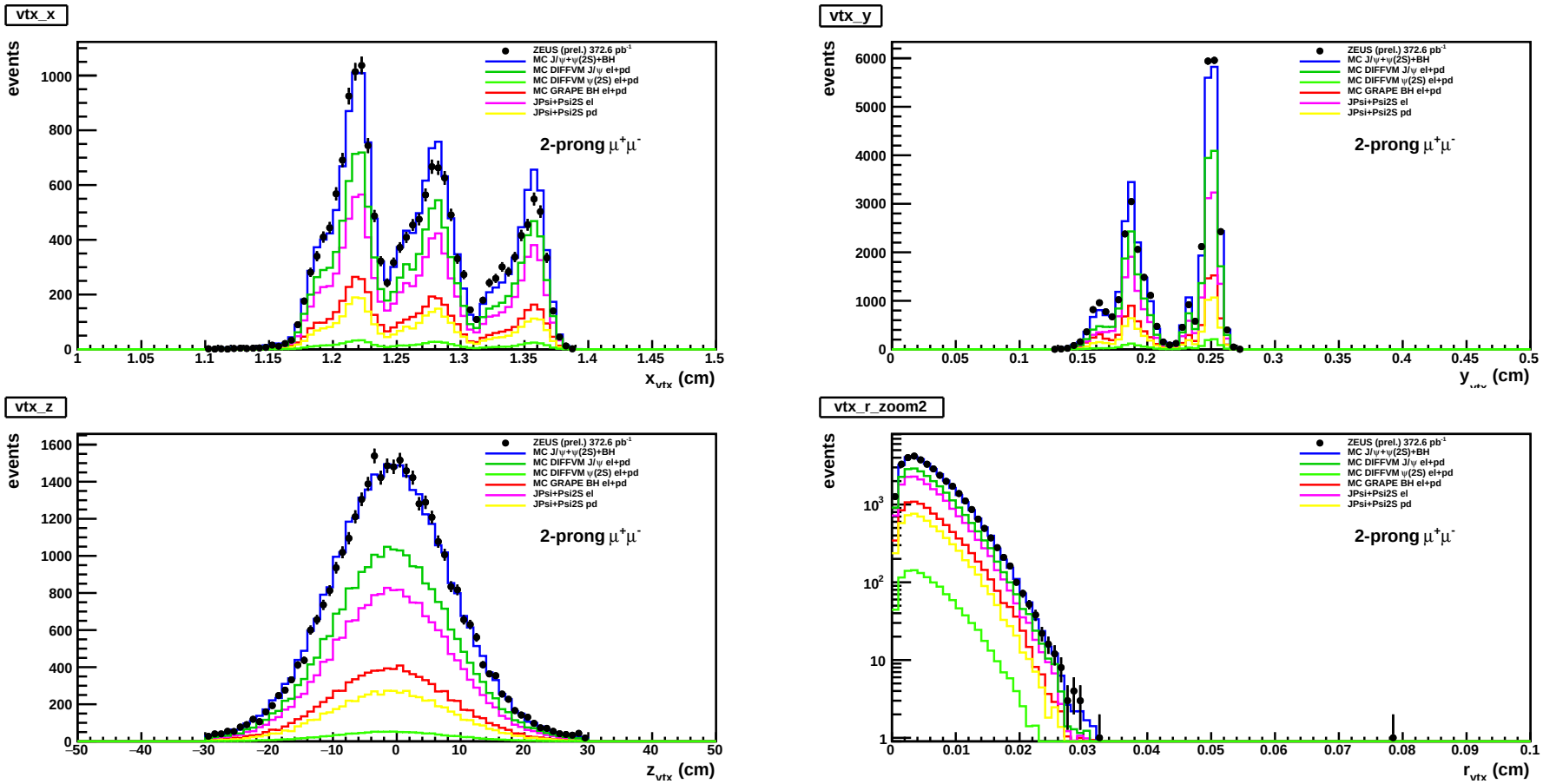






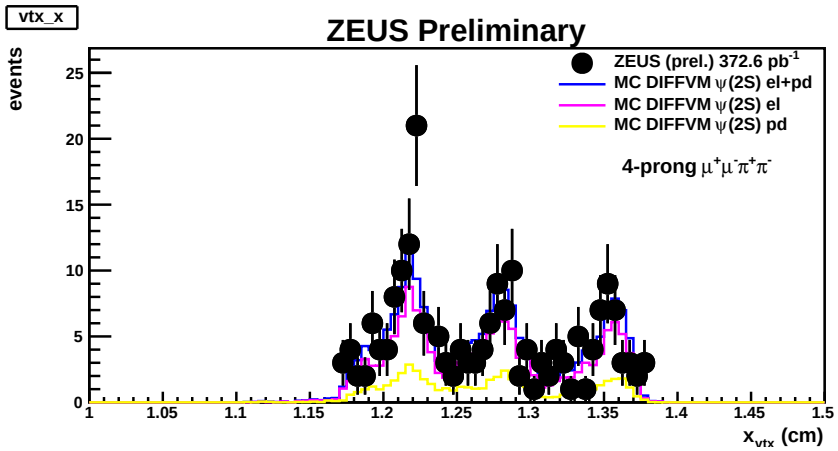
- DATA points before clean-up cuts (only 2-prong selection)
- $x_{vtx}, y_{vtx}, z_{vtx}, \rho_{vtx} = \sqrt{(x_{vtx} - x_{bspt})^2 + (y_{vtx} - y_{bspt})^2}$ (cm)
- $x_{vtx}, y_{vtx} \rightarrow$ beam-spot distribution, well described in MC

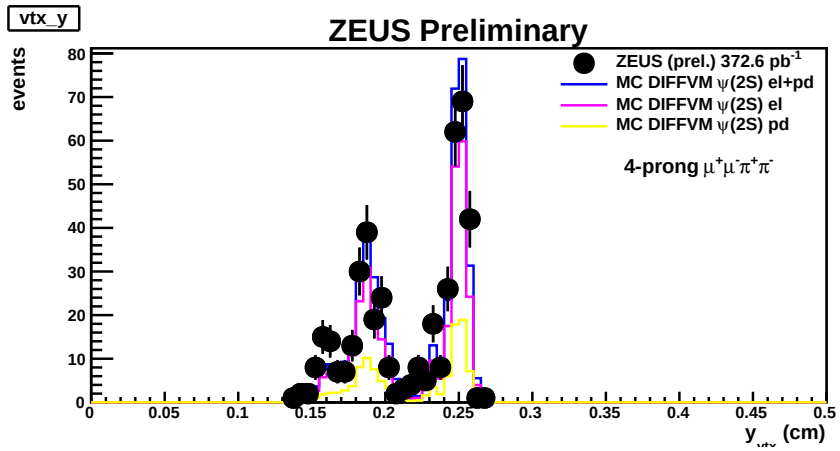
2-PRONG: Vertex distribution after clean-up cuts

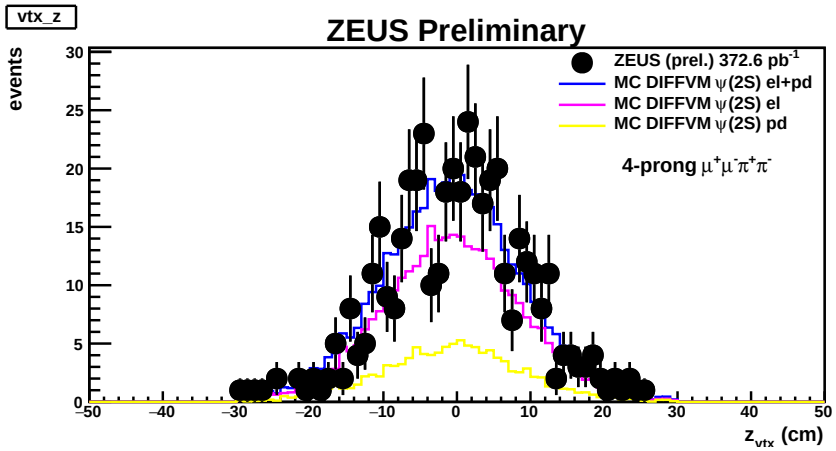


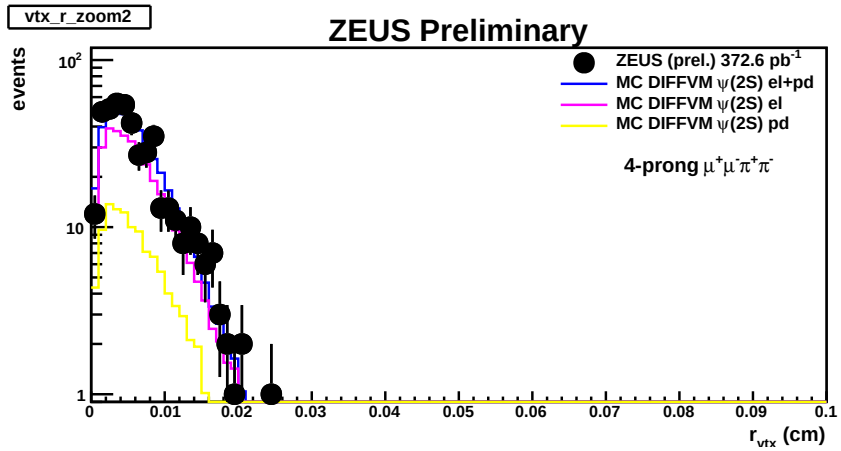
- DATA/MC after all selection cuts (2-prong sample)
- $x_{vtx}, y_{vtx}, z_{vtx}, \rho_{vtx} = \sqrt{(x_{vtx} - x_{bspt})^2 + (y_{vtx} - y_{bspt})^2}$ (cm)
- $x_{vtx}, y_{vtx} \rightarrow$ beam-spot distribution, well described in MC

4-PRONG: Vertex distribution after clean-up cuts









- DATA/MC after all selection cuts (4-prong sample)
- $x_{vtx}, y_{vtx}, z_{vtx}, \rho_{vtx} = \sqrt{(x_{vtx} - x_{bspt})^2 + (y_{vtx} - y_{bspt})^2}$ (cm)
- $x_{vtx}, y_{vtx} \rightarrow$ beam-spot distribution, well described in MC