Summary of electron studies & $\tau \longrightarrow e$ MC study

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OPERA Collaboration Meeting – LNGS – 15/06/2011

Electron Group : Physics motivation & status of studies

- **ν_e (see Carlo's talk)**
- **$\tau \rightarrow e$**
  - 18% of τ decay
  - Decay search tool development in progress (Ariga & Florian)
  - Shower reconstruction tools are ready. Data/MC comparison to be done (Frank, Carlo)
  - Efficiency study ongoing (Umut, Budimir, Florian)
  - BG study to be done (Florian)
- **$\tau \rightarrow h$ (Nγ)**
  - 37% of $\tau \rightarrow 1h$ - P_T cut 300MeV/c with γ, 600MeV/c without.
  - establish a detection/energy algorithm for low energy γ (<2GeV/c) (Nakatsuka, Kitagawa)
  - γ pointing (Nakatsuka, Kitagawa, Tomoko, Ariga)
  - close contact with $\tau \rightarrow h$ group.

Outline

- Electron studies
  - MC Efficiency (Umut, Budimir, Florian) (see Andrea's talk)
  - CS shower study (Umut, Kitagawa, Fabio) (see Carlo's talk)
  - Extended Scanback (Matteo)
  - $\tau \rightarrow e$ MC study
    - Decay search tool (Ariga, Florian)
    - Daughter electron energy estimation (Florian)
- Gamma studies
  - π^0 mass reconstruction (Tomoko)
  - Gamma pointing accuracy (Nakatsuka)

ELECTRON STUDIES

MC Study

MC OpEmuRec efficiency

Umut
Budimir
Florian

	Surviving Brick Finding	*At least 1 CS track*	*At least one scanback track in Plate number < 55*	Location efficiency : MC true = Rec vertex plate
Numu-CC	***0.786***	***0.744***	***0.705***	
Numu-NC	***0.545***	***0.463***	***0.438***	
Tau-e DIS	***0.677***	***0.638***	***0.572***	
Tau-e QE	***0.629***	***0.496***	***0.419***	
Nue DIS		***0.694***	***0.665***	
Nue QE	***0.681***	***0.664***	***0.632***	

Brick Finding under investigation

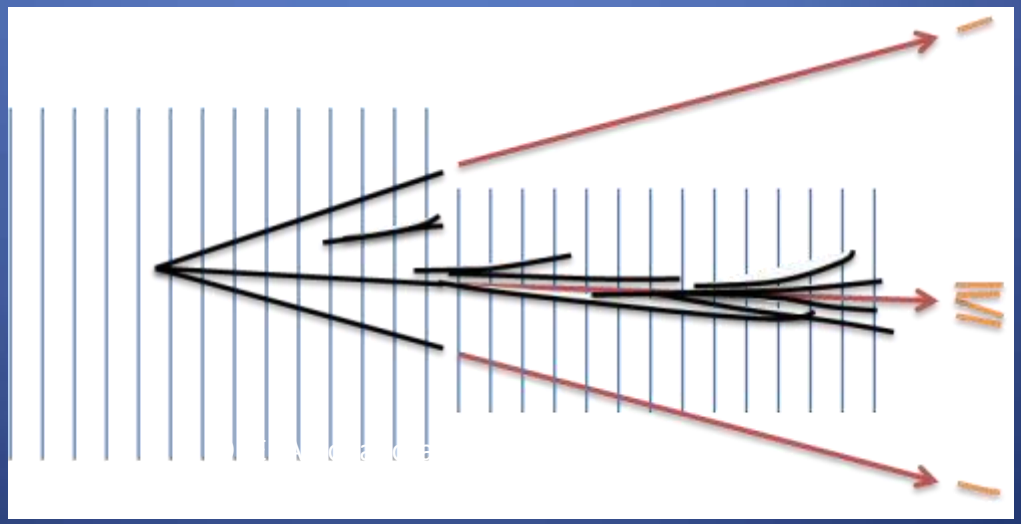
NEW !

nbers:

Type	BF	CS	SB(pl<55)	SB Pl<55 and dz(5plate)	vertex	Vertex Dr<1mm
numuCC	0.763	0.723	0.683	0.669	0.493	0.470
numuNC	0.555	0.466	0.435	0.383	0.306	0.269
Taue DIS*	0.667	0.619	0.557	0.480	0.374	0.254
Taue QE*	0.668	0.536	0.447	0.325	0.199	0.015
TauMu*	0.687	0.555	0.510	0.492	0.438	0.405
Tau1P*	0.642	0.599	0.558	0.524	0.539	0.452

CS shower study

- Purpose for both $\tau \rightarrow e$ and ν_e : improve electron ID
- For located events
  - Extrapolate 1ry tracks to CS. (no gamma)
  - Search shower on CS
  - If shower-like tracks are found on CS, open additional volume



CS shower study : Results

- Strategy and criteria defined from NC-like data → need MC study for tuning
- Number of events:
  - 553 located nue DIS (beam)
  - 526 located numuNC for BG

	Ntrk>=4 dr<2500	Ntrk>=5, dr<2500	Eff	BG, Ntrk>=4 dr<2500	BG, Ntrk>=5 dr<2500	BG rate
2mm150mrad	**409**	381	**0.74**/0.69	**46**	38	**0.09**/0.07
2mm250mrad	430	407	0.78/0.74	55	43	0.10/0.08
3mm150mrad	417	385	0.75/0.70	54	44	0.10/0.08
3mm250mrad	444	425	0.80/0.77	65	54	0.12/0.10

We decided a preliminary cut is :

Ntrk >= 4 CS tracks, $\delta\theta < 0.15$ rad, $\delta r < 1500$ microns

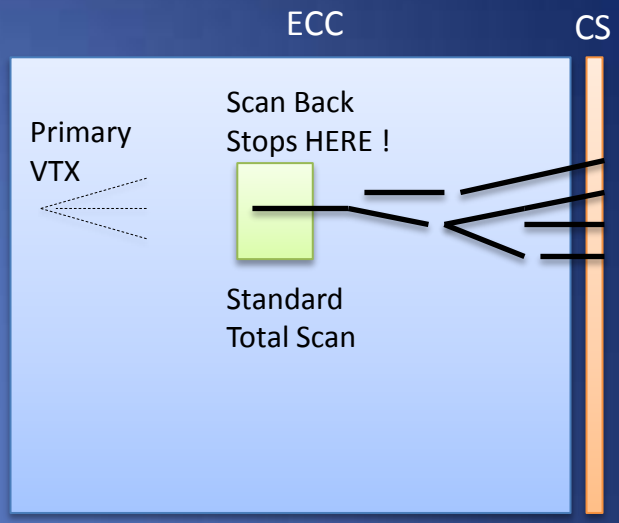
Next step : same study with oscillated ν_e

Shower-like Pattern Search from Scanback

Goal : recover events with e.m. shower for which the scanback fails to reach the primary vertex

How: search for shower-like pattern from scanback data

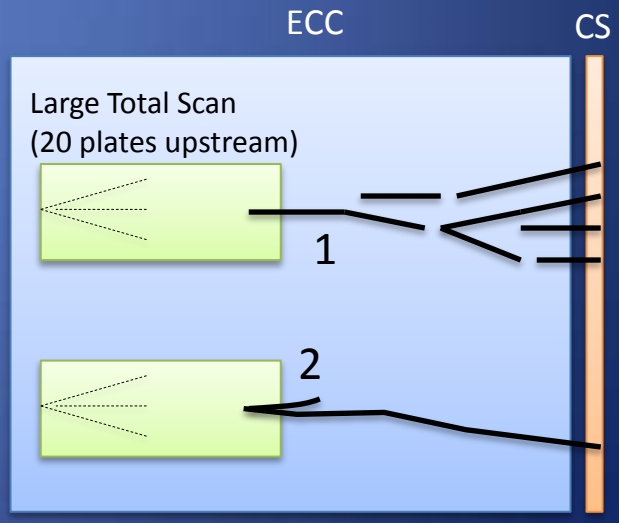
if a shower-like pattern is found the total scan volume is enlarged to include the primary vertex



A shower-like pattern could be defined according to one of the following ideas:

1. converging tracks
   some SB tracks (with similar angle) are converging to one or fewer tracks

2. e-pair
   an e-pair is confirmed by visual inspection at the stopping plate → study on going



Converging pattern in SB Results

Test to evaluate the trigger performance with MC data :
/sps/opera/operap/production/OpEmuIO/march2011/…/SB

MC DataSet	Events with >= 3 SB paths	Events with conv. track pattern	True Shower(*)	Fake(*)
TAUE	610	352	327 (93%)	25 (7%)
NC	331	91	68 (75%)	23 (25%)
CC	473	108	79 (73%)	29 (27%)

* 75% of path formed by joined SB tracks into a converging pattern are MC true electron tracks

We have a tool which can identify in the scanback electron showers with good purity

➔Try to recover non located events

e-pair study is on going

MC Study

Converging Pattern Efficiency

Preliminary

Sample: 1000 TAUE and TAUEQE events (/sps/opera/operap/production/OpEmuIO/march2011/TYPE/SB) taking into account **Oscillation Probability**

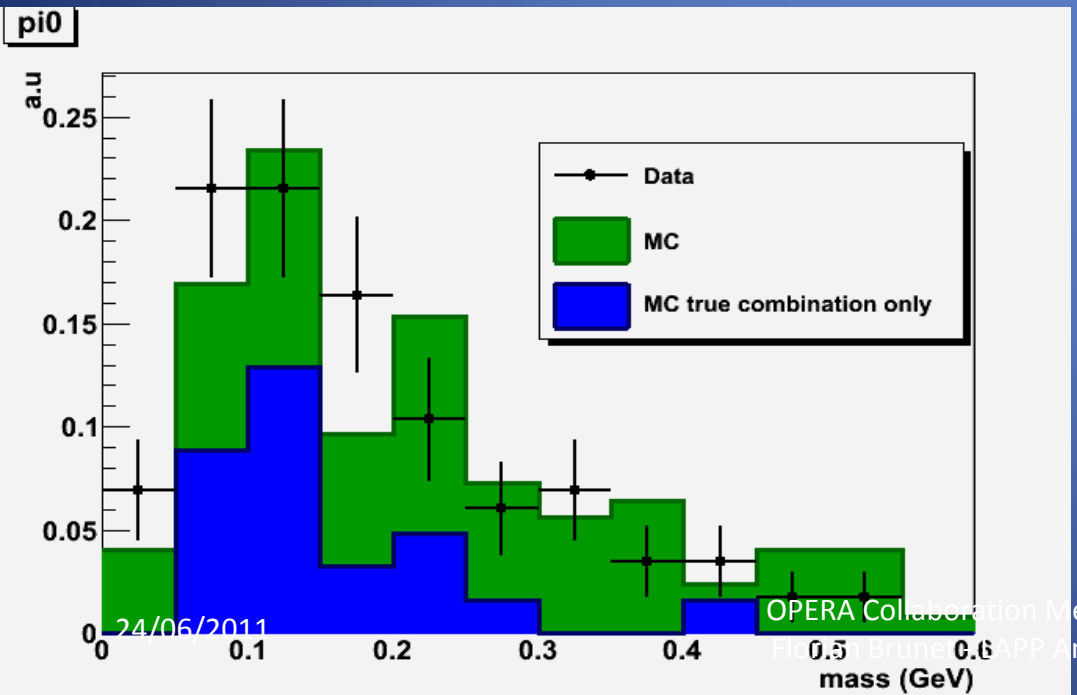
Type	TAUE	TAUEQE
At least one CS connected in brick conteining neutrino interaction	63.8%	49.6%
Neutrino interaction inside standard volume	49%	31%
Neutrino interaction not inside standard volume	14.8%	18.6%
Scanback with converging pattern	0.49%	0.7%
Vertex inside extended volume	0.25%	0.36%

Convering pattern efficiency is **very low** for TAUE and TAUEQE events not located with standard procedure. Probably because events not located with standard procedure are interactions in the upstream part of the brick and with an associated electron (daughter of tau) with low energy (see next slide)

GAMMA STUDIES

π^0 mass reconstruction

- Data reconstruction
  - γ search
    - Volume: 10 ~ 20 plates
    - Selection: IP < 250 μm & Nseg>=3 (track efficiency is about 85 % for 500 MeV)
  - energy is estimated by shower **algorithm**.
  - If shower tool fails → **MCS method** is used



Comparison with reconstructed MC

MC sample : 1000 numucc

Next step :

→ Increase MC statistics

→ Possible error if 1ry tracks inside shower

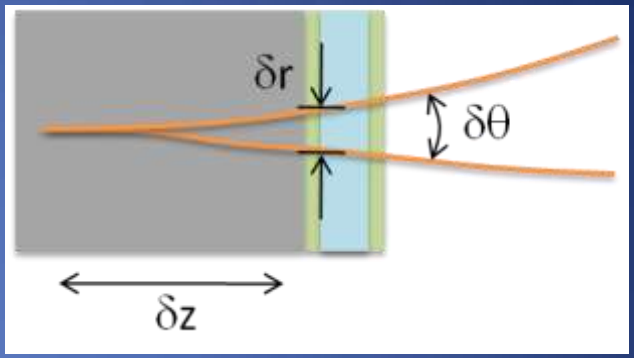
Tomoko
Nakatsuka
Ariga

Gamma pointing accuracy

- Goal:

  Parametrize pointing accuracy

  = f (E, δθ, δr)



- Pointing accuracy depends on E and δz in lead. δz can be estimated using opening angle (δθ) and distance (δr).

- A method to estimate δz has been defined

➔ Improvements are under study : use Energy for pointing estimation, neural network analysis

$\tau \rightarrow e$ efficiency MC study steps

- Brick Finding: ok
- Scanback : Extended volume for SB with converging pattern
- Total Scan : ok
- Decay Search : developing DS tool in parallel with charm WG
- Special volume = full brick : implementation done.
- Shower rec: OK for special volume. 2 brick reconstruction on going
- Energy measurement: OK
- Kinematical cuts: To be implemented.
- BG estimation: Not yet

MC Sample - OpRelease 4.0

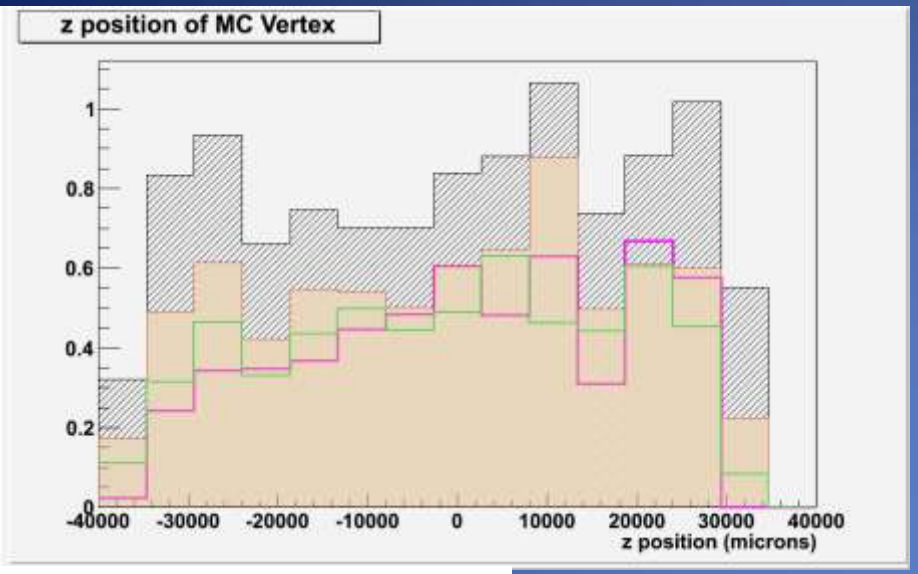
Samples of 1000 $\tau \rightarrow e$ DIS & QE produced by Elisabetta

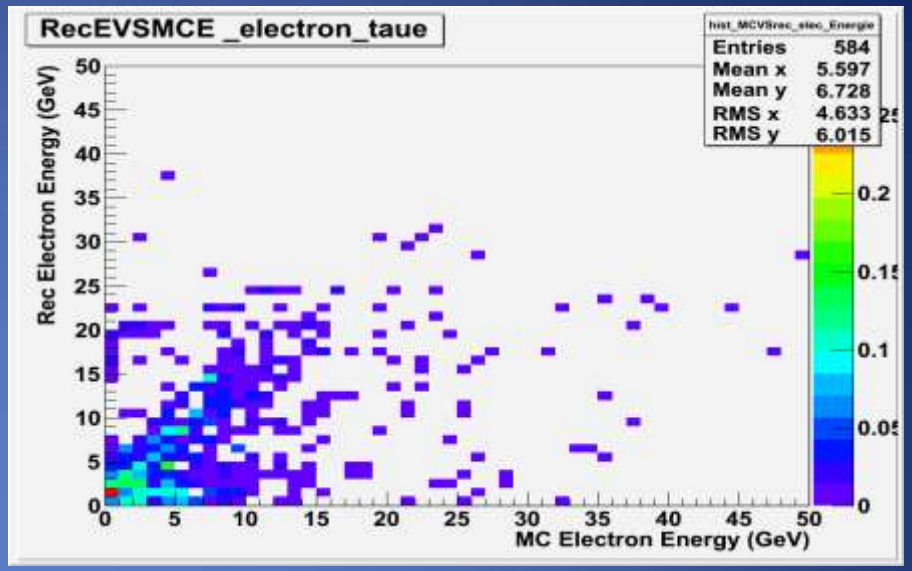
/sps/opera/operap/production/OpEmuIO/march2011/TAUE/DATA/tauefo remu_tgt1000_OpR4.0_rec_11.root

- Processed through OpEmuIO
- Processed through OpEmuRec packages : CS, Scanback, Link, Alignment, Track & Shower by using all plates available in the brick

- All packages up to OpEmuRec Track are taken from the release $GROUP_DIR/soft/OpRelease4.0_emulsion_march2011/
- OpEmuRec Shower is released here : /sps/opera/scratch/flbrunet/analysis/OpRelease_2011-04-04_OKwithShower/4.0/OpEmuRec/

$\tau \longrightarrow e$ DIS channel



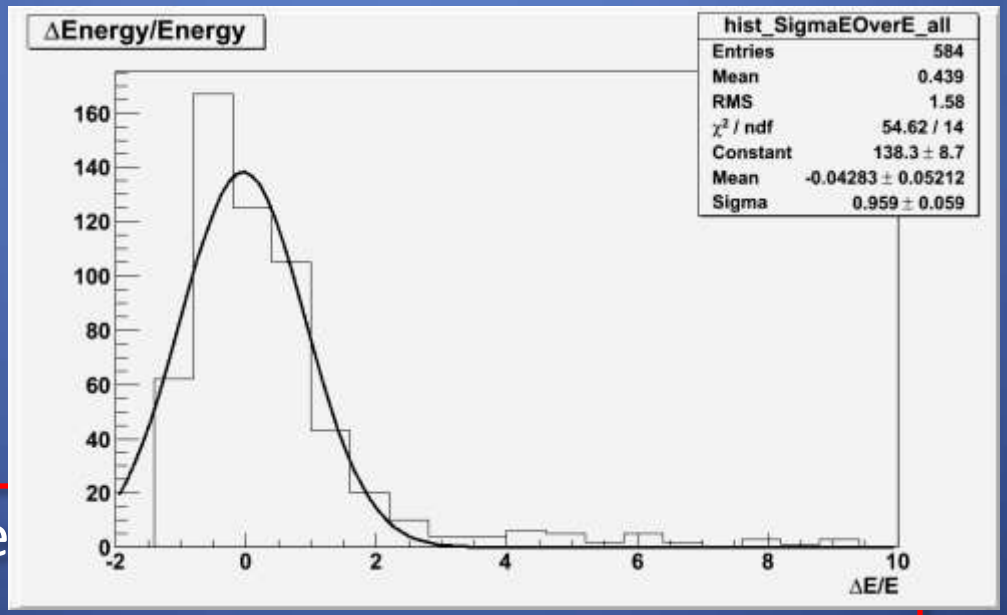


Z MC truth vertex

Z MC truth vertex BF OK

Z MC truth vertex SB OK

Z 1st BT of shower



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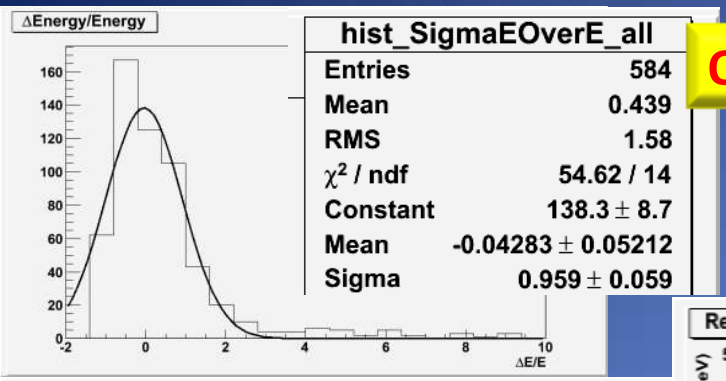
τ⟶e DIS channel : contamination pion



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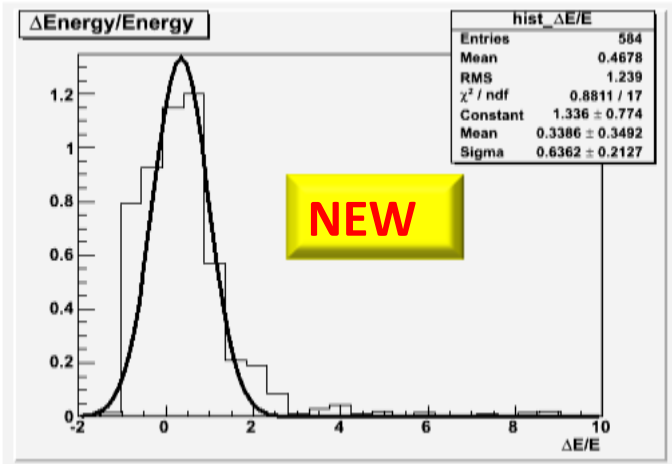
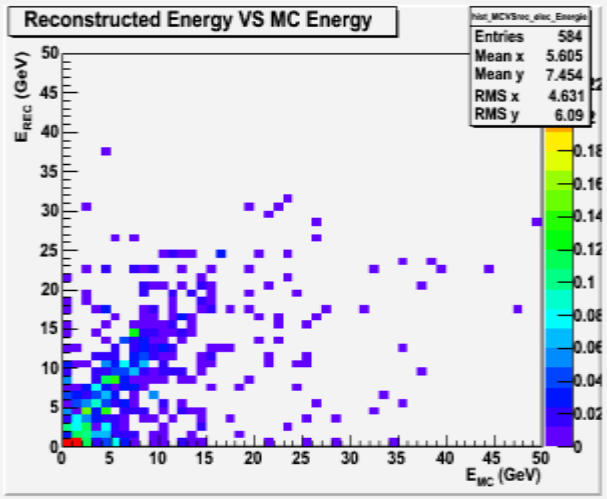
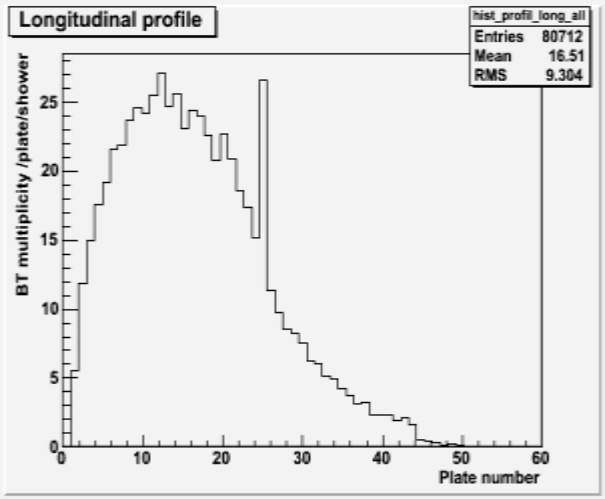
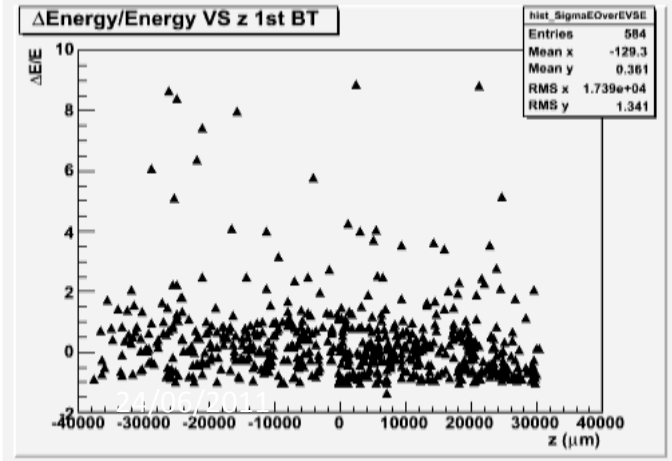
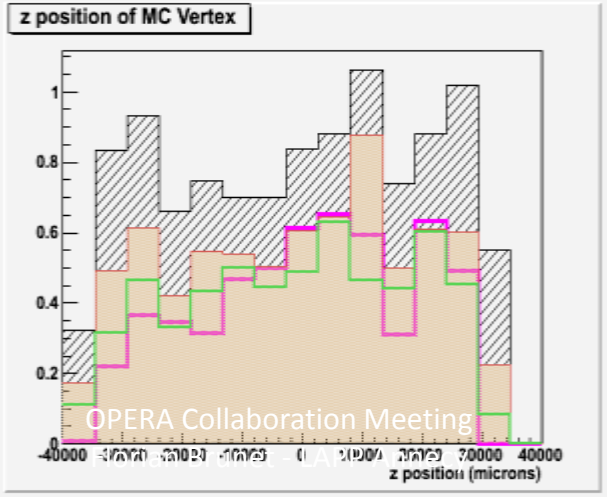


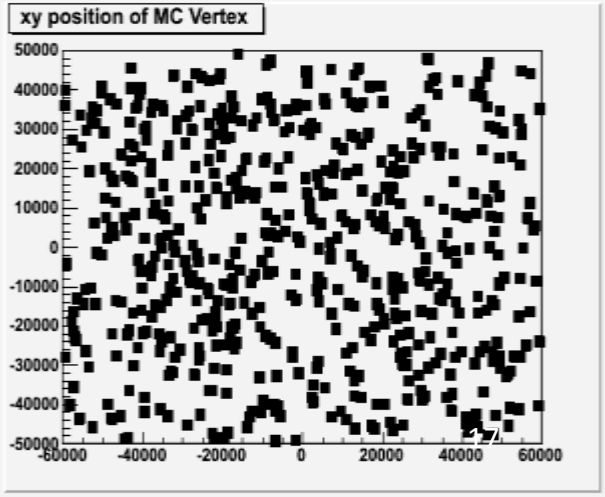
NEW



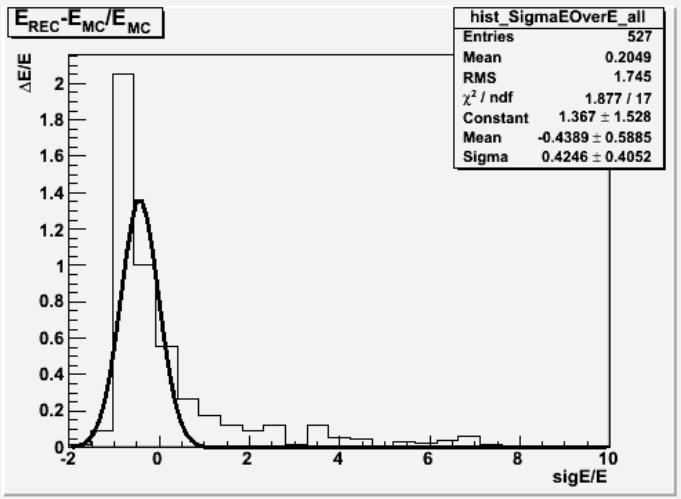


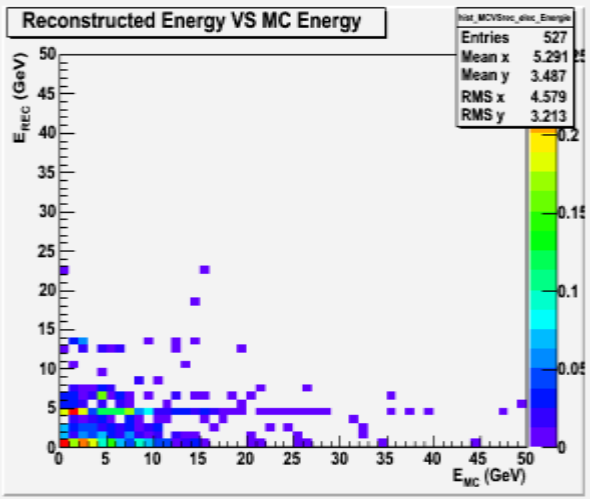


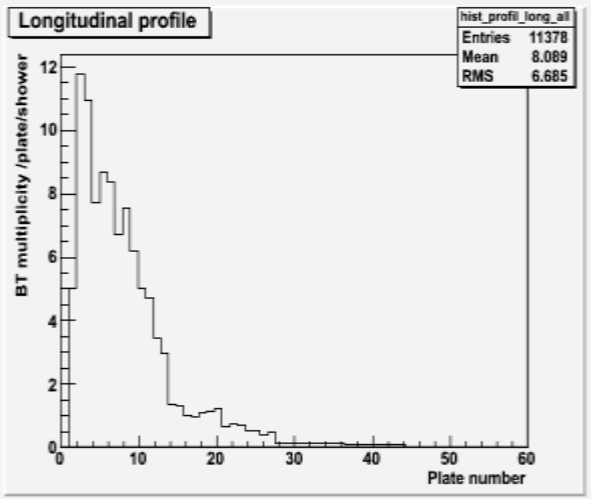


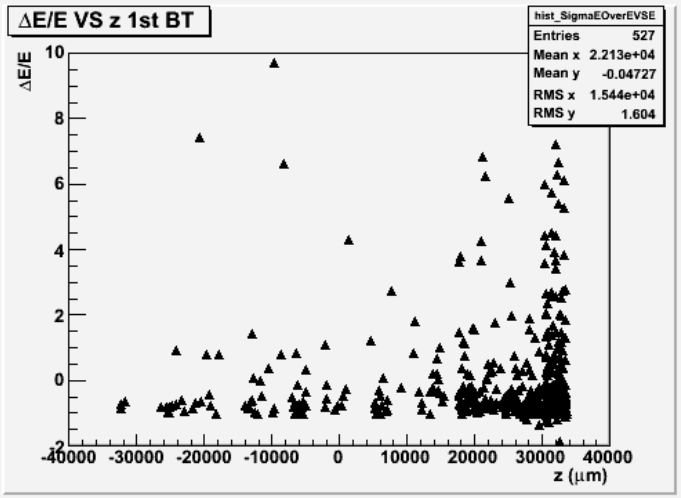


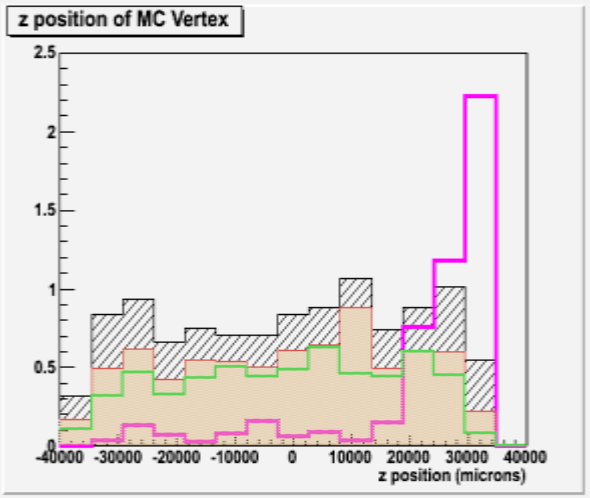
τ⟶e DIS channel : upgrade Frank Rec

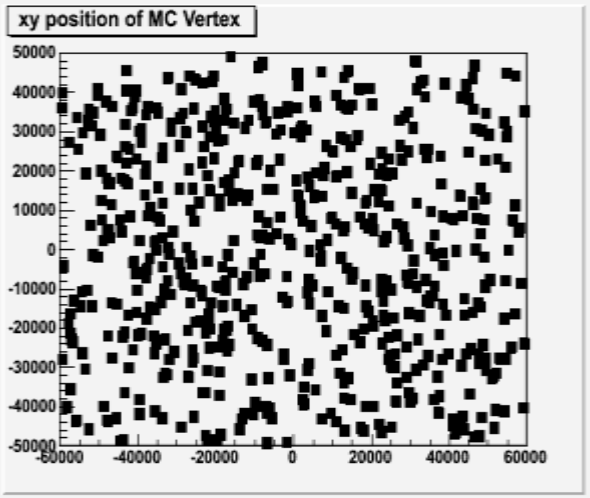




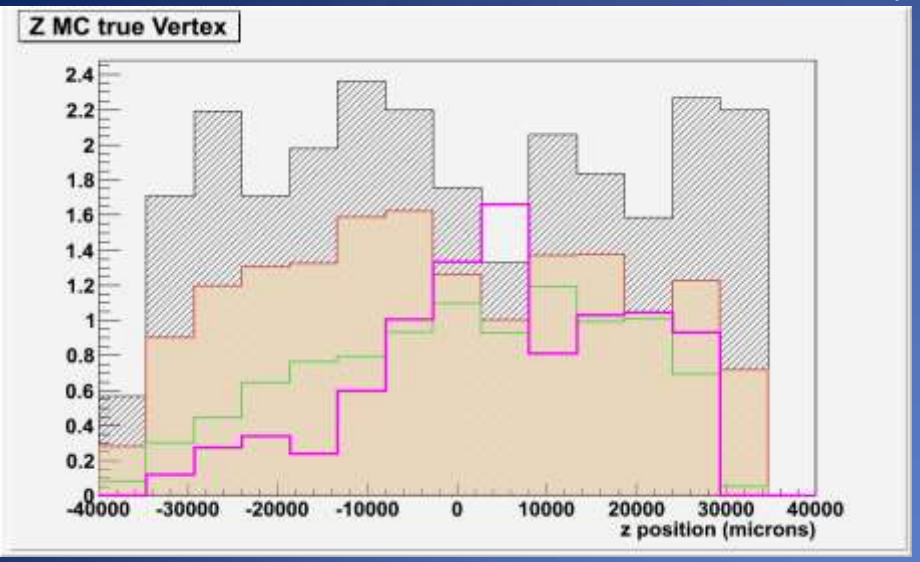




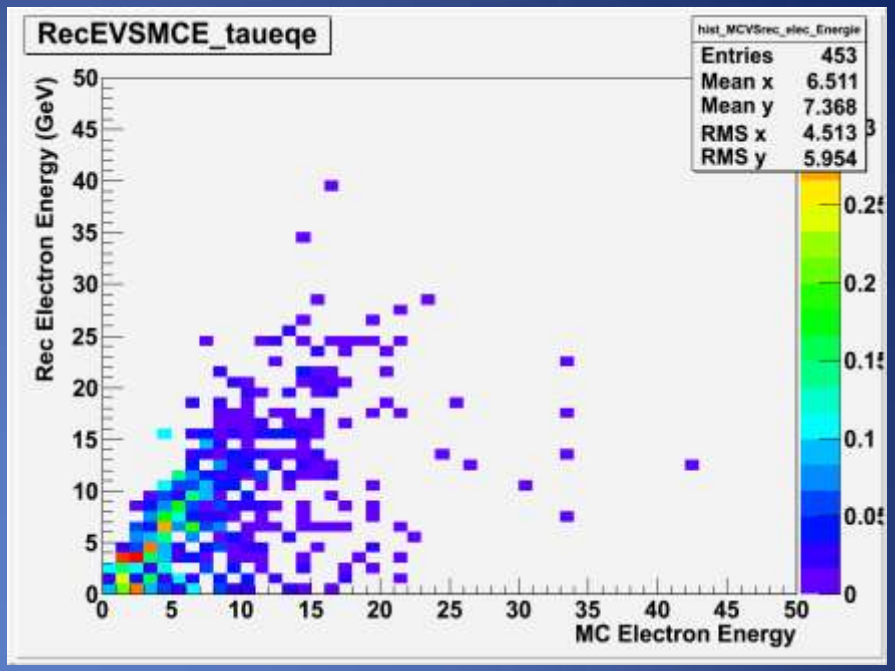


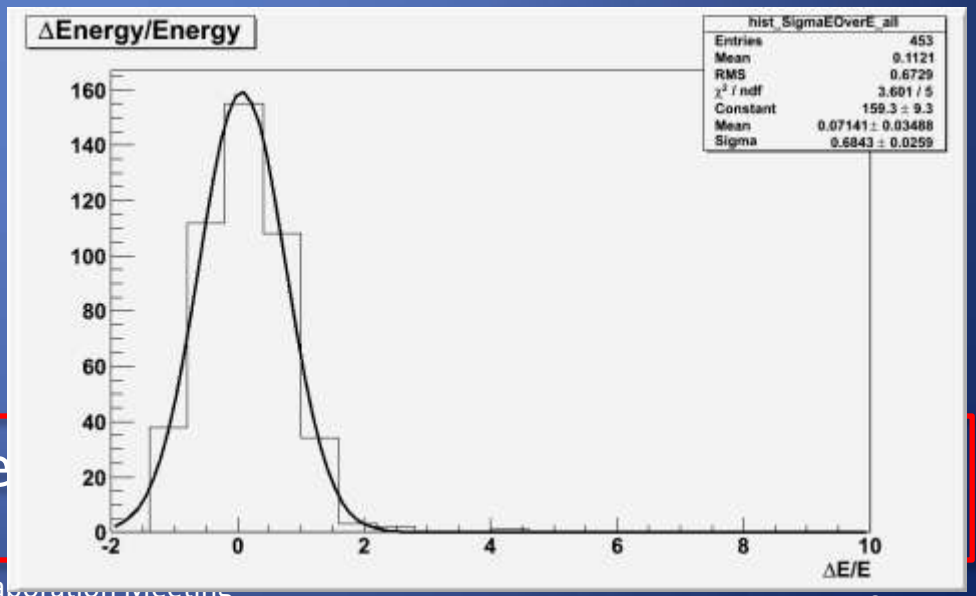


τ⟶e QE channel



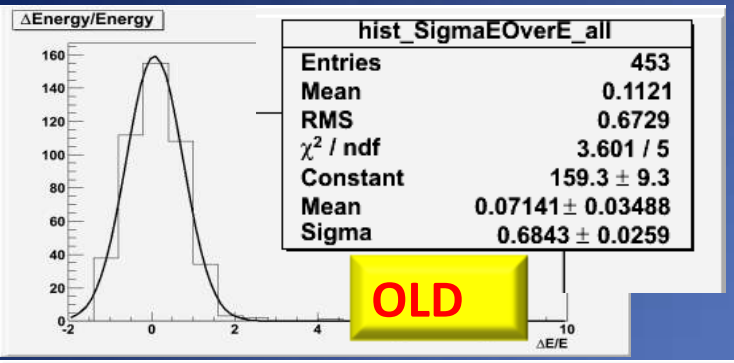
Z MC truth vertex
Z MC truth vertex BF OK
Z MC truth vertex SB OK
Z 1st BT of shower

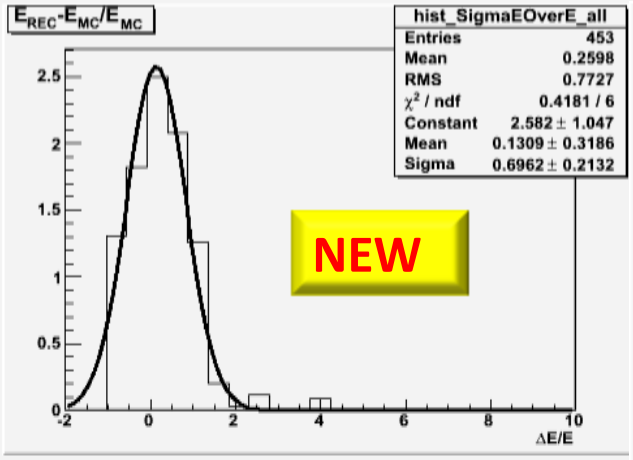


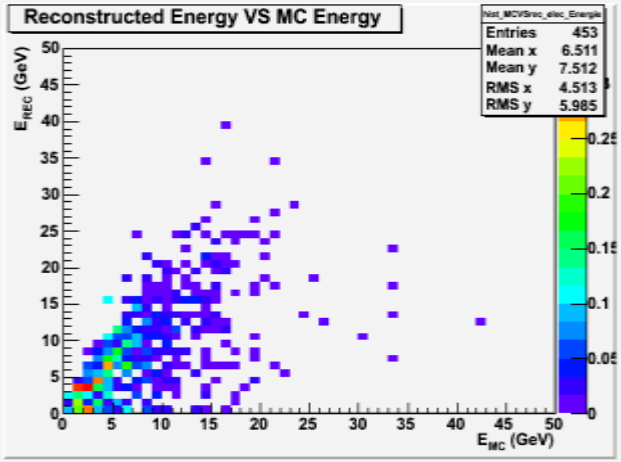


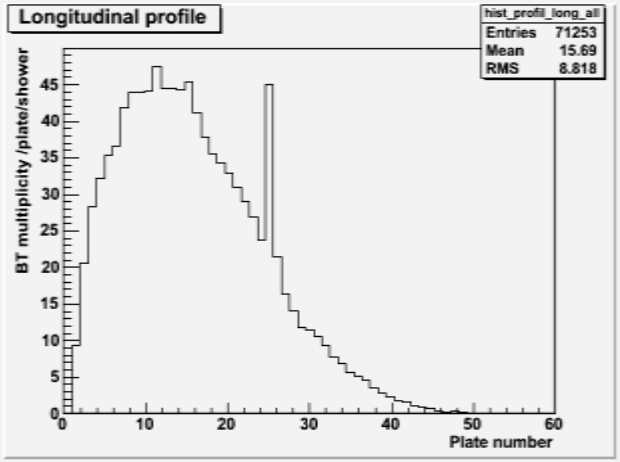
The critical point is scanback ➔ e

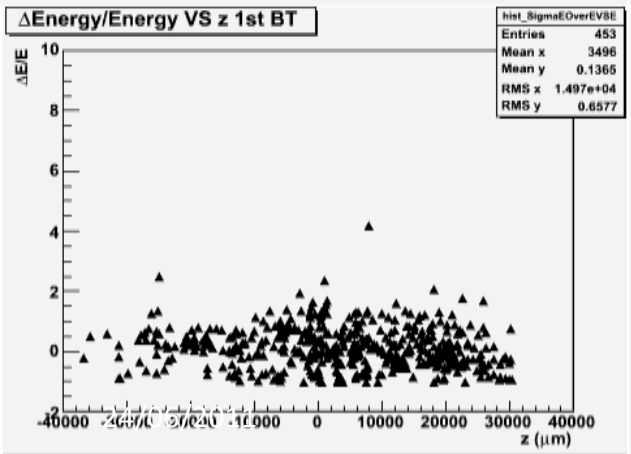
τ⟶e QE channel : contamination pion

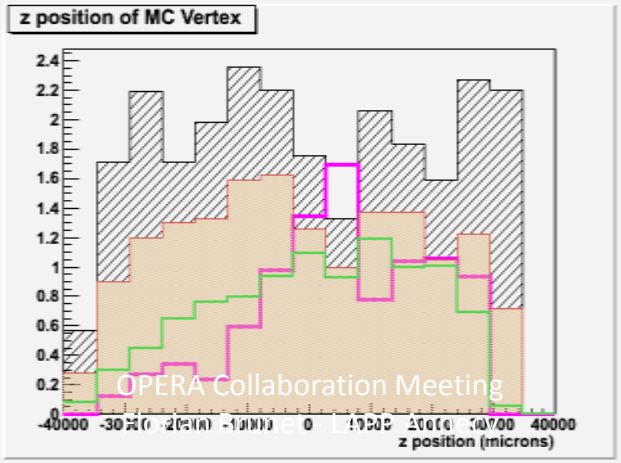


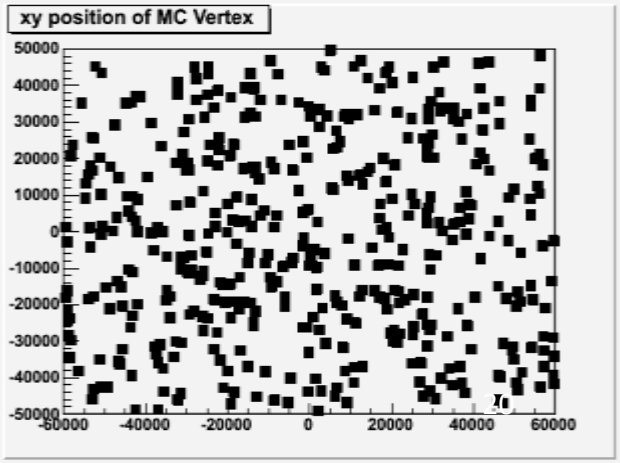




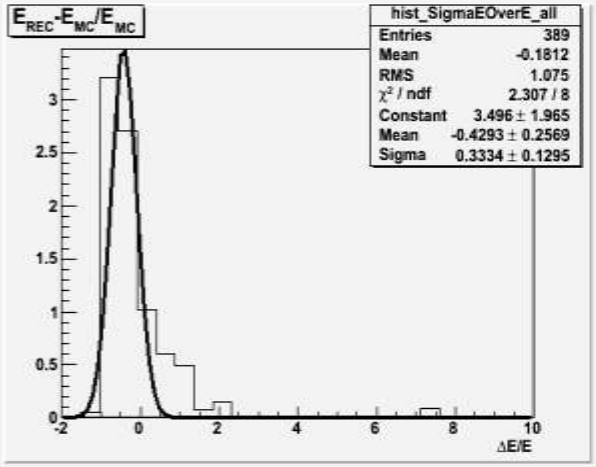


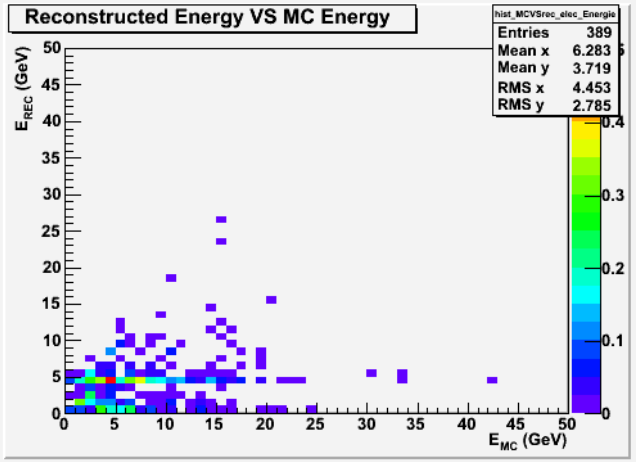


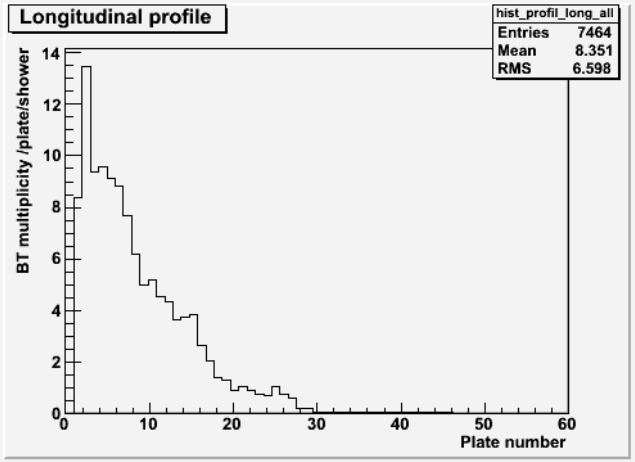


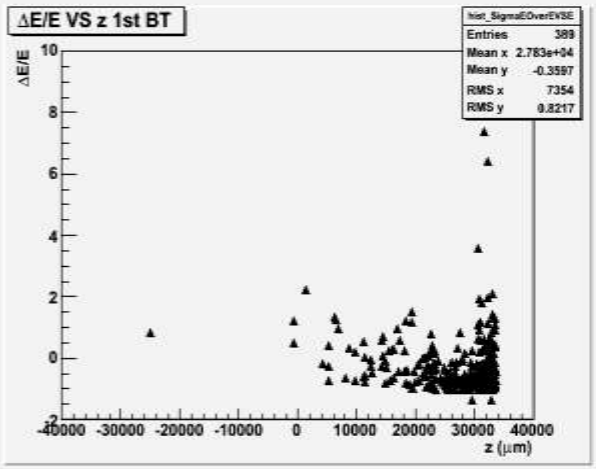


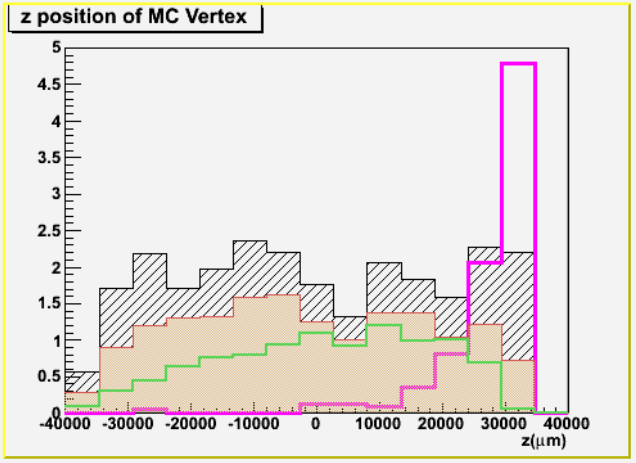
τ⟶e DIS channel : upgrade Frank Rec

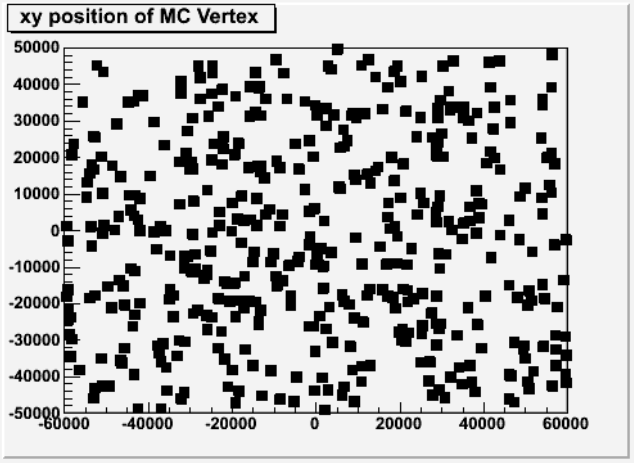












Future plans for EWG

- New calculation efficiencies + comparison Data/MC for ν_e (Andrea specially for SB)➔ Umut
- Extended SB for ν_e & $\tau \rightarrow e$ ➔ Matteo
- π^0 mass reconstruction ➔ Tomoko
- Low energy electron tracks in CS < 10 MeV ➔ Fabbio
- Electron Energy in TT ➔Pier Ferrucio + his student
- Shower Rec + Energy within 2 Bricks
- Shower overlapping bias in energy estimation

} Florian

Outlook

- Upgrade Frank Rec : shunt selection
- Upgrade OpEmuRec : study of shower contamination + 2-Brick analysis

BACKUP SLIDES

Electron Working Group activities : electron-γ shower reconstruction & $\tau \rightarrow e$ studies

- Analysis & reconstruction tools are being developped and start to give results
- Many MC studies within OpEmuRec

- Electron-ID with CS-method in progress
- Extended Scanback in progress
- Shower reconstruction = Ok
- Energy measurement = OK, though it needs more tuning
- $\tau \rightarrow e$ studies show efficiencies up to 50% for DIS, $\tau \rightarrow e$ QE efficiencies need more investigation

  $\tau \rightarrow e$: At decay search level → need to improve efficiency
- Calibration with π^0 mass = OK but needs more statistics
- Gamma pointing accuracy in progress

$\tau \longrightarrow e$ efficiencies

Decay search & kinematical cuts are missing

	Surviving Brick Finding	*At least 1 CS track*	*At least one scanback track in Plate number < 55*	At least one electron shower reconstructed
Tau-e DIS	***0.677 0.015***	***0.638 0.016***	***0.572 0.016***	***0.516 0.016***
Tau-e QE	***0.629 0.015***	***0.496 0.016***	***0.419 0.015***	***0.365 0.015***

- Good shower reconstruction efficiency
- Need implementation of decay search (see next slides) and kinematical cuts

Decay search for NC-like

- Reconstruction of primary vertex with standard parameters

→Selection of the most upstream and probable primary vertex

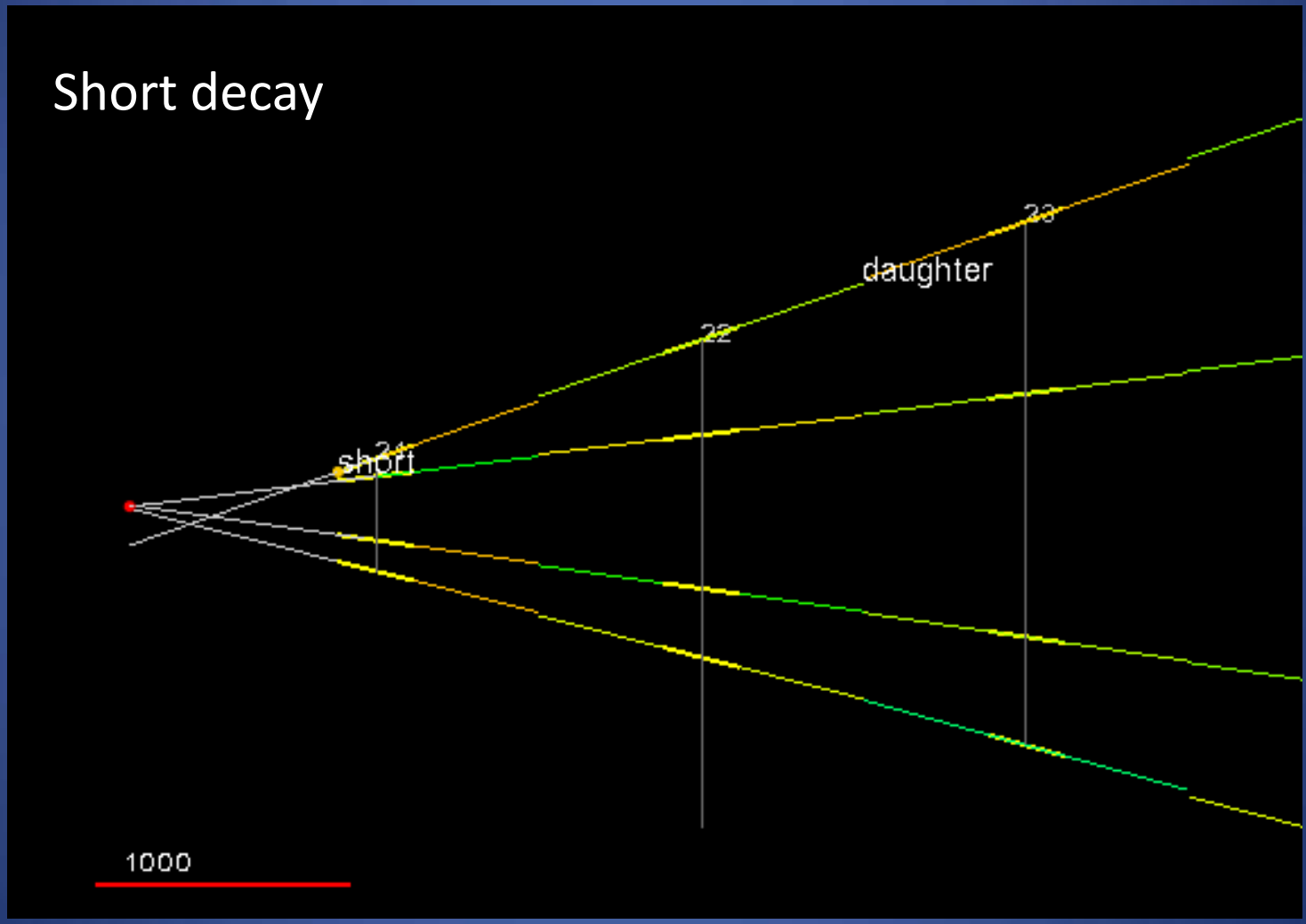
- Track search to attach to that vertex
- Kink search by measuring and selecting on : kink angle > 20mrad, IP < 20μm and removing low momentum tracks : daughter's θ_{RMS} > 15mrad

- Short kink case : consider tracks with at least 3 basetracks and starting in the primary vertex plate

  ip > 5 + 0.1 x dZ, daughter's θ_{RMS} <20mrad

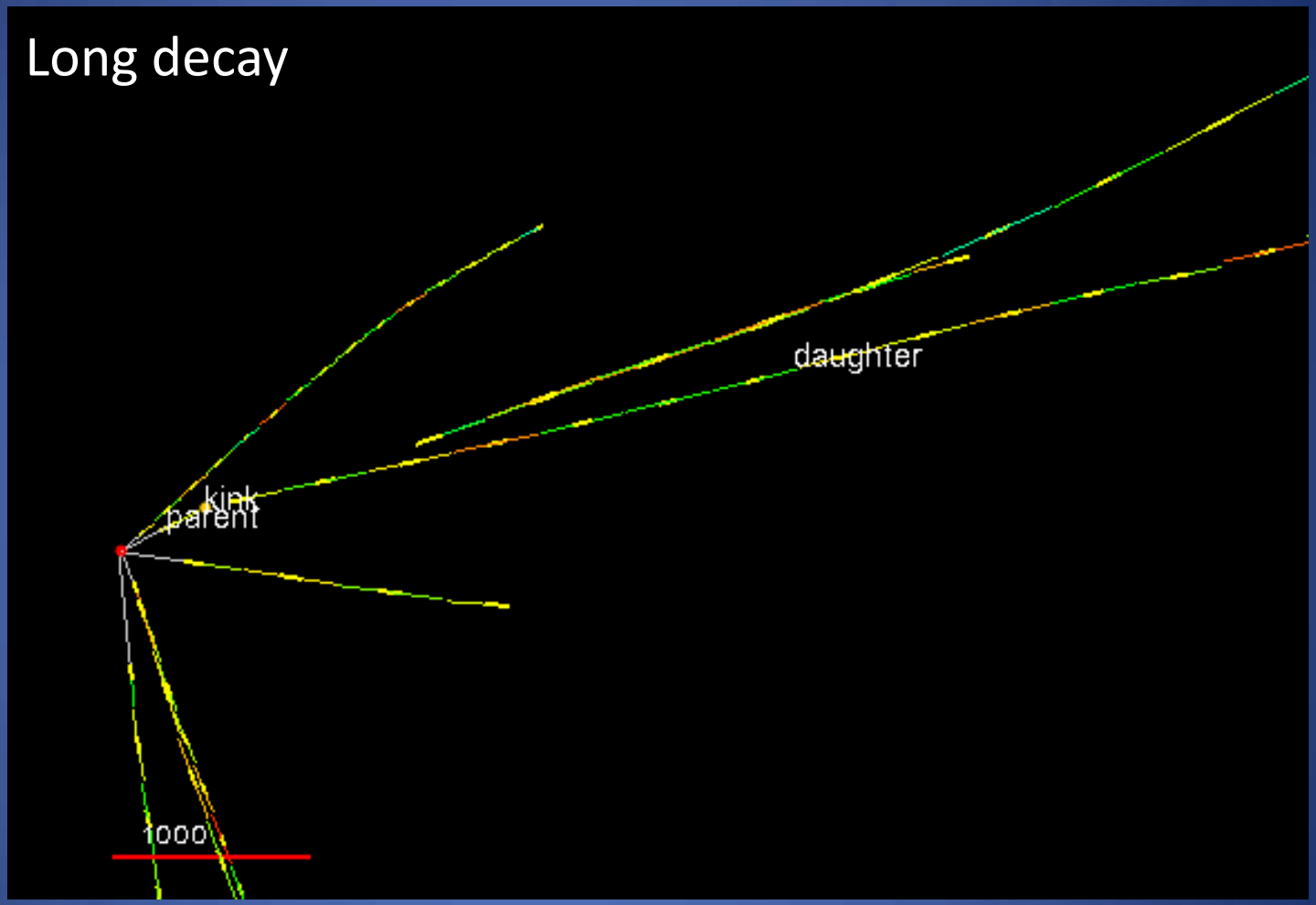
Ariga
Florian

Decay search on MC $\tau \longrightarrow e$ event



Ariga
Florian

Decay search on MC $\tau \longrightarrow e$ event



For 80% of events surviving scanback , we can reconstruct a decay vertex (46% of total number of events)

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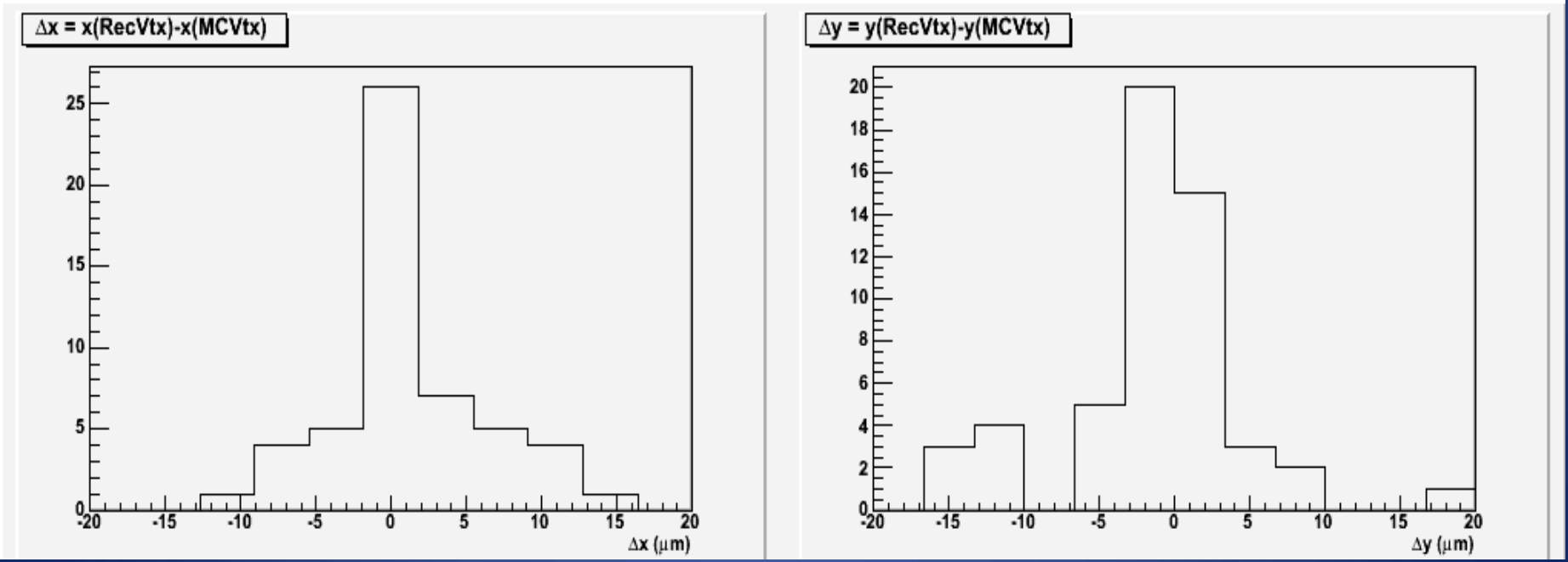
Decay vertices position resolution

- We remove fake decay vertices by cutting on position resolution $\Delta x \ \& \ \Delta y < 20 \mu m$

➔ Problem : ~ 20 % of events remains

- Reconstructed decay vertex position – MC true vertex position :



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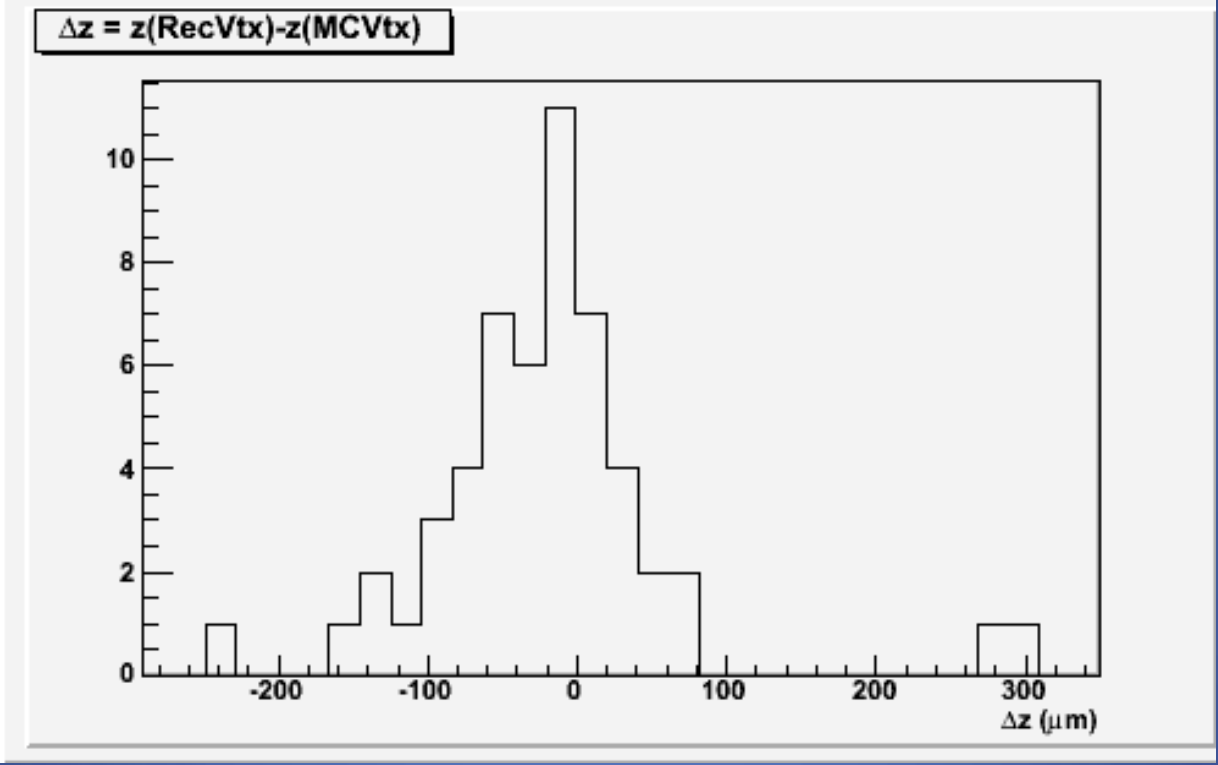
Decay vertices position resolution



Need to improve our reconstruction

→ Use scanback information to define precisely the primary vertex

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Inefficiency of the decay vertex reconstruction : long kink topology

- I checked out 58 long kink events where I could not reconstruct a decay vertex

Inefficiency	Number of events
1ry vertex out of Totalscan volume	10
Track reconstruction fails (in shower)	6
Rejected by selection : small kinks, low momentum daughter, IP cut	9
Very long kink	5
No tracks or 1ry vertex reconstructed	18
Special cases : decay vertex out of the brick, primary vertex in plate > 55, back scattering…	10

Could be recovered by extended SB

Small kink search already implemented