Results from ĐONUT

NAKAMURA M. (Nagoya Univ.)
+ ĐONUT Collaboration

(at ICHEP2000, Osaka, July 28)

AIM

Direct Observation of

ν_τ^{CC} interactions

Method

Emulsion Target
(ECC : Emulsion Cloud Chamber)

+

Automated Emulsion Read-out facilities

} Developed in Japan
- CHORUS
- OPERA
CNGS

+

Prompt ν Beam line
(Fermilab)

02

DONUT Collaboration

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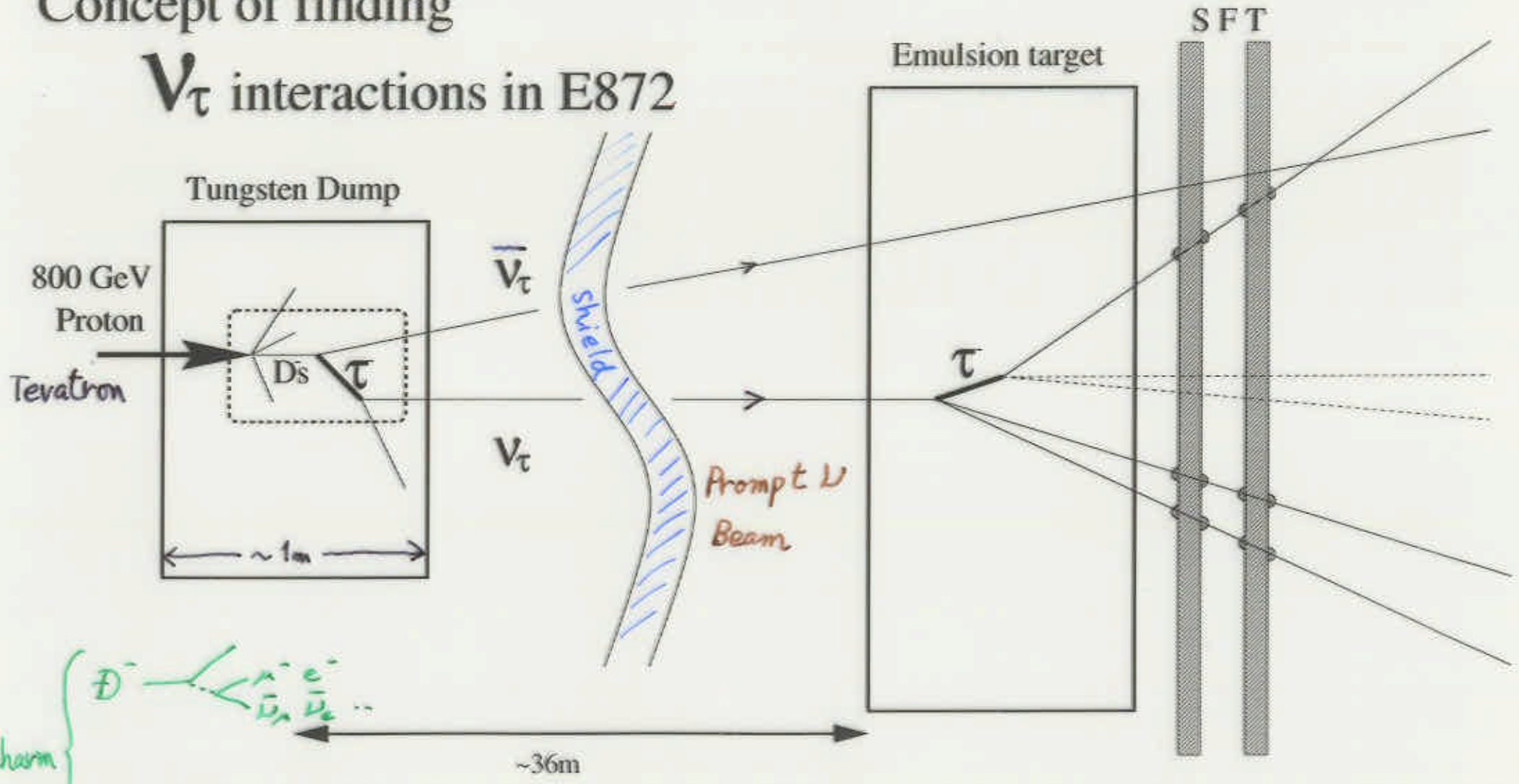
Concept of finding ν_τ interactions in E872

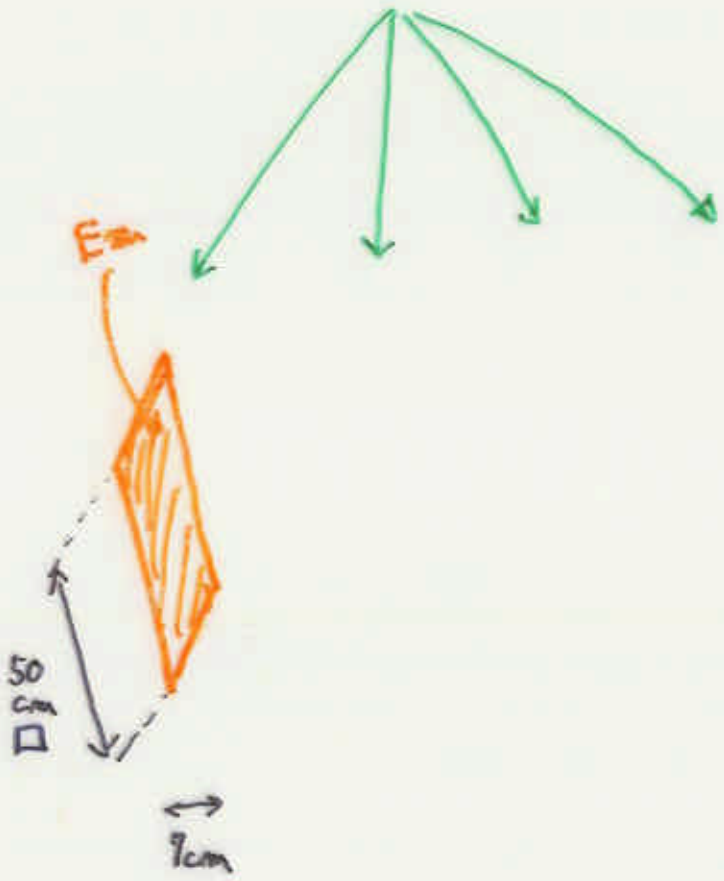


charm

D^- → $\mu^-\bar{\nu}_\mu$, $e^-\bar{\nu}_e$ ..

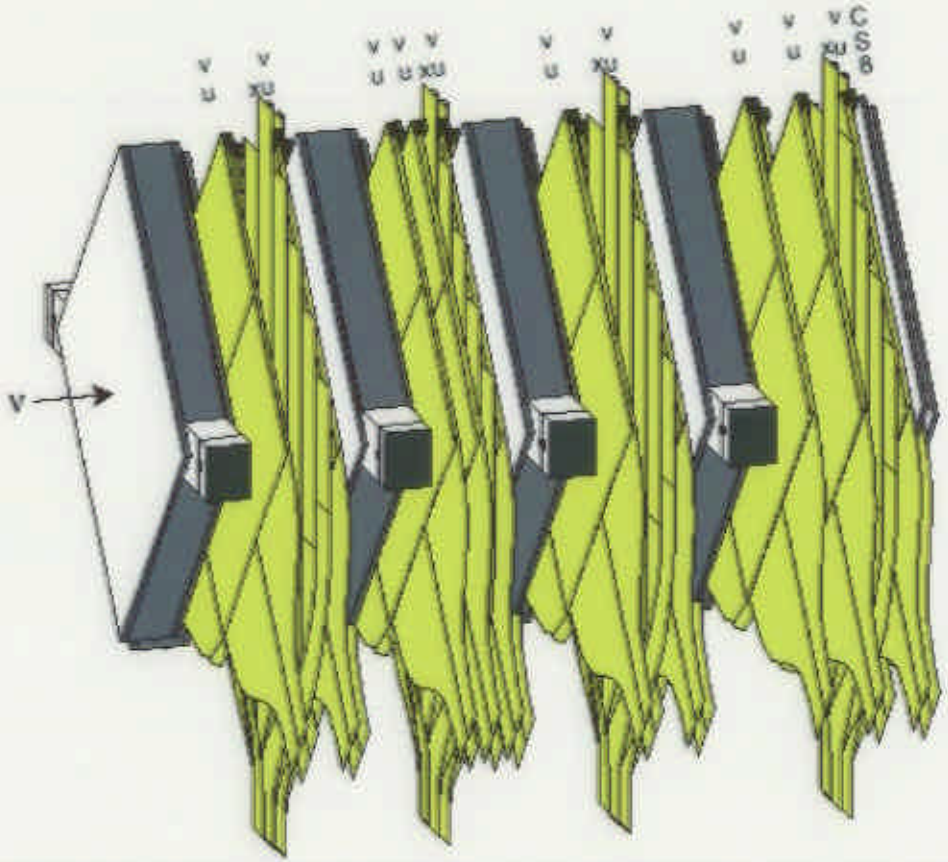
D_s^- ($\bar{c}s$) → W^- → $\tau^-\bar{\nu}_\tau$

$\left(\frac{\nu_e^{cc}}{\nu_\mu^{cc}+\nu_e^{cc}}\right)_{expect} \sim 5\%$

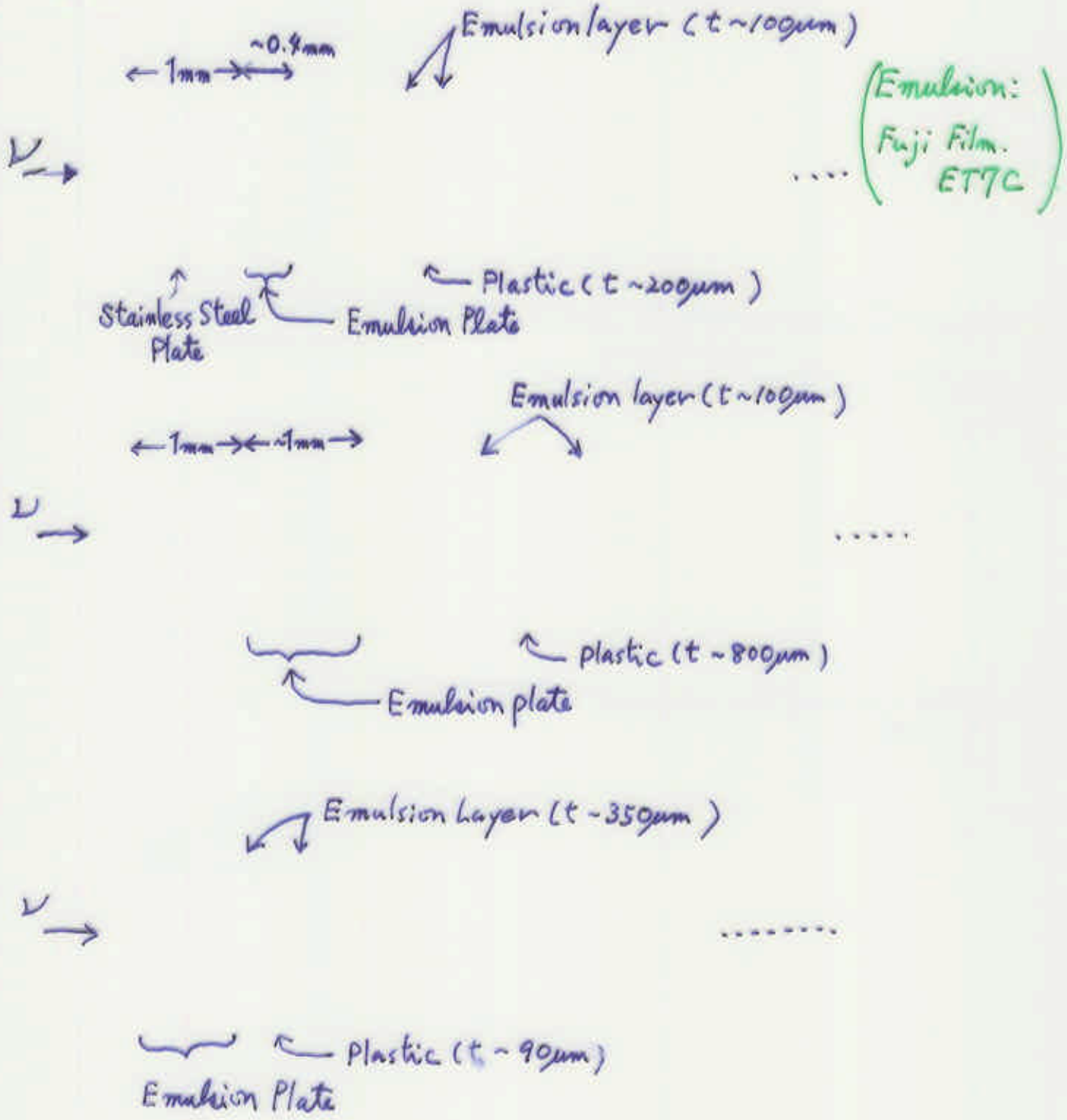


SPT (KURARAY φ500μm SCSP帯)
+ I.I.T. (HAMAMATSU, φ10cm I.I.T.)

Emulsion Target / Vertex Detector



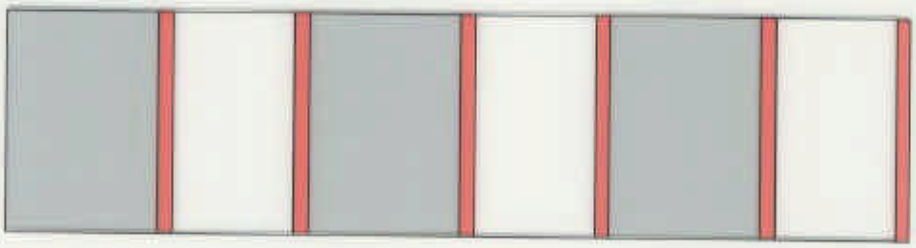
- Four target stations
- 260 kg total mass
- Interleaved with sci-fi
- Fibers → vtx prediction
- Total 7 modules exposed
- Modules ~2-3 X_0 each
- ~ 0.2 - 0.3 λ_{int} each


Emulsion layer (t ~ 100μm)
~0.4mm
← 1mm →
(Emulsion: Fuji Film. ET7C)
ν
Plastic (t ~ 200μm)
Stainless Steel Plate
Emulsion Plate
Emulsion layer (t ~ 100μm)
← 1mm → ← 1mm →
ν
plastic (t ~ 800μm)
Emulsion plate
Emulsion Layer (t ~ 350μm)
ν
Plastic (t ~ 90μm)
Emulsion Plate

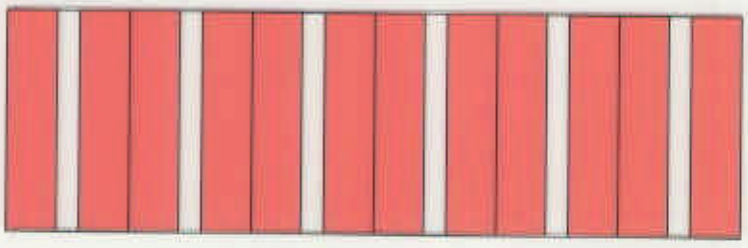
Cross sectional View of DONUT ECC

ECC200

ECC800



Bulk



Emulsion Readout Machine "TRACK SELECTER"

http://flab.phys.nagoya-u.ac.jp/new/project/system/system.html

Nagoya Univ.

— Basic Performance —

Recognized Track Segment
$(x, y, z, dx/dz, dy/dz) \Rightarrow$ 3D Vector

Checked by Penetrating μ-on.
($P \sim 30$ GeV/c)

Position Resolution

$\sigma_{position} \sim 0.3\,\mu m$

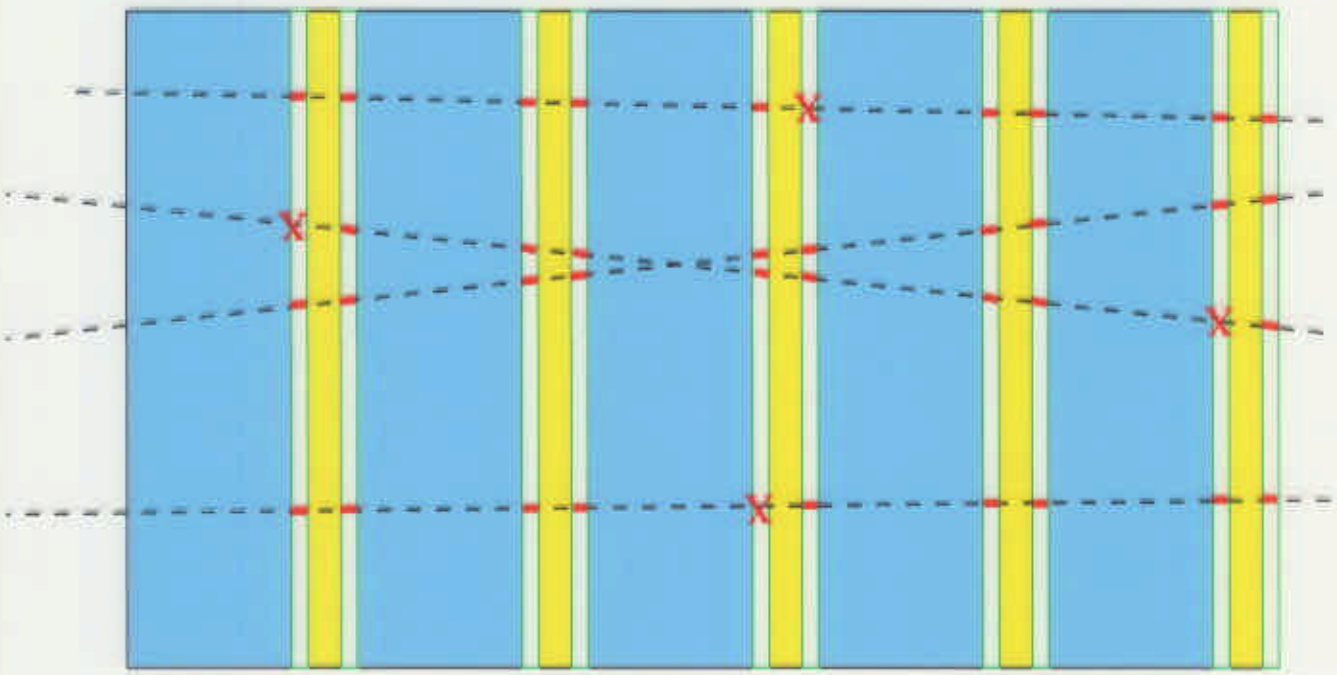
Angular Resolution

$\sigma_\theta^{Layer} \sim 5$ mrad (1 Emulsion layer)

$\sigma_\theta^{1Plate} \sim 2$ mrad (1 Emulsion Plate (200μm Base))

$\sigma_\theta^{2Plate} \sim 0.2$ mrad (2 Emulsion Plate for large P)

Position Resolution & Tracking efficiency of ECC+Track Selector



Statistics in DONUT

Reconstructed Vint Candidate in fiducial Volume — 699 eV

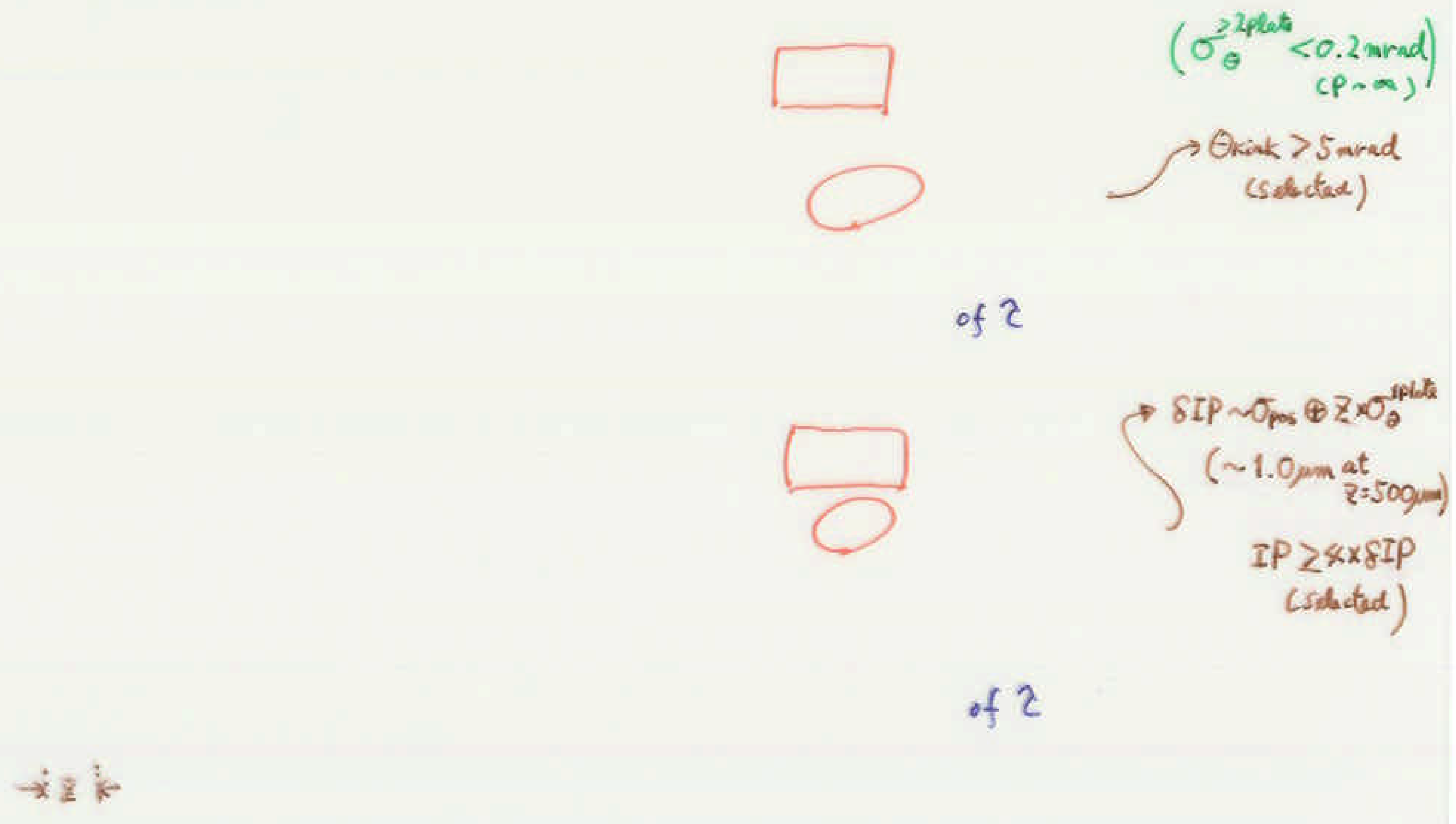
||

rejection of small multiplicity Event ($n_s \leq 2$) ⇐ High Density BG μ-on $3 - 10 \times 10^4/cm^2$

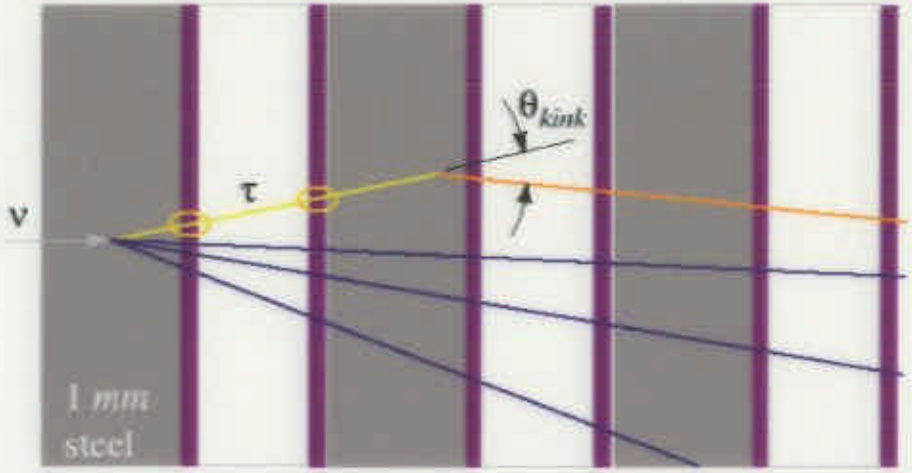
rejection of Super High μ-BG region $\approx 10^5/cm^2$: sideband (low energy μ)

⇓

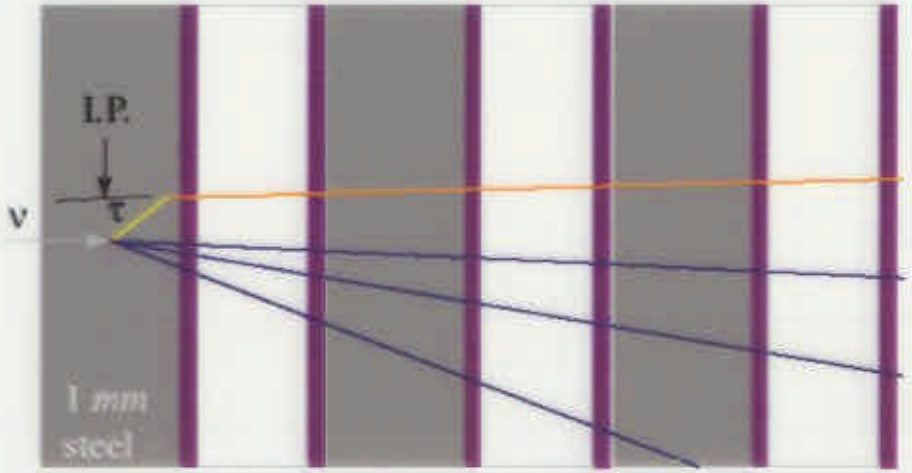
Vertex Location tried	451	⇐ NETScan
Vertex Located (Feb. 2000)	262	
Systematic Decay Search was applied	203	


$\left(\sigma_\theta^{>2plate} < 0.2\,mrad\right.$
$\left.(p \sim \infty)\right)$
$\theta_{kink} > 5\,mrad$ (selected)
of z
$\delta IP \sim \sigma_{pos} \oplus z \times \sigma_\theta^{1plate}$
$(\sim 1.0\,\mu m$ at $z = 500\,\mu m)$
$IP \geq 4 \times \delta IP$ (selected)
of z
z

Decay Search



1. *Long Decays*
   - parent measured
   - kink resolved
   - $\tau \Rightarrow$ no 1^{ry} *lepton*
   - ~75%



2. *Short Decays*
   - IP wrt 1^{ry} vertex
   - only daughter meas.
   - daughter seen in SFT.
   - ~25%

Selected Event Analysis

P measurement by Multiple Coulomb Scattering Meas. in ECC
- MC/TEST Exp./Calib. in @KEK CERN DONUT

Daughter Particle
P, P_T → electron ID. / μ-on ID

[if $P_T \geq 250$ MeV/c (Long)
$P_T^{min} \geq 100$ MeV/c (short)
or daughter = Lepton]

Electron ID. in ECC
- find { Starting Cascade Showers and/or Rapid Energyloss }
- MC/TEST EXP @CERN

μ ID. Downstream μ ID Counter

Try Lepton Check
e ID.
μ ID.

$\varepsilon_e \sim 70\%$ for ν_e^{cc} with ~1X_0

$\varepsilon_\mu \sim 79\%$

τ Detection Eff. [MC]
- ε_τ(long) ~66%
- ε_τ(short) ~ ??%

Without Try Lepton → **τ sample**
4 : long
1 : short
All kink

With Try Lepton → **Charm Sample**
2 charged (1 kink)
($1\nu_\mu^{cc}$, $1\nu_e^{cc}$)

Expected (MC)
Charm
2.4 charged (0.9 kink)

Background Estimation

	Background from Charm	Background from 2ndary INT	TOTAL	found
τ long	0.24	0.20	0.44	4
τ Short	0.09	0.04	0.13	1

- Charged Charm with Kink Decay ⊕ Lepton ID. failure
  - [only 0.9 event expected]
- NC + 2ndary + Lepton ID. fail. + 2ndary
  - P_T cut !

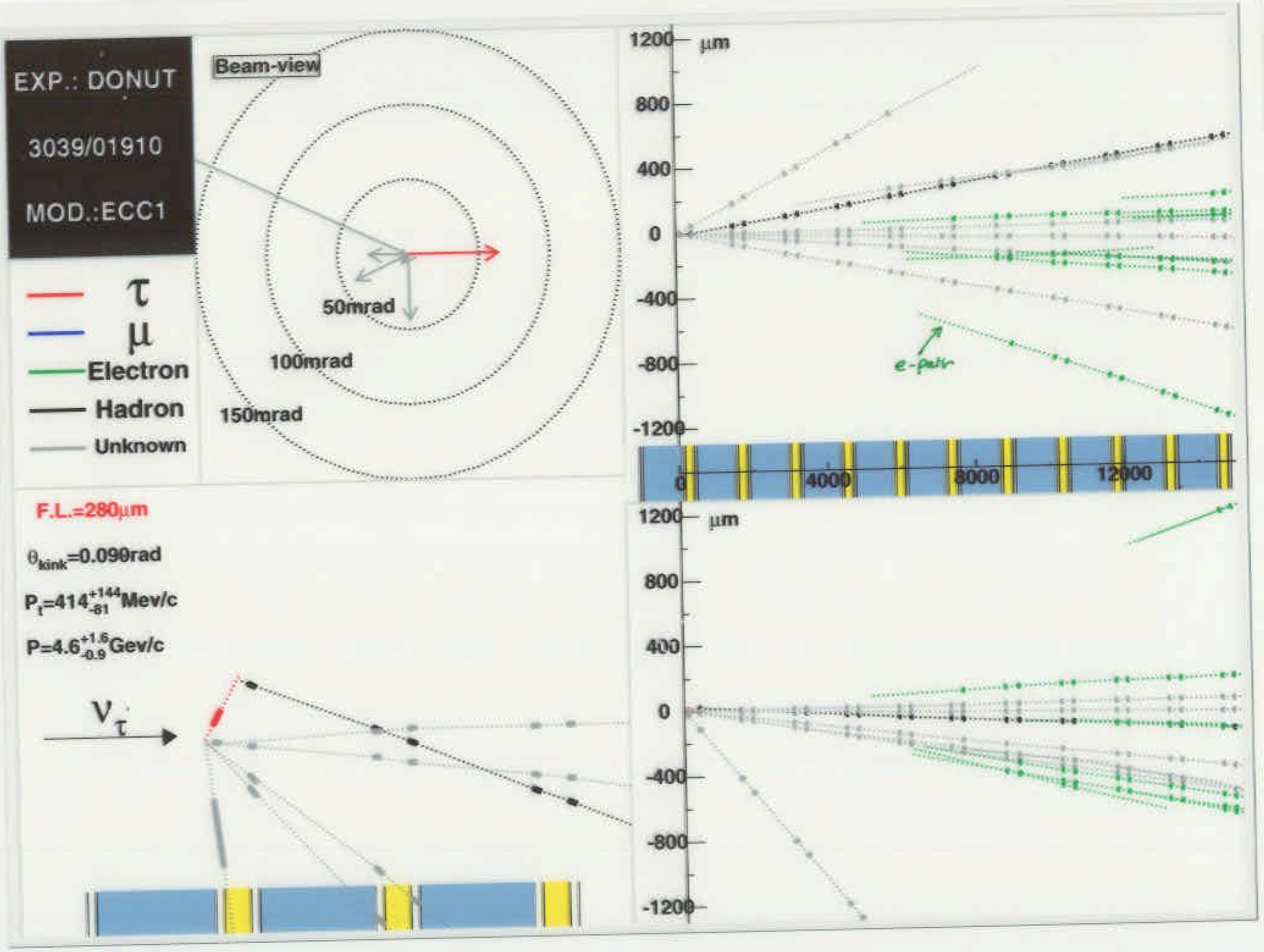
$\otimes \nu_\tau$

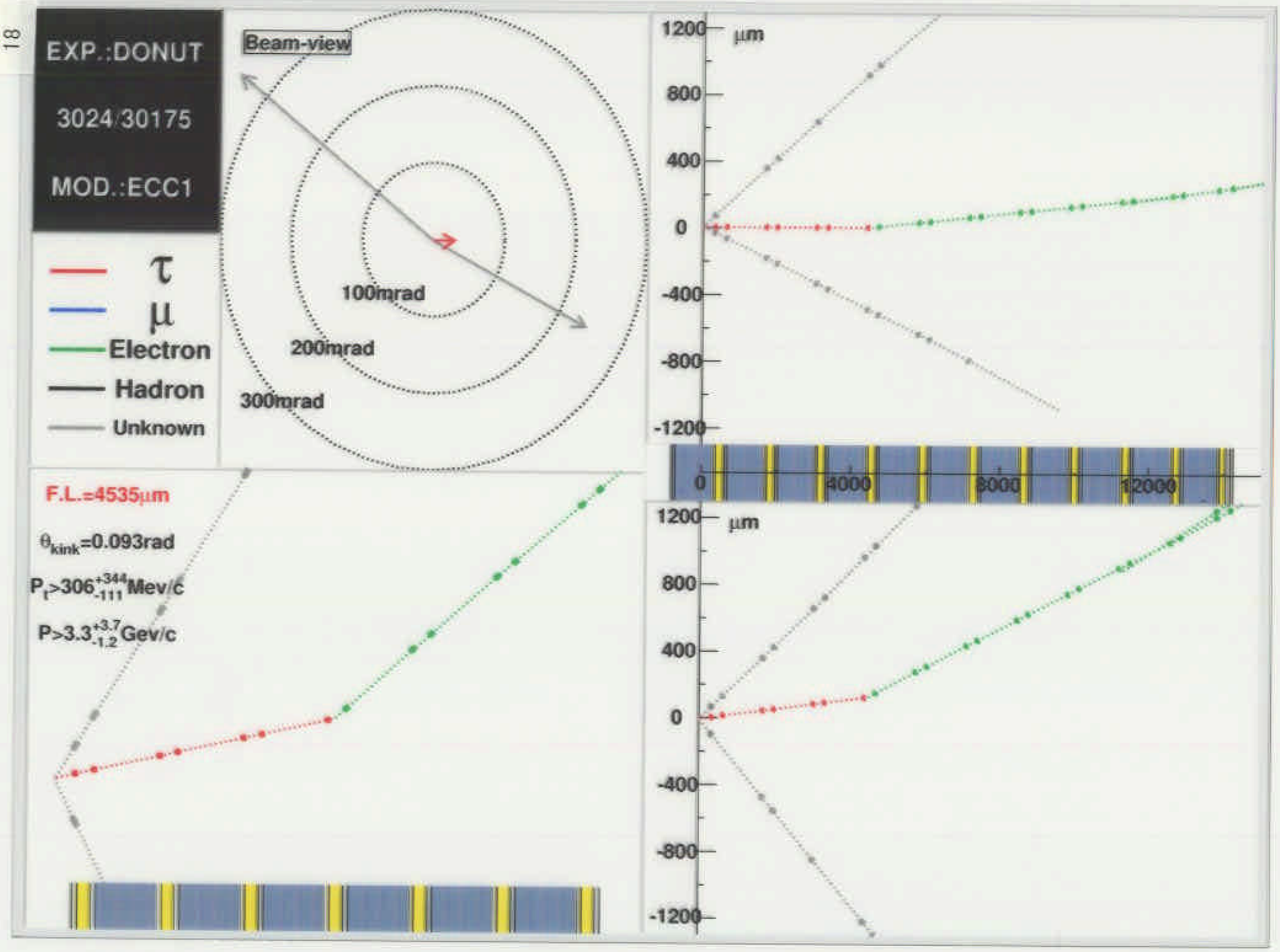
τ

$\tau \to h \omega X$

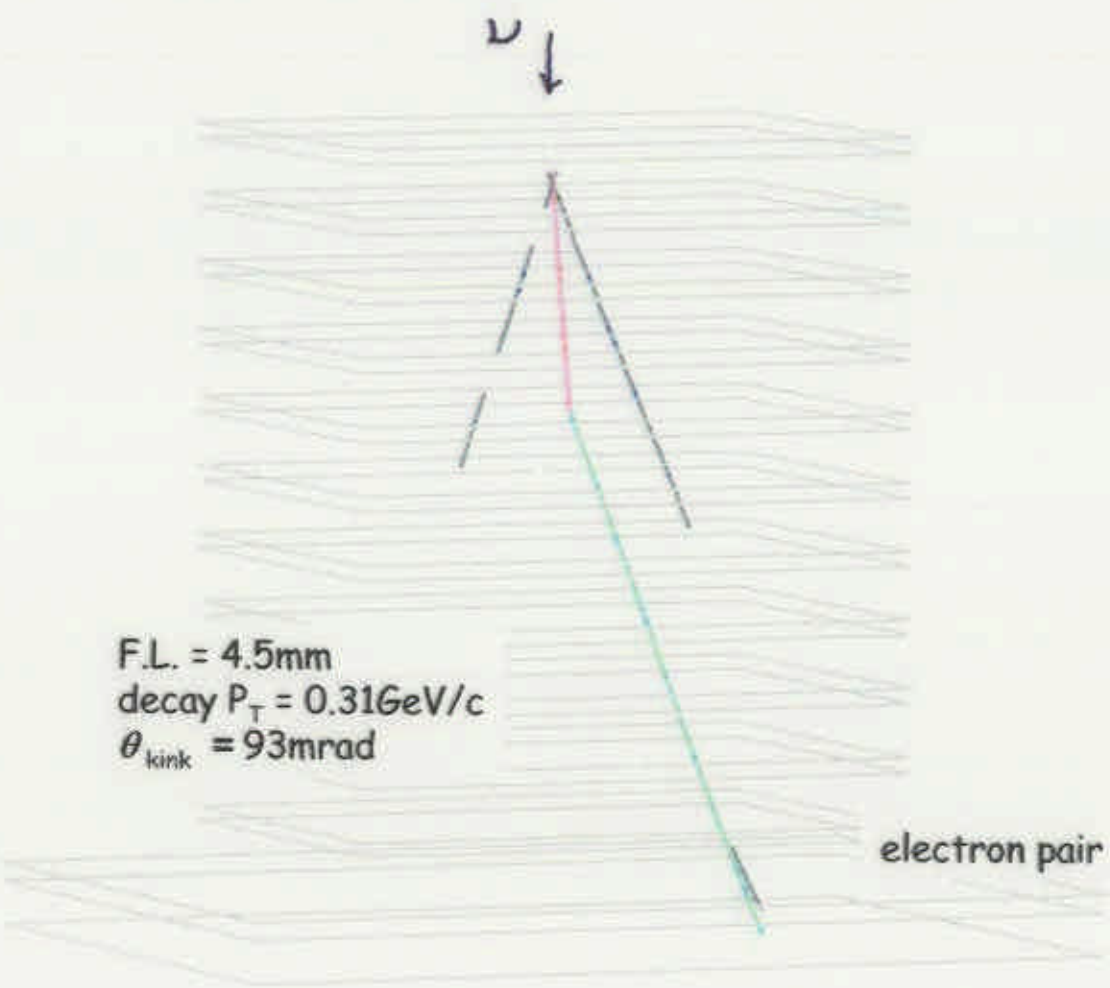
(from $\pi^0 \to 2\gamma$)
$\hookrightarrow \gamma \to e^+ e^-$

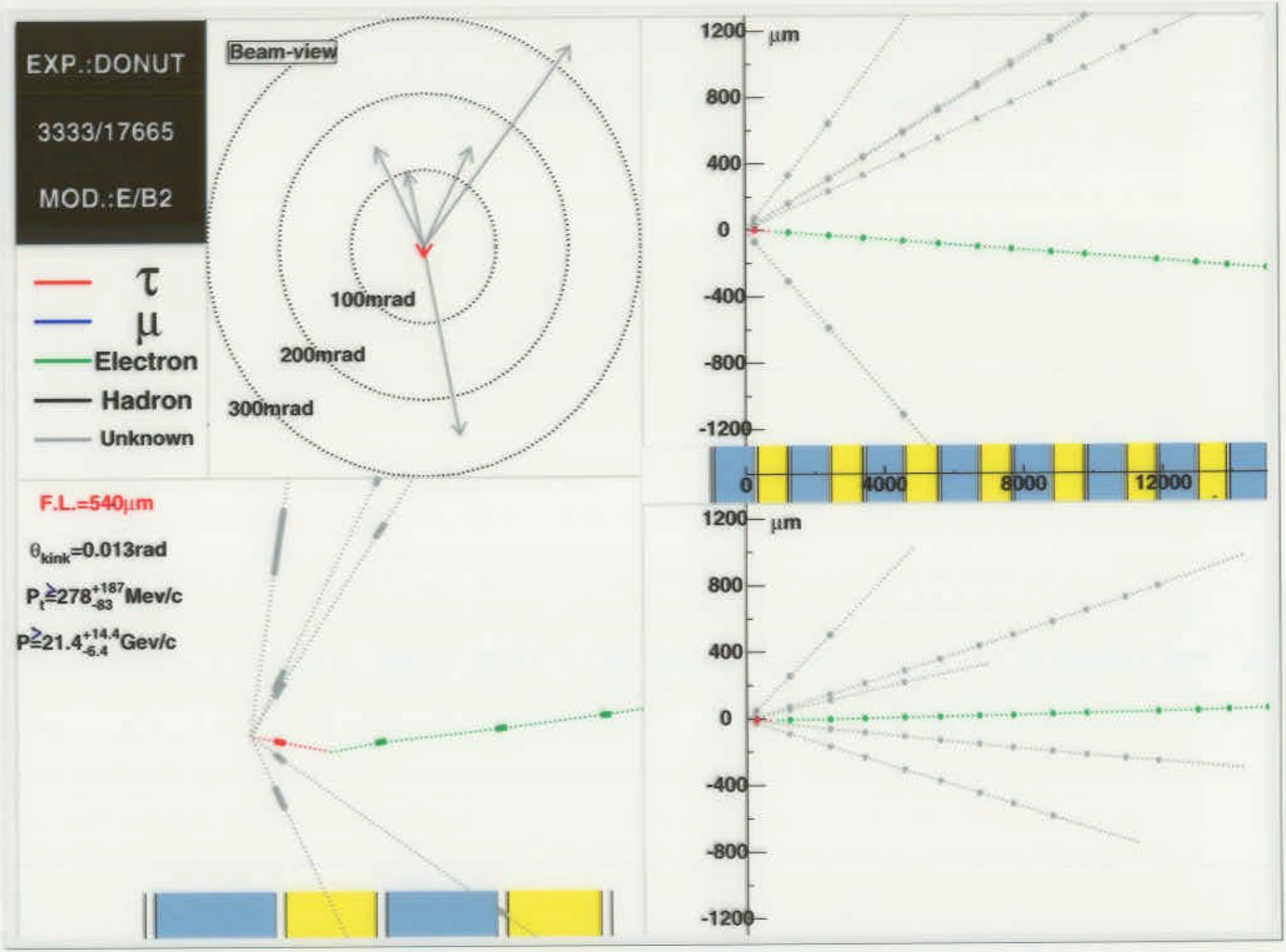
τ

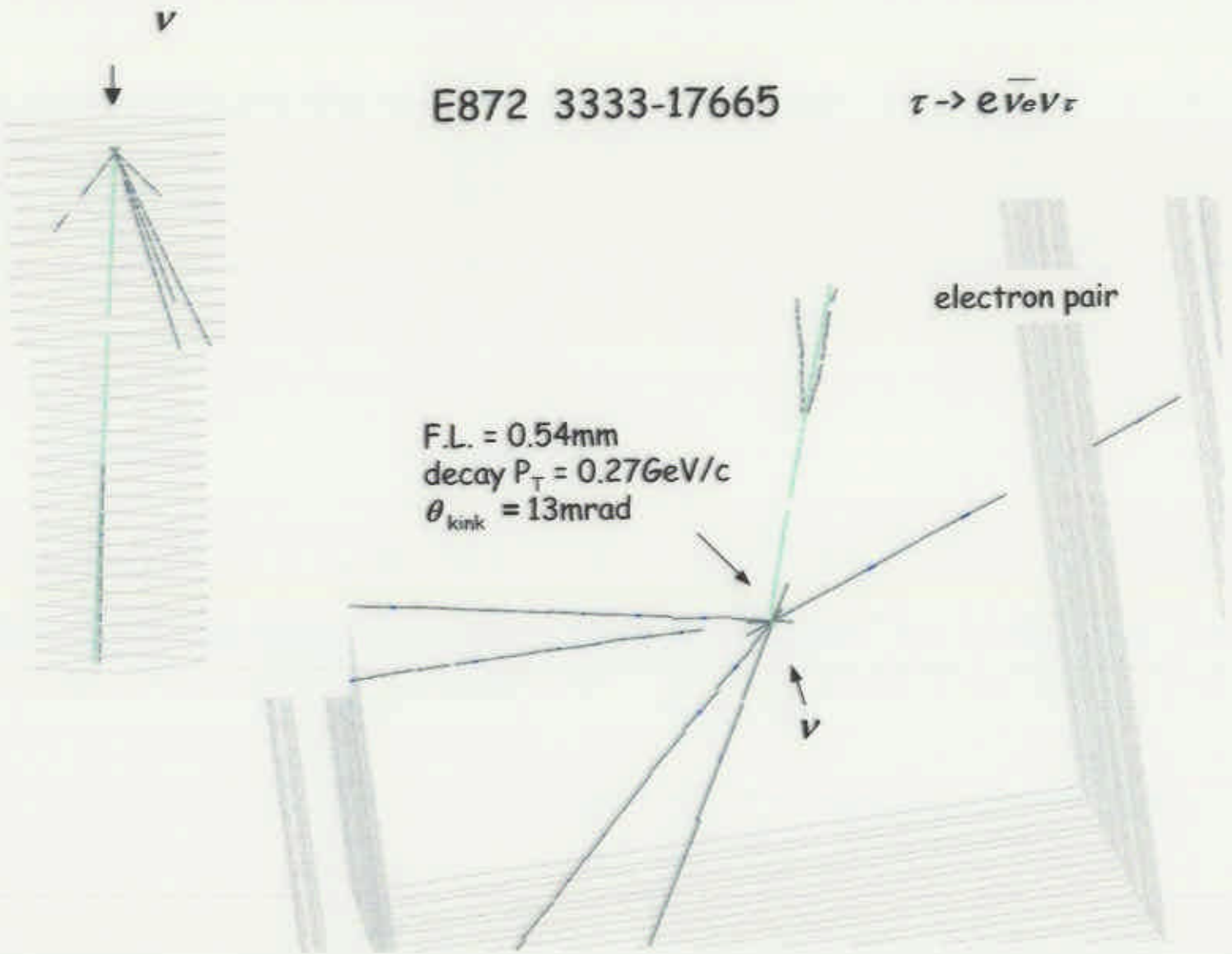

EXP.: DONUT
3039/01910
MOD.:ECC1
Beam-view
τ
μ
Electron
Hadron
Unknown
50mrad
100mrad
150mrad
1200
μm
800
400
0
-400
-800
-1200
e-pair
0
4000
8000
12000
F.L.=280μm
θkink=0.090rad
Pt=414+144-81Mev/c
P=4.6+1.6-0.9Gev/c
ντ

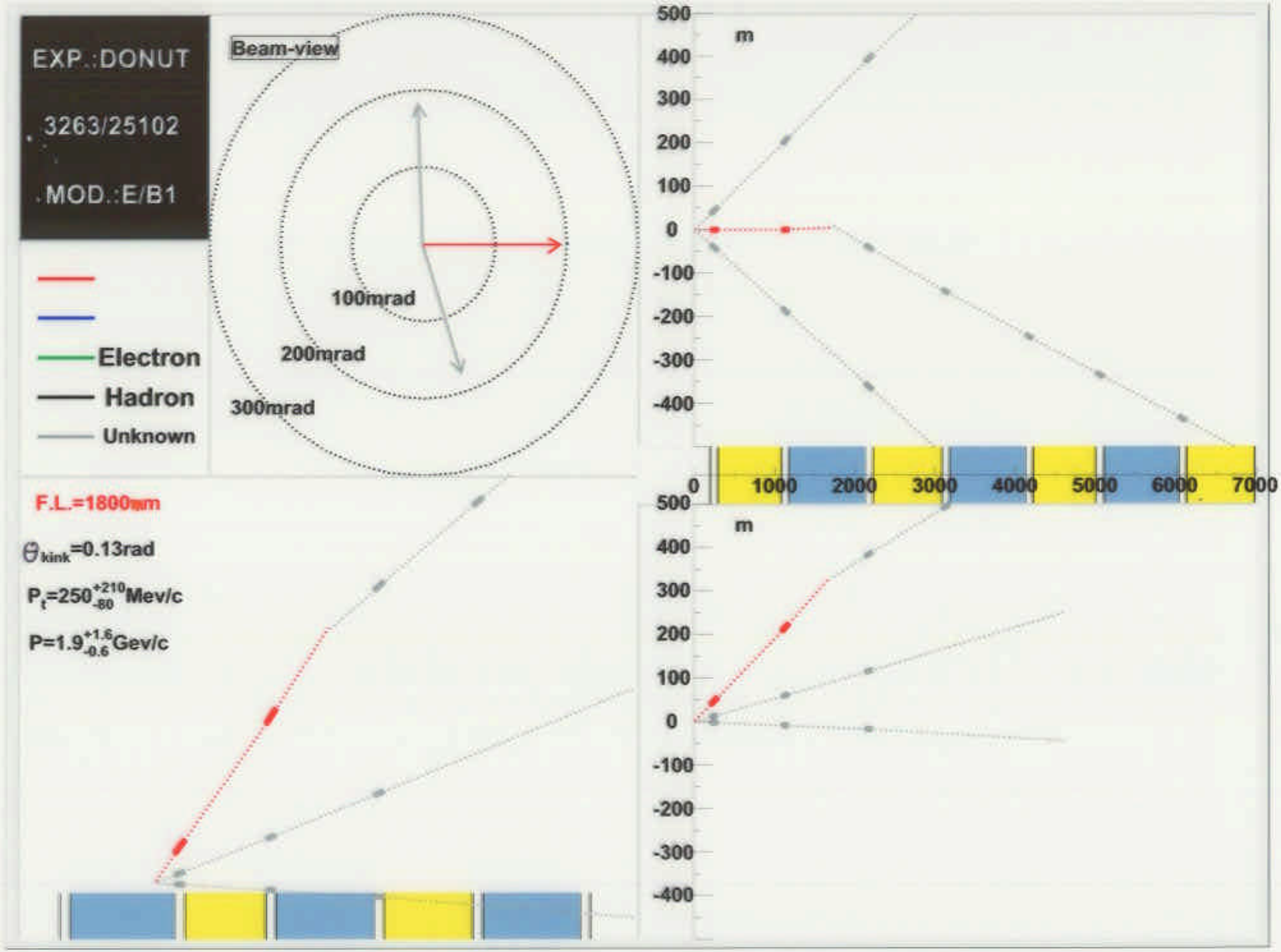

EXP.:DONUT
3024/30175
MOD.:ECC1
τ
μ
Electron
Hadron
Unknown
Beam-view
100mrad
200mrad
300mrad
1200
μm
800
400
0
-400
-800
-1200
0
4000
8000
12000
F.L.=4535μm
θkink=0.093rad
Pt>306+344-111Mev/c
P>3.3+3.7-1.2Gev/c

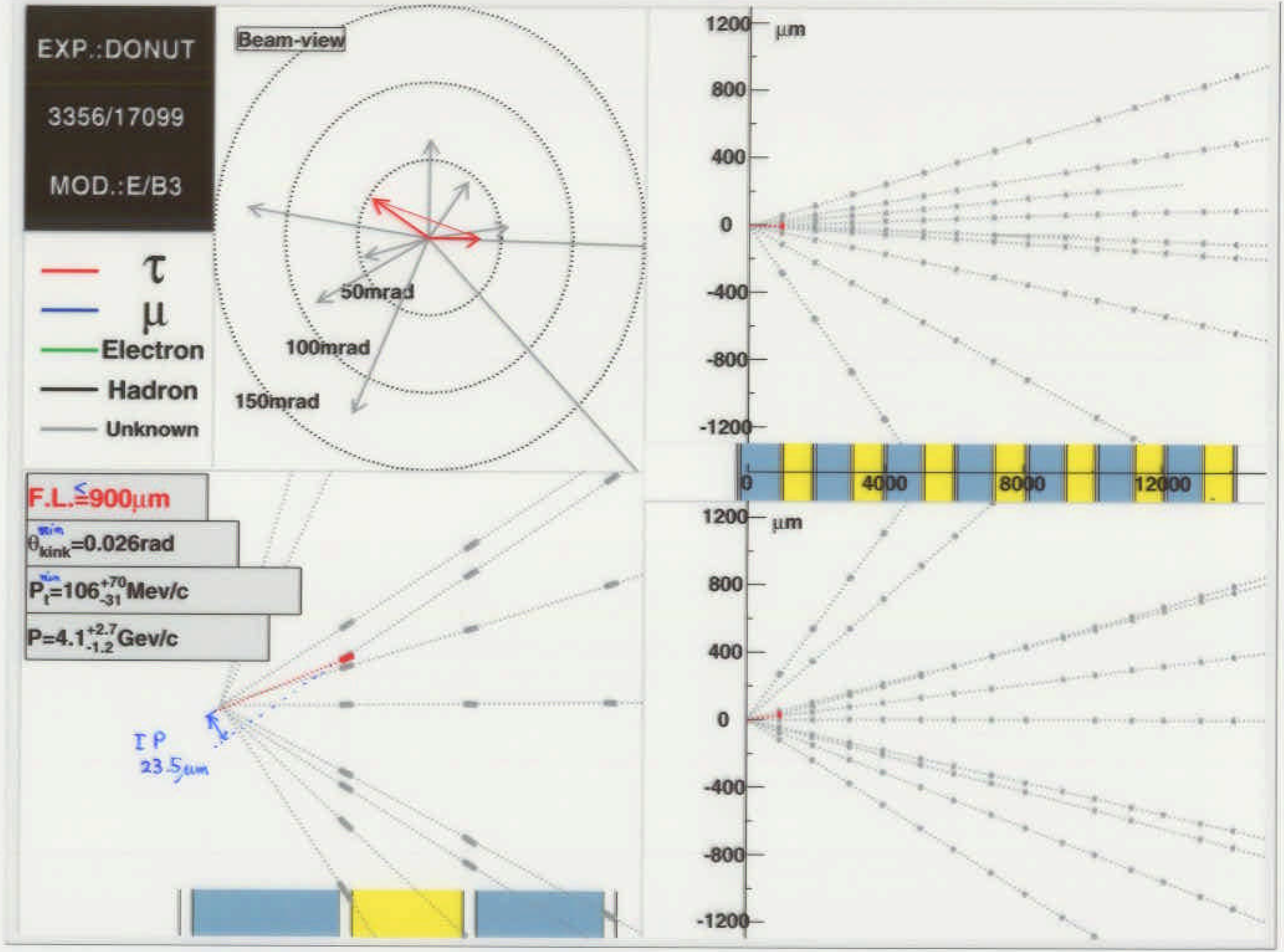
E872 3024-30175 $\tau \to e\, \bar{\nu}_e \nu_\tau$




EXP.:DONUT
3333/17665
MOD.:E/B2
τ
μ
Electron
Hadron
Unknown
Beam-view
100mrad
200mrad
300mrad
F.L.=540μm
θkink=0.013rad
Pt≥278+187-83 Mev/c
P≥21.4+14.4-6.4 Gev/c
1200
μm
800
400
0
-400
-800
-1200
0
4000
8000
12000

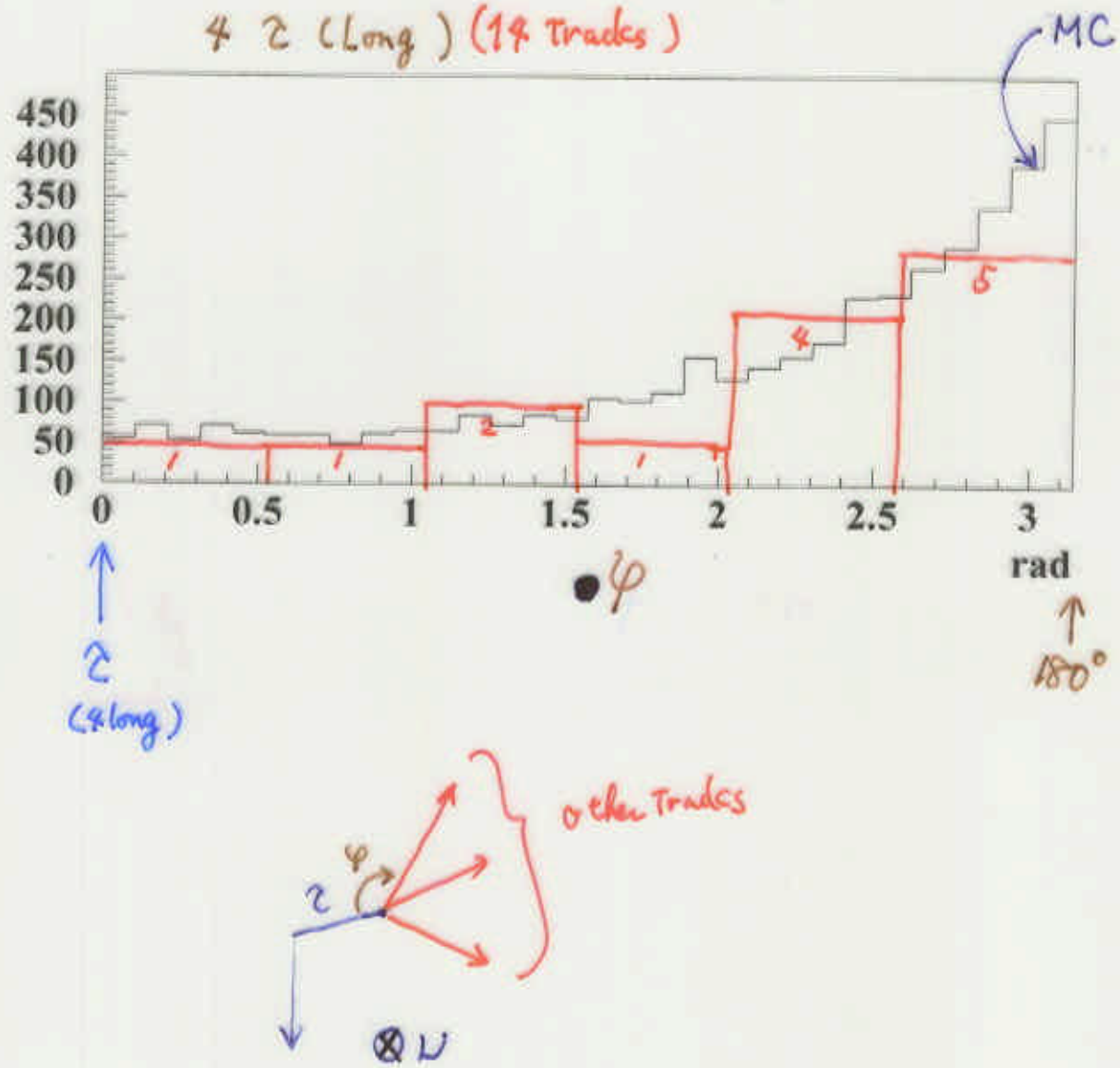

ν
E872 3333-17665
τ -> e ν̄e ντ
electron pair
F.L. = 0.54mm
decay P_T = 0.27GeV/c
θ_kink = 13mrad
ν


EXP.:DONUT
3263/25102
MOD.:E/B1
Beam-view
100mrad
200mrad
300mrad
Electron
Hadron
Unknown
F.L.=1800mm
θ_{kink}=0.13rad
$P_t=250^{+210}_{-80}$Mev/c
$P=1.9^{+1.6}_{-0.6}$Gev/c
m
500
400
300
200
100
0
-100
-200
-300
-400
0
1000
2000
3000
4000
5000
6000
7000


EXP.:DONUT
3356/17099
MOD.:E/B3
Beam-view
τ
μ
Electron
Hadron
Unknown
50mrad
100mrad
150mrad
F.L.≦900μm
θ_{kink}^{min}=0.026rad
P_t^{min}=106$^{+70}_{-31}$Mev/c
P=4.1$^{+2.7}_{-1.2}$Gev/c
IP
23.5μm
1200
μm
800
400
0
-400
-800
-1200
0
4000
8000
12000

Short Decay

Azimuthal Angle φ (τ – other charged Tracks) Distribution.



Conclusion

- DONUT has 5 ν_τ^{CC} events

  (4 long Decay
  1 short Decay)

  Expected BG (0.44 for long
  0.13 for short)

  (If ($\frac{\nu_\tau^{\alpha}}{\nu_\mu^{\alpha}+\nu_e^{\alpha}} \sim 5\%$) then expected 2 is
  (3.9 long
  0.7 short))

NEXT

- Increase statistics × 2

  ⇒ Need faster Emulsion Read-out System
  within 2001 Prototype for OPERA will be ready.
  (× 20 faster)
  DONUT will be the first User.

  ⇒ $\mu\nu_\tau$, NHL (??)