Status Report of DONUT Experiment

Direct Observation of Nu Tau

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Outline

- Motivation/Goals
- Experimental Setup
- Data Analysis Status
- Present Work
  - Individual Event Probabilities
  - Location Efficiency
  - Cross Section Measurement
- Conclusions

Motivation/Goals

Old Results:

- Directly observed the charged current tau neutrino interaction! (Phys. Lett. B 504 (2001) 218-224)
- Upper limit on tau neutrino magnetic moment, $\mu_{(\nu\tau)} < 3.9x10^{-7} \mu B$ (Phys. Lett. B 513(2001) 23-29) (Reinhard Schwienhorst)

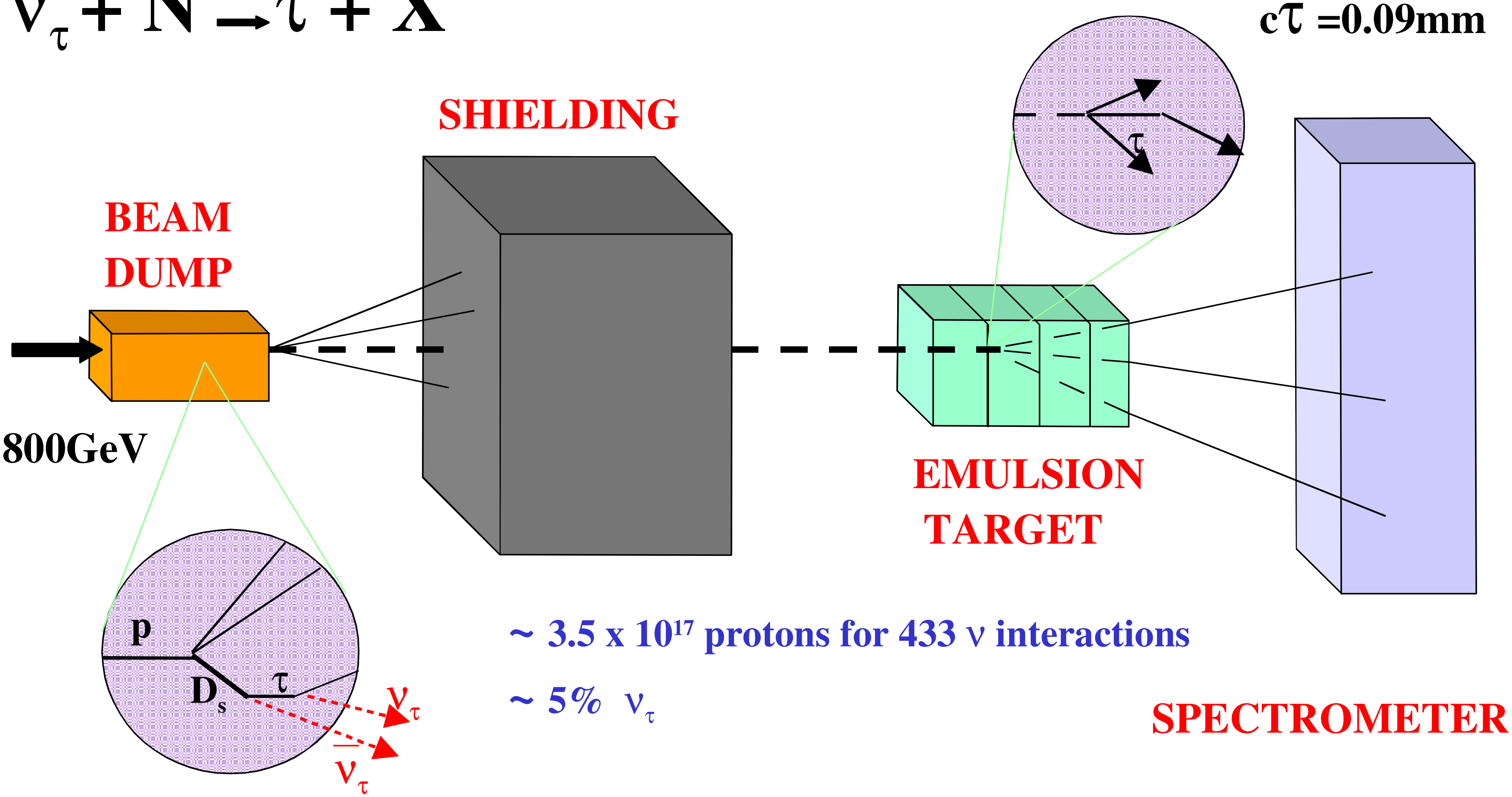
Preliminary Results:

- Extended data set from 203 to 437
  - Observed 3 more tau neutrino interactions (total 7 candidates)
- Calculated individual event probabilities (Jason Sielaff 2002)
- Working on interaction cross section measurement
  - Is tau neutrino standard model particle?
- Two theses down (Sielaff, Schwienhorst), two to go (Erickson, Maher)

Experimental Setup – Block Diagram

directly observe cc interactions of the ν_τ

$$\nu_\tau + N \rightarrow \tau + X$$



~ 3.5 x 10^{17} protons for 433 ν interactions

~ 5% ν_τ

Data Analysis Status – Then and Now

6.6×10^{6} triggers

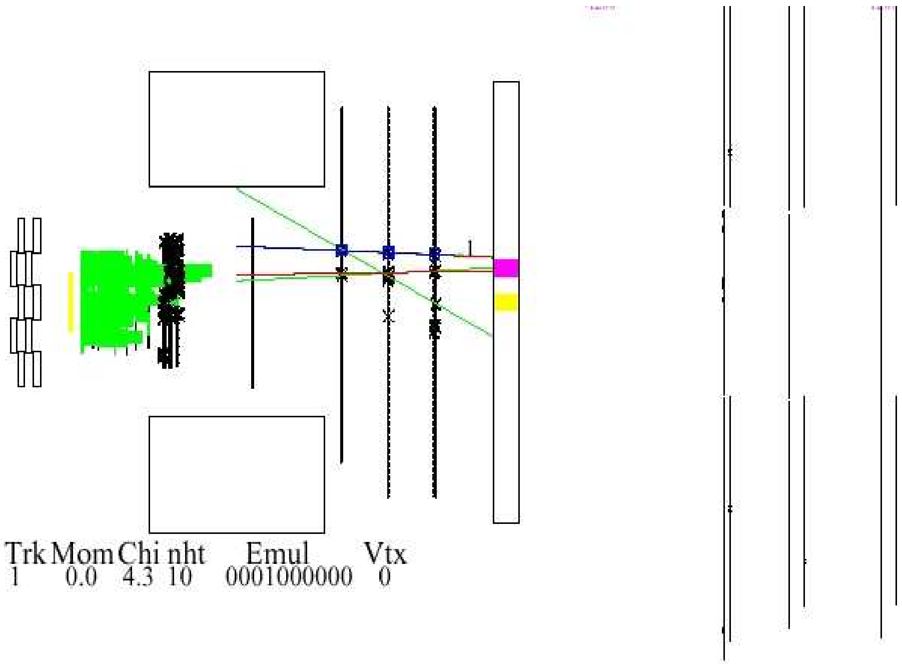
Then	Now	
1026	898	predicted vertices from spectrometer
878	699	within fiducial volume
647	511	digitized emulsion data exists
647	451	emulsion vertex location attempted
437	264	vertex found
437	203	systematic decay search
7	4	$\nu\tau$ candidates

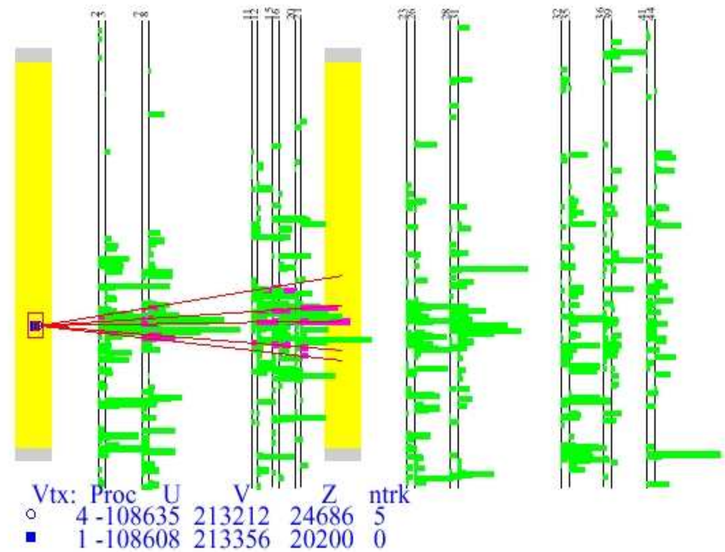
69% 59%

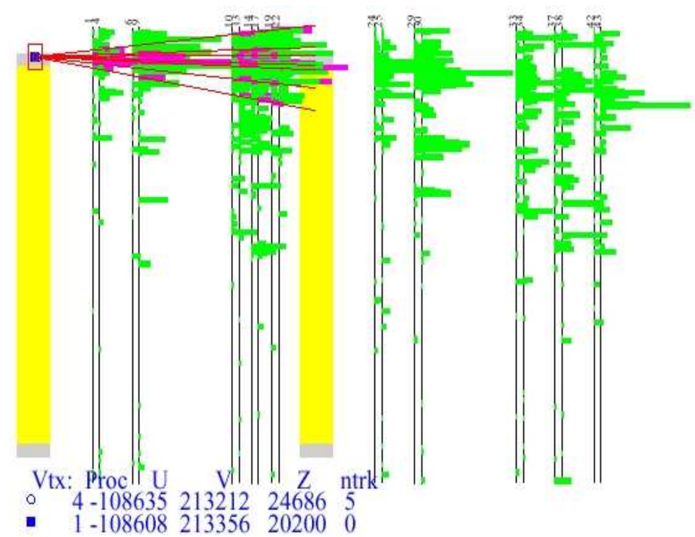
Location efficiency

7 charm candidates

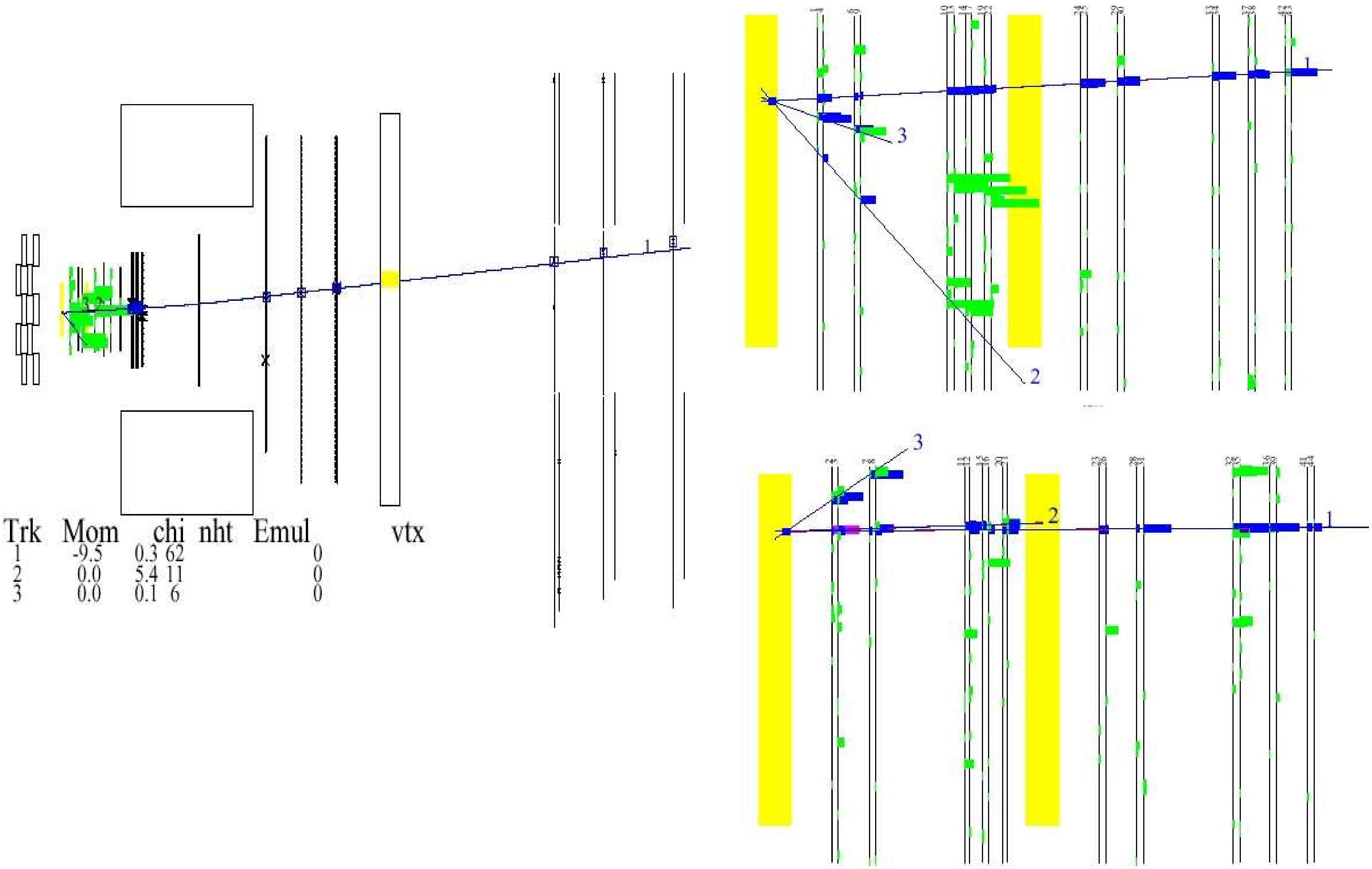
Messy Event – No Emulsion Data





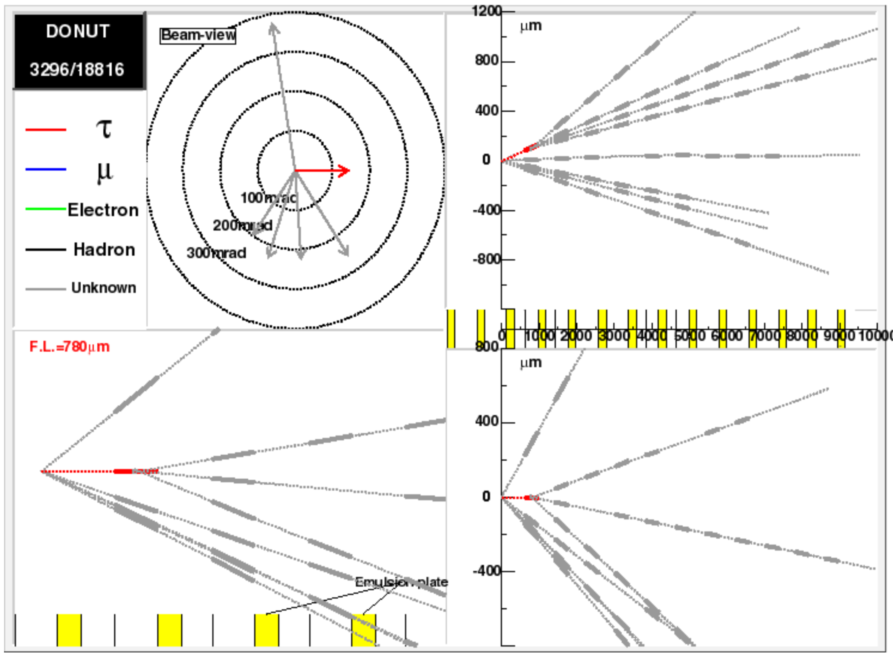


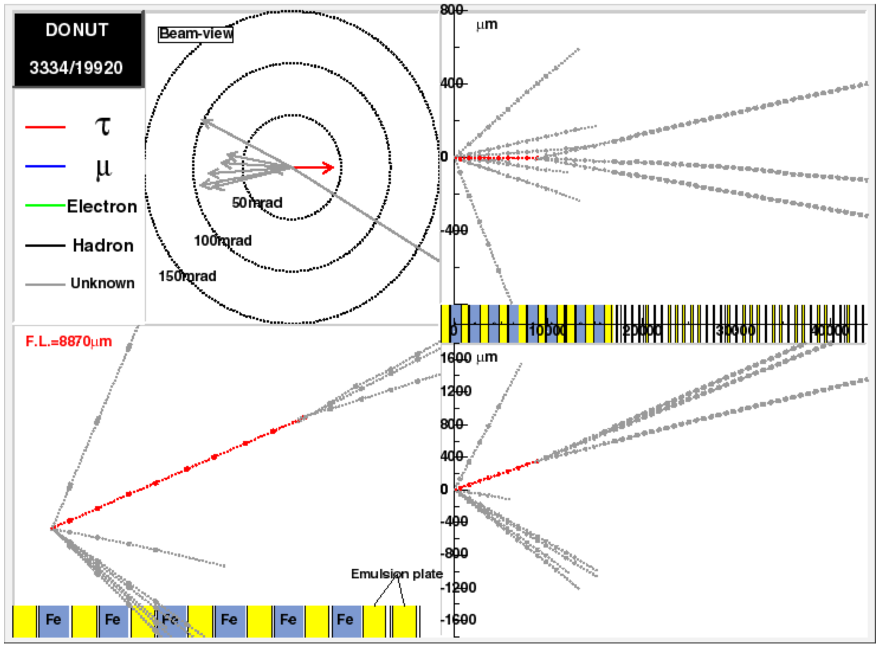
Typical Event – Emulsion Data, Not Located

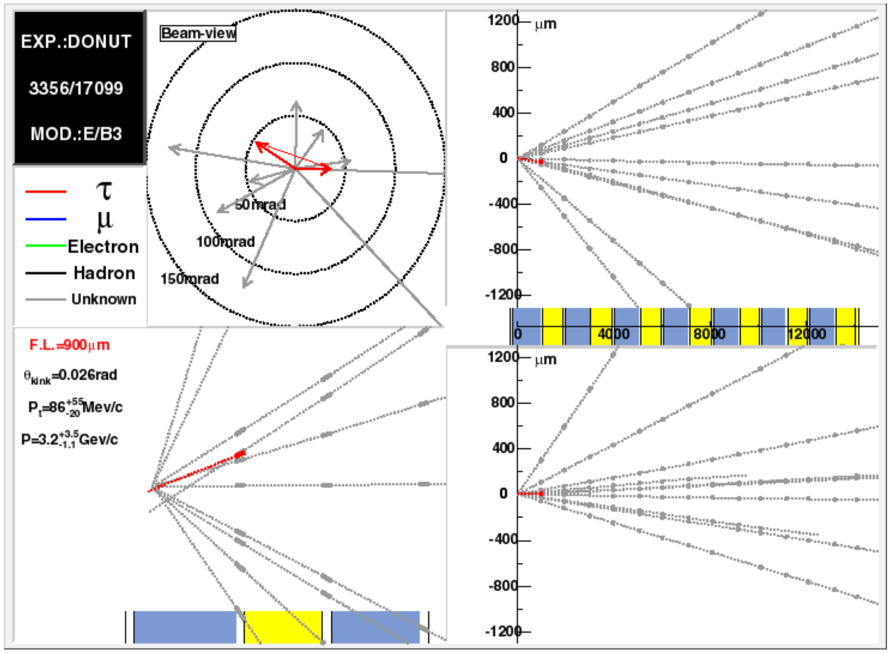


Trk	Mom	chi	nht	Emul	vtx
1	-9.5	0.3	62	0	
2	0.0	5.4	11	0	
3	0.0	0.1	6	0	

New ν_τ Candidates







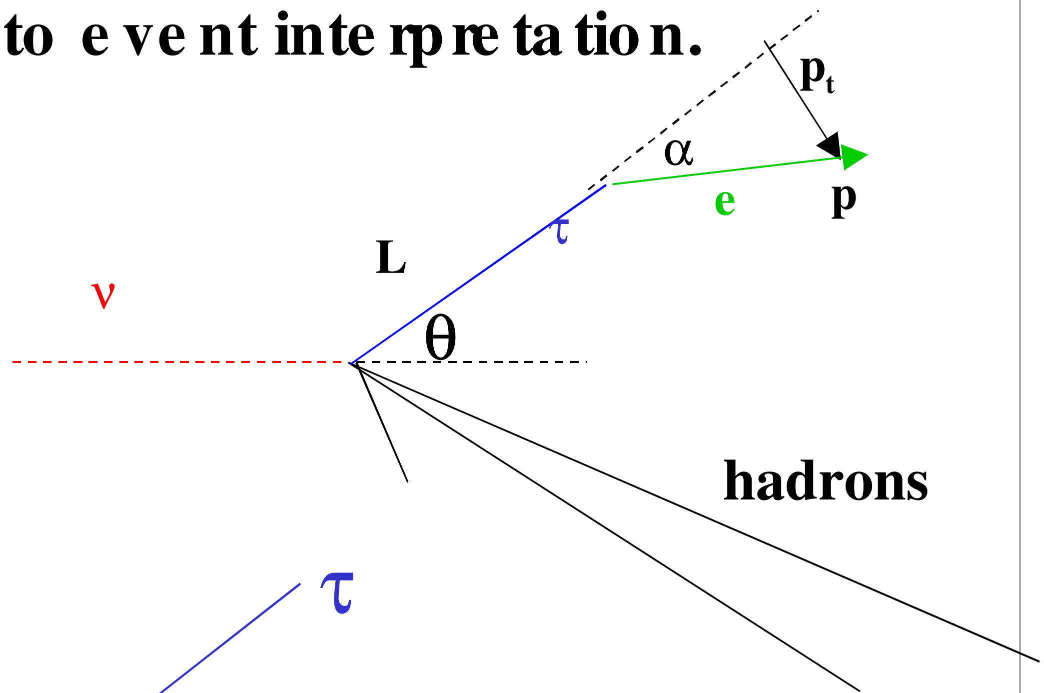
Event analysis not complete

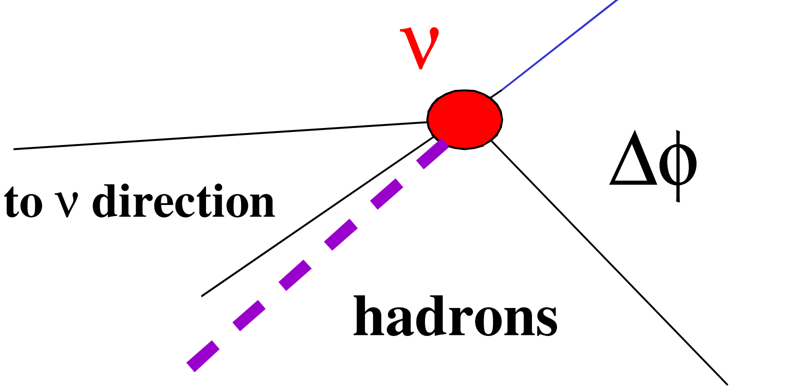
Individual Event Probabilities - Observables

Use **3-parameter** or **5-parameter** analysis to assign probabilities to event interpretation.

Parameters

- Track production angle θ
- Event angular symmetry Δϕ
- Track decay length L
- Daughter momentum
- Daughter decay angle





Individual Event Probabilities
Jason Sielaff's Thesis

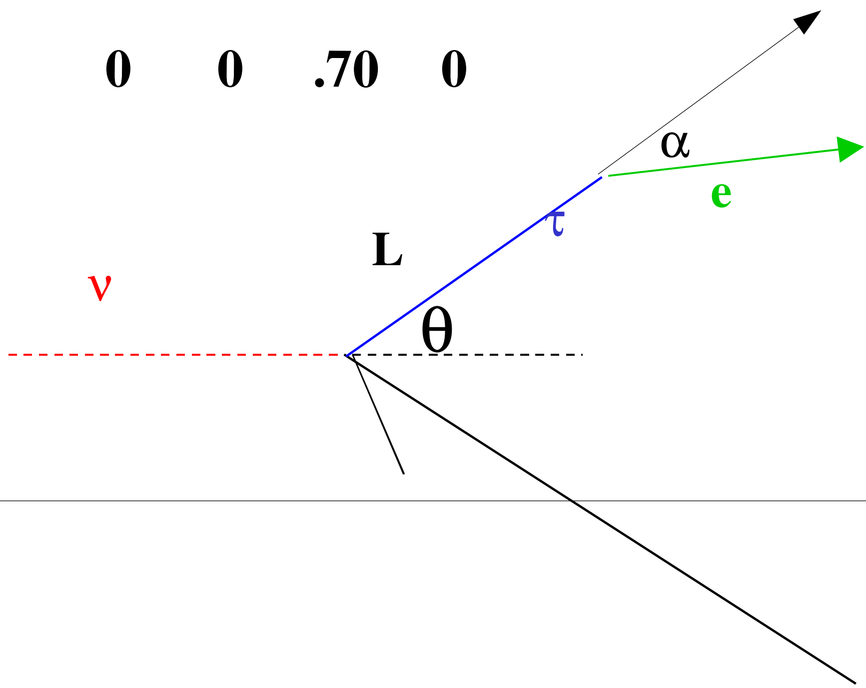
Single Prong Event Parameters

- Track production angle
- Event angular symmetry
- Track decay length
- Daughter decay angle
- Daughter momentum

Probability all events are background $= 5 \times 10^{-5}$

Single Prong

	3024_30175	3039_01910	3263_25102	3333_17665
ν_τ cc	.70	.98	.16	.99
ν + charm	.30	.02	.14	.01
ν + hadron scatter	0	0	.70	0



Individual Event Probabilities

Probability all events are background = 2.2×10^{-7}

3 parameter analysis

5 paramter analysis

Trident Event Parameters

- **Track production angle**
- **Event angular symmetry**
- **Track decay length**

	Single Prong								Tridents	
	3024_30175		3039_01910		3263_25102		3333_17665		3334_19920	3296_18816
ν_τ cc	.87	.70	.99	.98	.06	.13	.99	.99	.96	.89
ν +charm	.13	.30	.01	.02	.03	.14	.01	.01	.03	.01
ν + hadron scatter	0	0	0	0	.91	.73	0	0	.01	.10

Cross Section Measurement

Check to see if the number of tau neutrino charged current interactions DONUT observed agrees with theory – check lepton universality

Cross section can be calculated in different ways

- Calculate an absolute expected number of tau neutrino charged current interactions using first principles and measured cross sections, relating event yield to protons on target
- Normalize expected number against number of electron and muon neutrino charged current interaction observed by DONUT

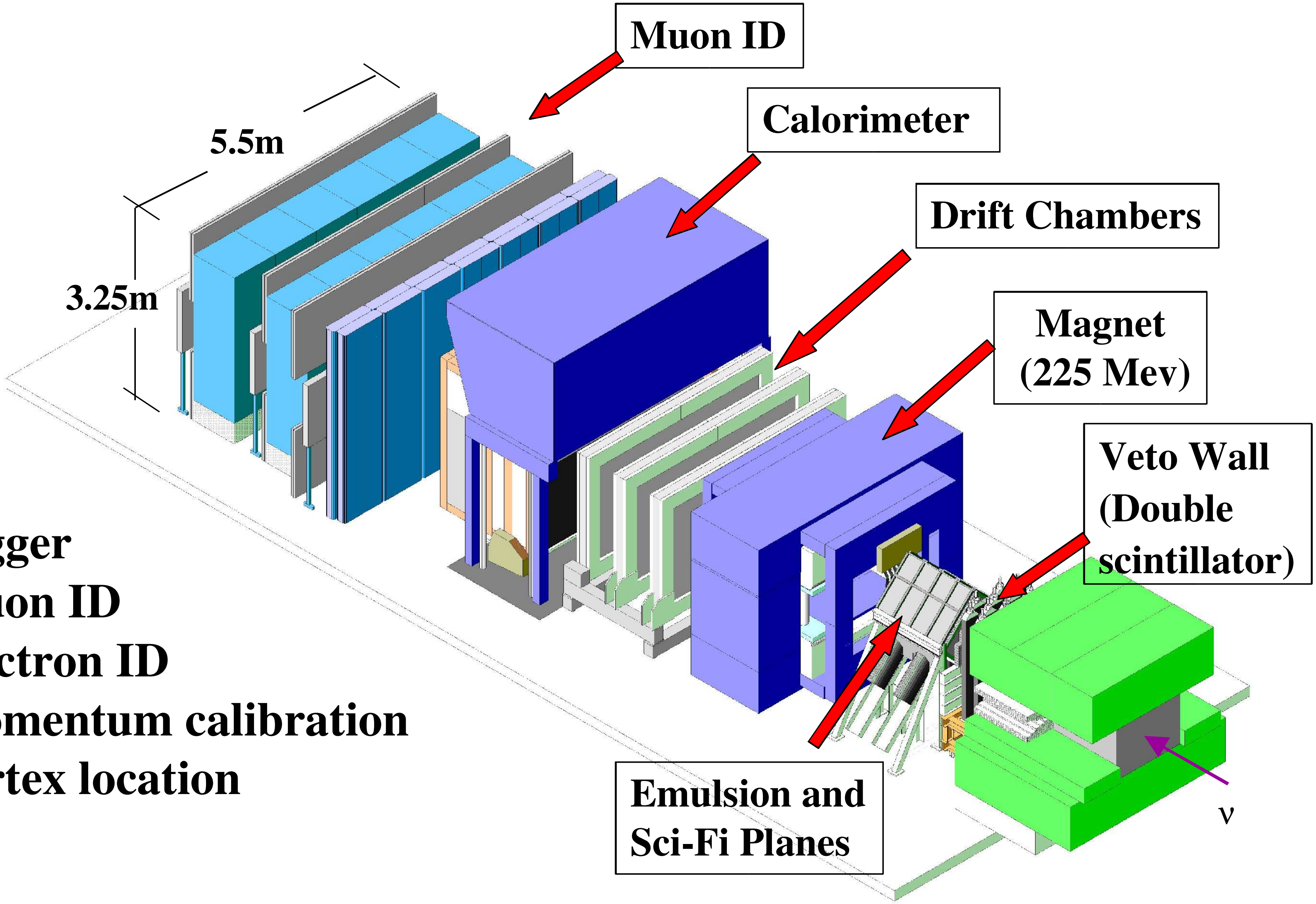
The following quantities are necessary:

- Must define specific cuts to create data set
- Must know efficiencies (trigger, selection, location, lepton id)

Conclusion

- **Increasing event sample continues**
  - **From 203 to 437**
    - **Problems are getting harder**
    - **Located 4 events in the last month**
- **Better understanding of efficiencies and more tau and charm events**
  - **Improved understanding of backgrounds and systematics**
- **Better discrimination of tau neutrino interactions and background events**
- **First Cross Section Mesaurement of tau neutrino**
- **Improving technology for future detectors to study short lived particles.**

Spectrometer



- trigger
- muon ID
- electron ID
- momentum calibration
- vertex location

Individual Event Probabilities

$$P(x\,event_i) = \frac{A_i * PDF_i(x)}{\Sigma_J A_j * PDF_j(x)}$$

P = The probability of a set of observables, *x*, being a result of event *i*, where $i \in (\nu_\tau cc, charm, hadronic\ scatter)$.

Two inputs for each event type:

1. A_i prior probability:

   Knowledge of the likelihood of each event *i*

   Relative Normalization (aka N_{signal}, $N_{charm\ bkg}$, $N_{int.\ bkg}$),

2. $PDF_i(x)$: probability density function

   Probability of finding event in $(x, x+\Delta x)$

   where *x* is a 3- (for trident events) or 5- (for single prong events) tuple of parameters specific to the individual event