Upstream Stops Analysis

Current Status

Ryan Bayes

$\mathcal{TWIST}$ Collaboration Meeting, January 31, 2009

1. Available Upstream Stops Data Sets
2. Monte Carlo Validation
3. Reconstruction Bias
4. Detector Inefficiency
5. Systematic Measurements

Outcomes of upstream stops studies

- validate the Monte Carlo with respect to data.
  - evaluate difference in scattering and energy loss
  - estimate differences in the tails
- refine systematics of the positrons interactions in the detector.
  - measure the associated scale for systematics
  - sensitivities measured from target stops
- test the efficiency of the track reconstruction.
  - feeds back into assumption of fiducial region

Upstream Stops Data Sets

- Latest analysis of data sets

Set Number	Description	Runs Analysed	Good Runs
set73anal8	Silver stopping target	385	365
set80anal1	Aluminium stopping target	353	209
set89anal1	Large Aluminium target	655	635

- One data set has not been analysed: set 68.

Upstream Stops Monte Carlo

- Latest Monte Carlo generation and Analysis

Generation #	Description	Runs Generated	Good Runs
gen432anal4	Match s73an8	516	508
gen433anal1	Match s73an8, δ-rate $\times 0.01$	297	295
gen434anal1	Match s73an8, δ-rate $\times 3$	294	280
gen435anal1	Match s73an8, δ-rate $\times 10$	279	265
gen630anal1	Match s89an1	811	769

- will regenerate MC to match set 73, set 89
  - do not use production Monte Carlo
- will need to generate MC to match set 80

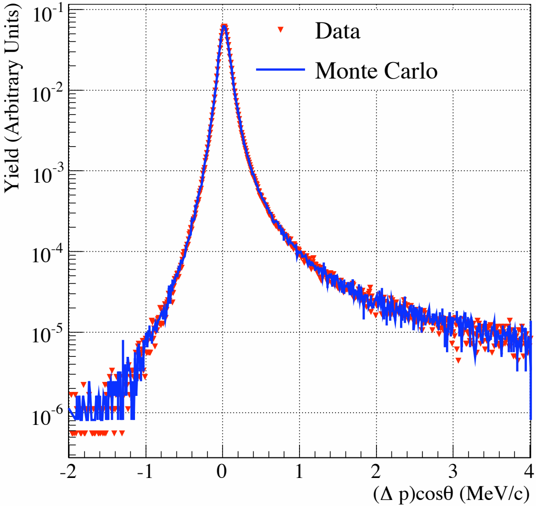
Integrated Difference between US and DS: $(\Delta p)\cos\theta$

	MPV (keV/c)	FWHM (keV/c)
Std Ag Tgt (s73a8)	41.64 ± 0.14	140.16 ± 0.08
Std Ag Tgt. Sim (g432a4)	44.20 ± 0.09	135.11 ± 0.06
Lg Al Tgt. (s89a1)	20.96 ± 0.09	124.92 ± 0.07
Lg Al Tgt. Sim. (g630a1)	22.15 ± 0.10	121.19 ± 0.08
Std Al Tgt (s80a1)	32.75 ± 0.17	130.5 ± 0.1
2004 Al Target (s33a3)	28.4 ± 0.1	155.9 ± 0.1
2004 Al Target (g333a1)	29.65 ± 0.04	141.64 ± 0.04

- Momentum loss differs by 2-3 keV/c between data and MC
- Difference between Lg. Al. Tgt. and Std. Al. Tgt. Momentum loss due to missing PCs at target.

Integrated Difference between US and DS: $(\Delta p)\cos\theta$

Distribution of momentum differences for data and MC



- Events within the fiducial region
- Large target geometry
- Tail count ratio:

data	0.01054 ± 0.00008
MC	0.01069 ± 0.00009
Compare to Rob's Results	
data	0.0142 ± 0.0001
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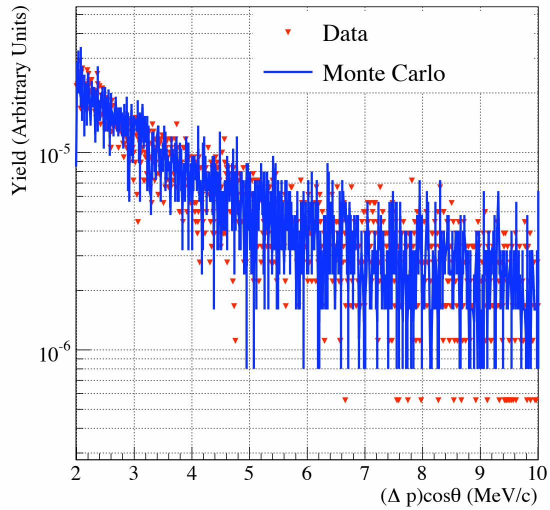

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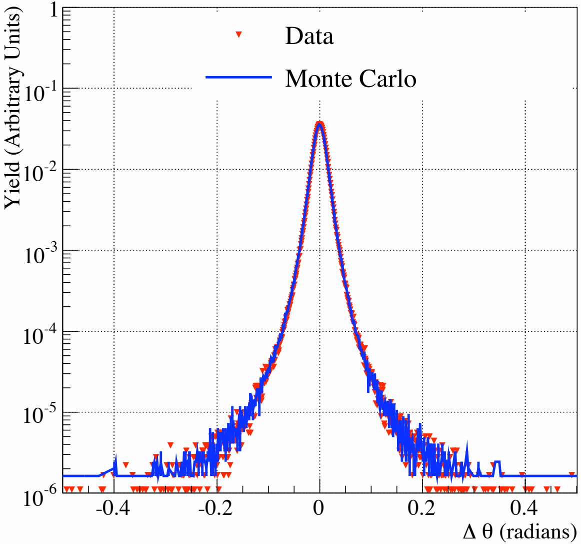
Integrated Difference between US and DS: $\Delta\theta$

	MPV (mrad)	FWHM (mrad)
Std Ag Tgt (s73a8)	-0.07 $\pm$ 0.04	54.34 $\pm$ 0.03
Std Ag Tgt. Sim (g432a4)	-0.21 $\pm$ 0.03	51.31 $\pm$ 0.02
Lg Al Tgt. (s89a1)	0.11 $\pm$ 0.01	23.47 $\pm$ 0.01
Lg Al Tgt. Sim. (g630a1)	-0.08 $\pm$ 0.02	24.12 $\pm$ 0.01
Std Al Tgt (s80a1)	0.09 $\pm$ 0.04	28.58 $\pm$ 0.03
2004 Al Target (s33a3)	0.97 $\pm$ 0.02	29.75 $\pm$ 0.02
2004 Al Target (g333a1)	0.581 $\pm$ 0.007	29.159 $\pm$ 0.007

- Mean scattering angle differs by 0.15 mrad between modern MC and Data
- Mean scattering angle differs by 0.4 mrad between 2004 MC and Data
- Scattering angle is still non zero - Why?

Integrated Difference between US and DS: $\Delta\theta$

Distributions of scattering angle at the target for Data and MC



- Event from within fiducial region
- Large target geometry
- Difference between distributions very small
  - Indicates differences in MPV and σ

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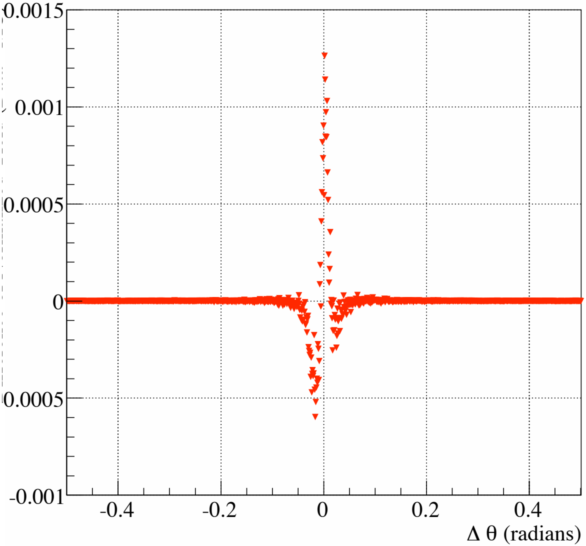

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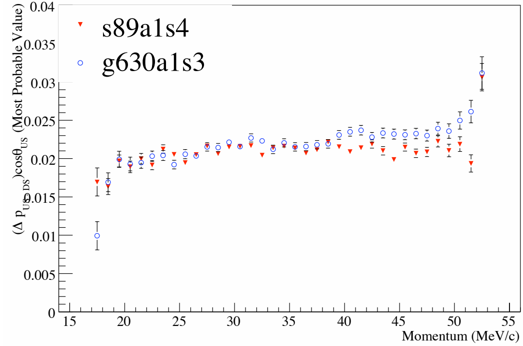
Source of Peak Deviations in $(\Delta p)\cos\theta$

Consider peak momentum loss through the momentum spectrum



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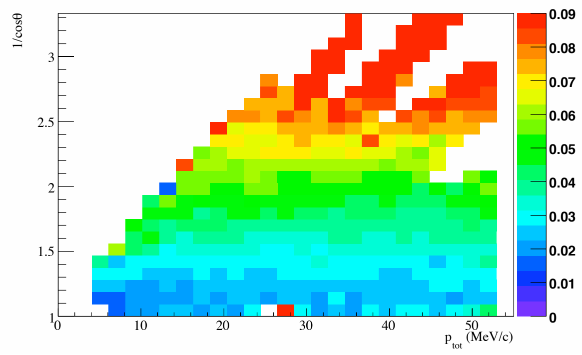

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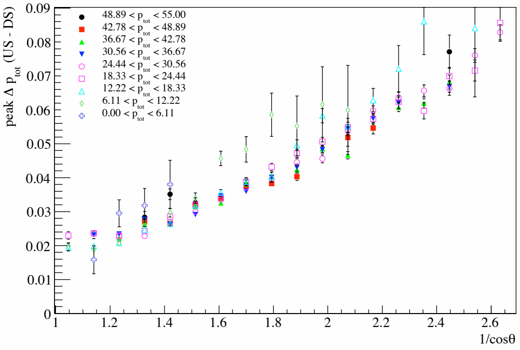

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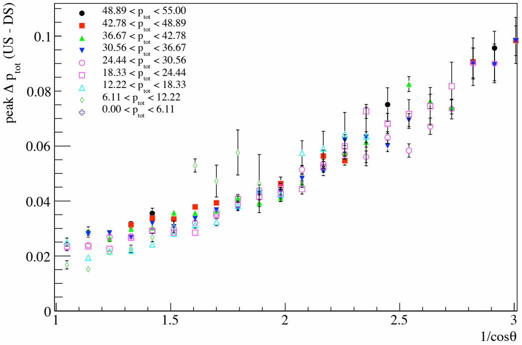

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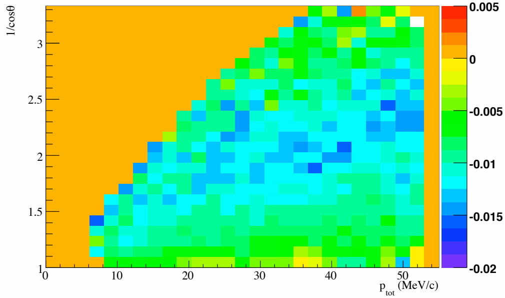
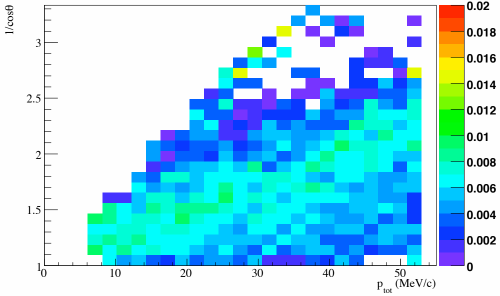
Momentum Bias At The Target Module





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- Magnitude of biases is similar (Not the same)
- Bias changes little with momentum ($\approx$2 keV/c)

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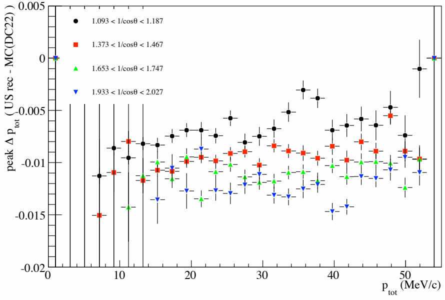

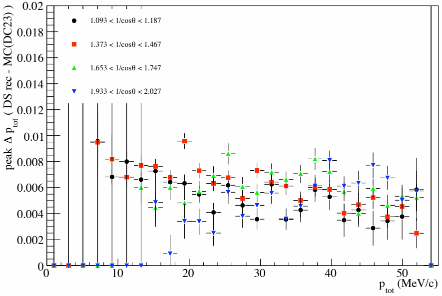

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Schematic Approach to Momentum Bias

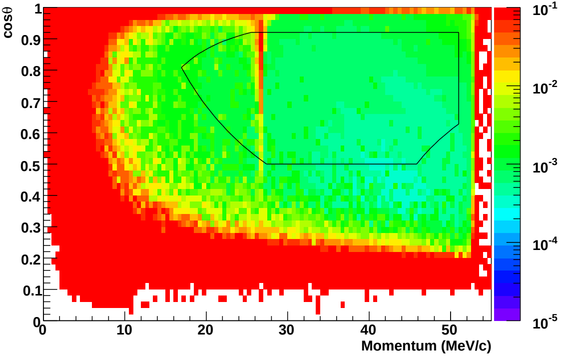
Consider Positron entering the detector with momentum p_0

- At PC 22: $p_{US} = p_0 - \frac{\Delta_{TR}}{2\cos\theta_{true}} - \frac{C_{US}}{\cos\theta}$
- At PC 23: $p_{DS} = p_0 - \frac{\frac{3}{2}\Delta_{TR}+\Delta_{tgt}}{\cos\theta_{true}} + \frac{C_{DS}}{\cos\theta}$
- Momentum Bias at PC 22: $B_{US} = \frac{\Delta_{TR}}{2\cos\theta_{true}} - \frac{C_{US}}{\cos\theta}$
- Momentum Bias at PC 22: $B_{DS} = \frac{C_{DS}}{\cos\theta} - \frac{\Delta_{TR}}{2\cos\theta_{true}}$
- US momentum bias opposite sign w.r.t. to DS momentum bias
- Difference of Momenta across target:

$$\Delta p = p_{US} - p_{DS} = \frac{\Delta_{tgt}}{\cos\theta_{true}} + B_{US} - B_{DS}$$

Upstream Downstream Relative inefficiency

Inefficiencies Measured from Large Target geometries



- Data
- Monte Carlo
- Difference: (Data - Monte Carlo)/σ
- Upstream track Inefficiency
  - Downstream track, No upstream track; $P(d|U)$
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- Monte Carlo less efficient than data

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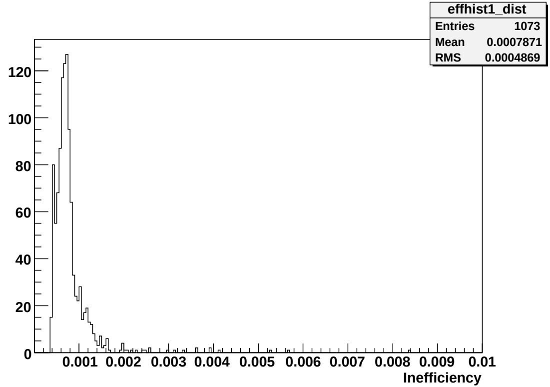

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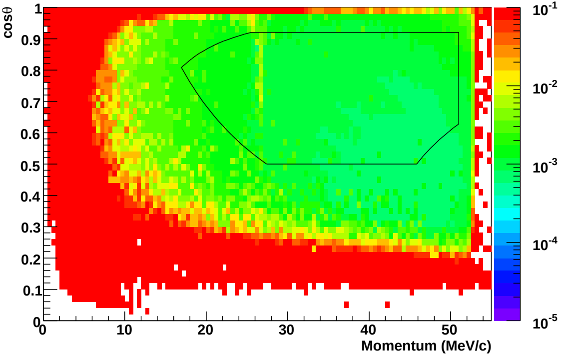

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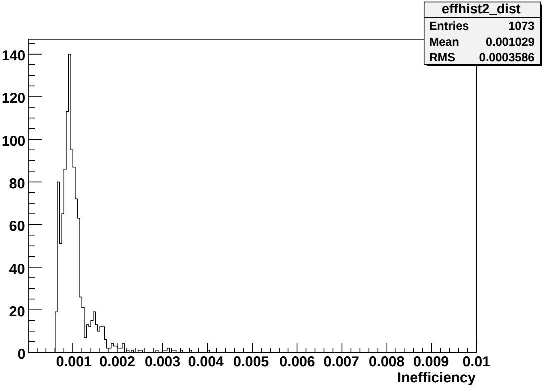

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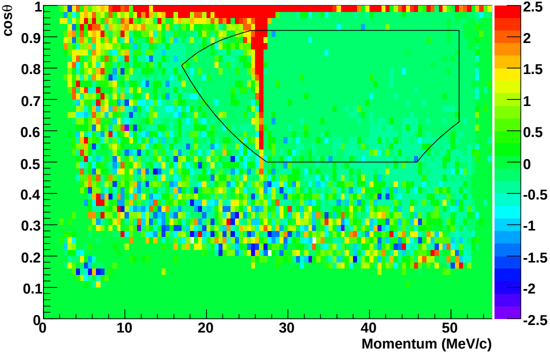

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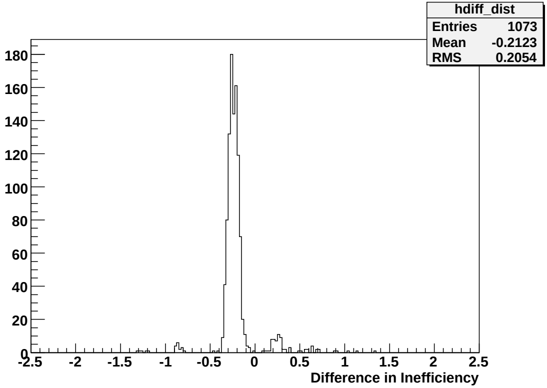

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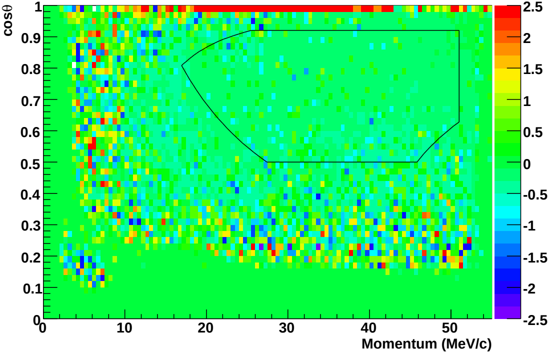

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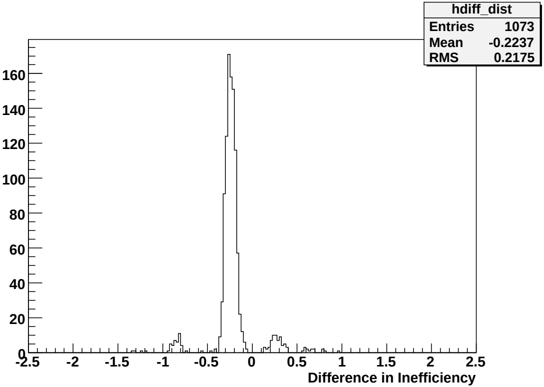

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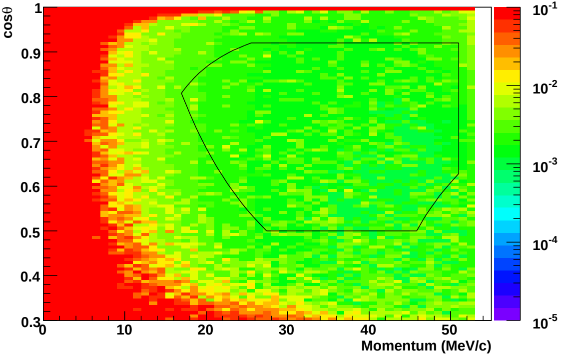
Truth Bank Derived Inefficiency

Look for reconstructed tracks when there is a MC track



- No upstream track reconstructed: MC track exists
- No upstream or downstream track reconstructed: MC track exists

- Assuming MC track exists when downstream track exists

$$P(u|D) \approx P(u|M) - P(u \cap d|M)$$

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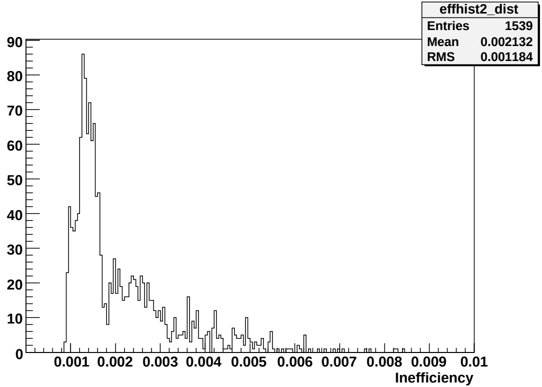

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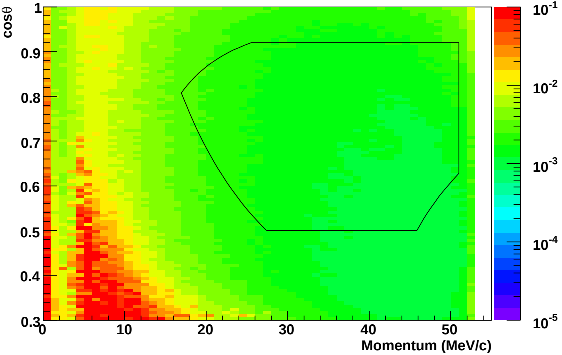

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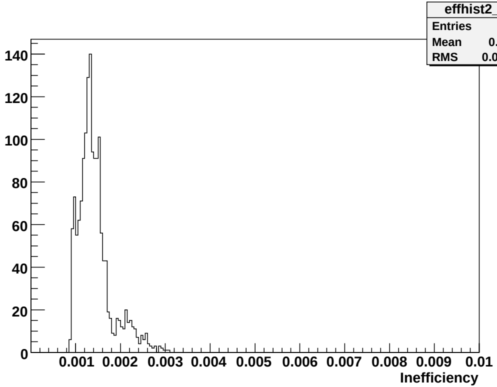

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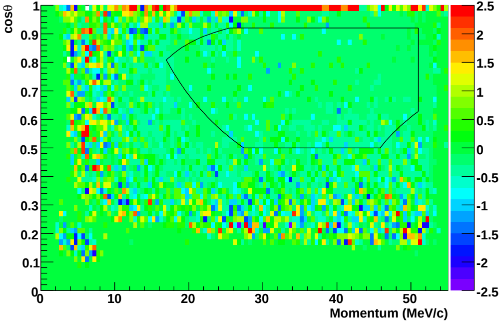
Consequences of Inefficiency Measurements

- The region immediately surrounding fiducial is sound
- Difference in data and Monte Carlo for US and DS
  - is small (0.2 σ)
  - is similar
  - is negative (eg. $P_{data}(u|D) > P_{MC}(u|D)$)

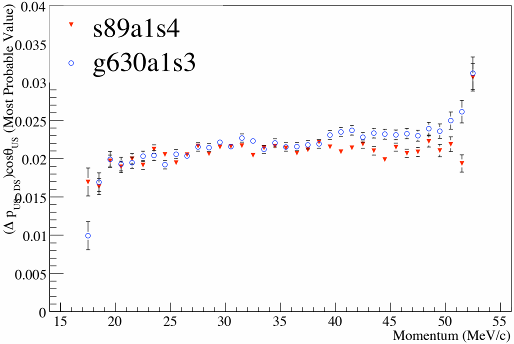


If fiducial region defined by stability of inefficiency:

- fiducial region may be expanded.
- will have to reconsider justification of cuts.

Momentum and Angle Effects in the Endpoint Calibration

- Can we relate endpoint calibration to US stops?
- Difference between data and MC momentum behaviour



- Results of rel. ecal. s84a6 to g584a1+2

$a_{up} = 4.9 \pm 1.4$
$a_{dn} = -4.8 \pm 3.2$
$b_{up} = -7.34 \pm 2.13$
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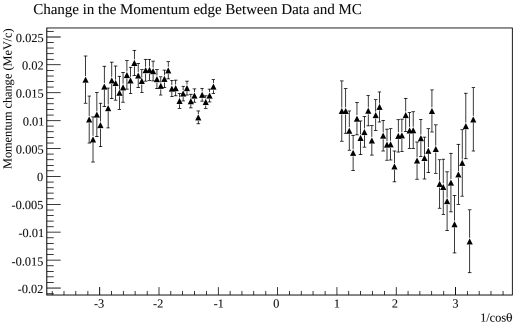

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Relationship between Energy Calibration and US Stops

- Assume energy calibration result is completely additive ie. $p_{rec} = p_{true} + B$
- The result of ecal measurement

$$\Delta p_{ecal}|_{edge} = p^{MC}_{true} + B^{MC} - p^{data}_{true} - B^{data}$$

- Sum of upstream and downstream measurements

$$\Delta p^{US}_{ecal} + \Delta p^{DS}_{ecal} = B^{MC}_{US} + B^{MC}_{DS} - B^{data}_{US} - B^{data}_{DS}$$

- Difference between data and Monte Carlo in upstream stops

$$\Delta p^{MC}_{US-DS} - \Delta p^{data}_{US-DS} = B^{MC}_{US} + B^{data}_{US} - B^{MC}_{DS} - B^{data}_{DS}$$

- N.B. in US stops $B_{US} \approx -B_{DS} + \delta$ so

$$\Delta p^{MC}_{US-DS} - \Delta p^{data}_{US-DS} = -\Delta p^{US}_{ecal} + \Delta p^{DS}_{ecal} + \delta^{MC} - \delta^{data}$$

Delta Ray Systematic Method

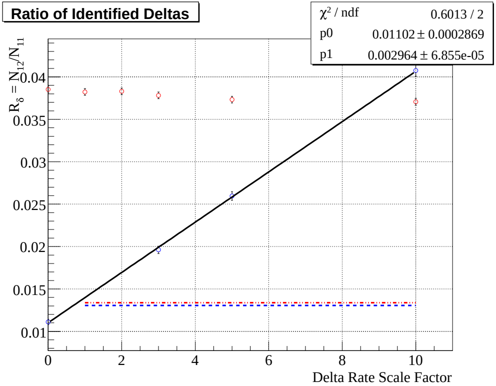
- Exaggerate delta ray cross section in target muon stops
- Identify delta rays in data and Monte Carlo
  - Measure difference in production rates
  - Compare difference rate in exaggerated simulation
  - Scaling Factor to be calculated:

$$S = \frac{R^{MC}_{\delta\times 10} - R^{MC}_{\delta}}{R^{data}_{\delta} - R^{MC}_{\delta}}$$

  - Rate most easily measured in upstream stops
    - Delta rays can be clearly isolated from positrons
    - Unambiguous charge measurement

Delta Ray Measurements

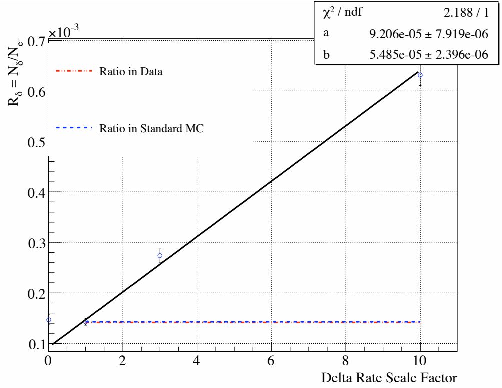
Match an extra downstream track to a through-going positron.



- This requirement alone is insufficient
- Data and Monte Carlo must be as similar as possible
- Track characteristics must match (CDA cut required)

Current Status

- More exacting criteria has been used
- There are still some problems



- Delta rate suppressed simulation shows no suppression
- Fit rate still shows significant background
- Incomplete correlation between the rates in truth banks and reconstruction

- If these results were accepted, $S = 330 \pm 2481$
- Difference $R_\delta^{data} - R_\delta^{MC} = (1 \pm 9) \times 10^{-6}$ (10 %)

Conclusions

- Match between data and Monte Carlo good for all three target modules
- Momentum bias results (if not source) is understood
  - relationship with for Δp_{US-DS} and ECal.
- Inefficiencies (from large target data) show consistant (flat) results US and DS
  - small deviation in data/ MC difference through fiducial
  - Inconsistancy between MC derived and US stop derived ineff. understood
- Delta ray systematc progressing

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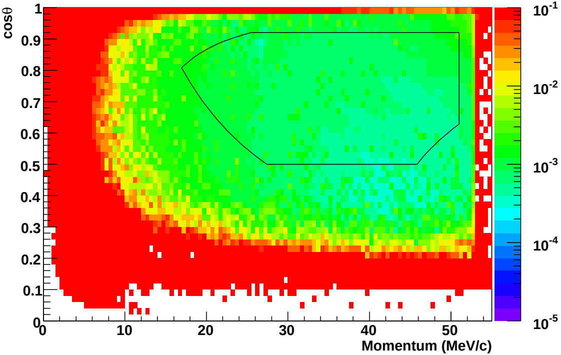

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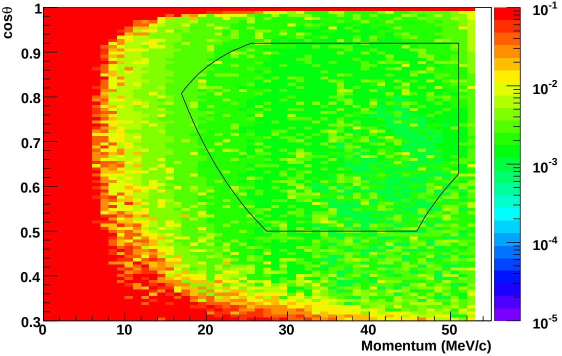

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