Structure Function Systematics

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Overview

- See discrepancies between the 10X Monte Carlo sample and the data
  - Muon momentum spectrum & EMCal (P/NP ratio)
  - ν angle, $\mu\nu$ scattering angle
  - Muon track reconstruction efficiency ~90% in MC, ~100% in data
  - Number of emulsion tracks
- Are these due to kinematic cuts or our choice of structure function?
  - Our standard MC uses Lepto structure function 9 = CTEQ2L
    - $Q^2 > 1$ GeV^2, $W^2 > 4$ GeV^2
  - Most PDF's don't model low Q^2 behavior
    - GRV does
- Lepto & GEANT do not simulate intra-nuclear re-interactions
  - Negligible effect on lepton variables
  - Perhaps an issue when comparing EMCal & SFT to the MC
- Lepto does not simulate quasi-elastic interactions
  - Expect QE contribution to be ~5%

Code fixed and not fixed

- Found and fixed ν angle problem in the MC
  - Applied data-derived target acceptance cuts in proj_targ
    - $-28.5 < U < 19.5$, $-27 < V < 21$ cm
  - Lowered the E872 dump by 4.1 cm
  - Rotated Lepto tracks into the ν coordinate system (gukine)
    - ~10 mrad max
  - Data/MC comparison histograms in neut.ps
    - Average ν angle is (0, 0.0012) at the target
- Muon reconstruction in-efficiency due to several factors:
  - 4% not matched to SFT hits
  - 4% not reconstructed in the DC's
  - 4% fail >3 MID hit cut
  - Inefficiency is worse at low momentum
  - These can be recovered with code improvements or by "faking it"

Variables used

- MC: use mc_truth.inc variables to identify CCmu & CCe
  - Use truth momentum/energy for muon/electron
  - For CCmu, require >3 truth MID hits
  - No CCe energy cut
  - Use lepton emulsion track angle rotated into X,Y
  - Generate Period 4 events
- Data: use identified CCmu/CCe events in events.lis
  - For CCmu located events use emulsion trk rotated in X,Y
  - For CCmu not-located events use spectrometer track angle at the predicted vtx
  - For CCe located events use electron track identified by EIDANAL
    - ~10 GeV min energy cut
  - CCe not-located events not used
  - Use events from ALL periods

Monte Carlo runs

- Generated 4k MC events with 50% CCmu, 50% CCe
- Settings & cuts standard except:
  - CTEQ2L - $Q^2 > 1$ GeV^2 (Standard)
  - CTEQ2L - $Q^2 > 0.3$ GeV^2
  - CTEQ5L - $Q^2 > 0.3$ GeV^2
  - GRV98 - $Q^2 > 0.01$ GeV^2
- Lepto re-weights events when the Q^2 cut is changed
- Associated histogram plot files
  - Sf_ccmu.ps, sf_cce.ps
  - CTEQ5L not shown – no significant differences from CTEQ2L

Results – Trigger Efficiency & Lepton ID

- Significant differences in MID tag efficiency for various PDF's & cuts
- MC errors ~1% (2k evts)

P Frac = 60%
P Frac = 50%

	Q2 min	Trig Eff	MID Tag Eff	Cce >10 GeV
CTEQ2L	1.00	96%	69%	88%
CTEQ2L	0.30	97%	75%	88%
GRV98	0.01	97%	77%	87%
GRV98-2	0.01	95%	72%	NA
GRV98	0.30	94%	71%	NA

- Patrick Thesis:
  MID tag Eff = 64%

Checking results w 10k MC jobs
Not done yet…

MID Efficiency

- Patrick required 1 MID hit/wall & >3 hits for muon tag
  - Ignored scintillator panels
  - Assumed equal tube efficiency
  - Estimates tube efficiency = 93% by "fitting" the distribution of 4,5,6 MID hits within a 10 cm window
  - Finds muon tagging efficiency = 98%
- We don't require 1 MID hit/wall
  - Changes tagging efficiency to 99%
- We use tube efficiency = 97% in the MC
  - Gaps between tubes not simulated
  - Changes tagging efficiency to 100%

Results – Histogram shapes

- Compare
  - Lepton track angles (θx θy) *Spectrometer acceptance*
  - Neutrino - muon/electron scattering angle – $\theta_{\mu\nu}$, $\theta_{e\nu}$ *Lepto*
  - Lepton momentum/energy *Lepto*
  - EMCal energy *Lepto*
  - See associated histogram files for CCe and CCmu events
- Compare histogram shapes - PAW/HBOOK routines
  - HBARX fills histogram statistics for (un)-weighted events
  - HDIFF uses Kolmogorov test ($0 < P < 1$)
    - Shape only – not normalization
    - Histograms are likely from same parent distribution if $P > \sim 5\%$

Results Summary

	CCmu							
	thet mu-nu Prob	thet mu-nu Ave	Mu Mom Prob	Mu Mom Ave (GeV)	Pt Prob	Pt Ave (GeV)	EMCal Prob	EMCal Ave (GeV)
Data		0.056		35		1.72		7.3
CTEQ2L 1	2%	0.066	4%	40	0%	2.11	100%	7.1
CTEQ2L 0.3	6%	0.064	1%	41	0%	2.05	100%	7.2
GRV 0.01	40%	0.060	0%	41	0%	1.99	20%	6.3

Beware of bias

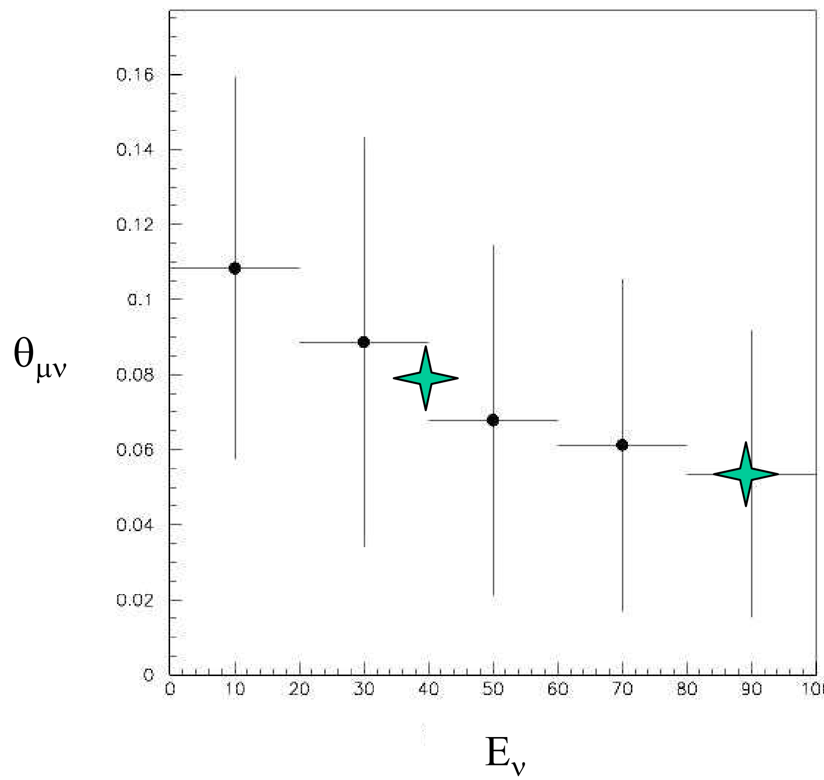
	CCe							
	thet e-nu Prob	thet e-nu Ave	Elect E Prob	Elect E Ave (GeV)	Pt Prob	Pt Ave (GeV)	EMCal Prob	EMCal Ave (GeV)
Data		0.044		51		1.95		36.0
CTEQ2L 1	0%	0.060	50%	55	0%	2.49	44%	37.0
CTEQ2L 0.3	4%	0.055	100%	54	0%	2.31	16%	37.0
GRV 0.01	0%	0.058	100%	53	0%	2.36	70%	37.0

Commentary

- More CCmu and CCe data events at very small $\theta_{\mu\nu}$(< 0.020) than the MC variants
  - Scanned the events: Low multiplicity, Nothing strange
  - Distributed as expected in stations 1 – 4
  - Get somewhat better agreement with lower Q^2 min cut
  - Probably QE events. Expect 5% * 280 = 14 QE CCmu
    - Match probabilities don't change significantly with $\theta_{\mu\nu}$> 0.020 cut
- Ave muon momentum lower in data than MC
  - MC E_ν is too high (assuming detector simulation OK)
- Ave $\theta_{\mu\nu}$ lower in data than MC for both CCmu and CCe
  - MC E_ν is too low (assuming detector simulation OK)
- GRV98 has significantly lower EMCal energy for CCMu events

$\theta_{\mu\nu}$ Scattering Angle & Prompt Fraction

- Larger scattering angle at lower neutrino energy
- Use as another handle on P/(P+NP)?



Check generated ν spectrum

Component	Nnu/PoT x10^-6	Fraction	Enu (GeV)	weighted Enu
Prim Charm	30	89.6%	56	50.15
2ndry Charm	2	6.0%	33	1.97
Lambda C	1.5	4.5%	81	3.63
			P Enu=	**55.7**
pi	69	72.6%	15.3	11.11
K	26	27.4%	26.7	7.31
			NP Enu=	**18.42**

From Patrick's thesis

- Generate 300 events (50% P)
  - Correct for interaction probability after target cut
  - Weighted E_ν = nup(4)*wgt_cs/intprb
  - Find Average Prompt E_ν = **58.4 GeV**
  - Find Average Non-Prompt E_ν = **19.5 GeV**

Generators OK

Emulsion Track Effects

- Study number of tracks & angular distributions
  - Require longish (>3 segment) tracks ~40 MeV momentum cut
  - Obvious biases
    - Location efficiency & broken tracks
- Phase 1 & Phase 2 vs MC PDF histograms in nem.ps
  - MC events have ~1 more emulsion track/event
  - Data CCe events have ~1 more emulsion track than CCmu
  - Angle between primary lepton and other vtx tracks (θ_{lh}) is
    - Reasonably well represented in CCmu events
    - Other trks accompany primary electrons within $\theta_{lh} < 50$ mrad
- No significant PDF related effects

Possible explanations

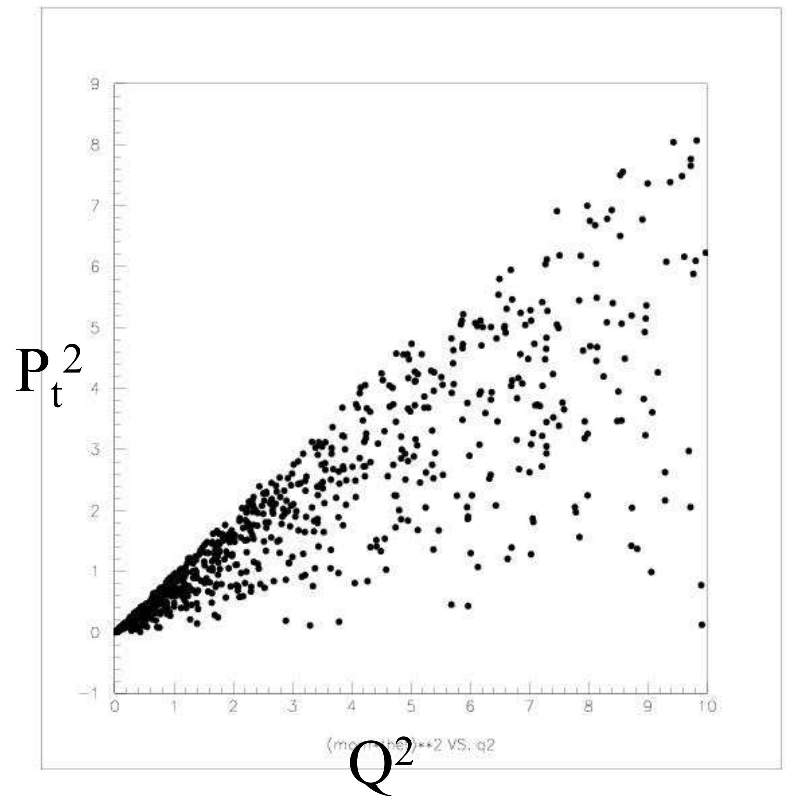
- Location efficiency & broken track bias unlikely
- NC + Mis-tagged hadrons? + poor simulation of hadron showers?
- Look for A dependence
  - Repeat plots with vtx location in emulsion, base, steel (embafe.ps)
    - Ave (A,Z) = Fe (56,26), Emulsion (79,35)
  - Ave Number of emulsion tracks the same
  - Number of small θ_{lh} tracks is enhanced in Fe compared to emulsion
    - Not due to 0.5 mm path length in Fe plates
- Scanned 27 events w vtx in steel, $\theta_{lh} < 50$ mrad
  - 14 un-ambiguous CCe (Asym EMCal, narrow SFT shower)
  - 13 hadronic(?) shower events – *Removed → see embafe2.ps*

Summary

- Corrected ν angle problem in the MC
- Trigger efficiency & MID??
- Data/MC differences in $\theta_{\mu\nu}$, p_t, muon mom shapes are not attributable to our choice of structure function, cuts
  - Differences are minor
  - Patrick found good agreement with muon momentum…
- Excess in small $\theta_{\mu\nu}$ events in the data probably QE events
- MC generated neutrino energy OK
- Electron ID needs work…

P_t cut

- Most DIS experiments apply Q^2 cuts to their data sample
- We can't measure Q^2, but $P_t^2 \sim Q^2$
- Apply $P_t^2 > 1$ GeV^2 cut
- Recreate histos
  - Sf_ccmu_pt.ps
- Compare next page



$P_t^2 > 1$ GeV^2

Pt > 1 GeV	CCmu							
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GRV 0.01	60%	0.065	0%	44	0%	2.40	80%	6.9

Better agreement w $\theta_{\mu\nu}$