CDF Measurement of Time-Integrated Mixing

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for the CDF Collaboration

Impact of the D0 Dimuon A_{SL} Result

- Result is 40 times SM expectation.
- Requires some serious theoretical gymnastics to accommodate the result.
- About 30 papers cite this result, most proposing a model to explain the result.
- The D0 analysis doesn't use dimuon mass or impact parameters.

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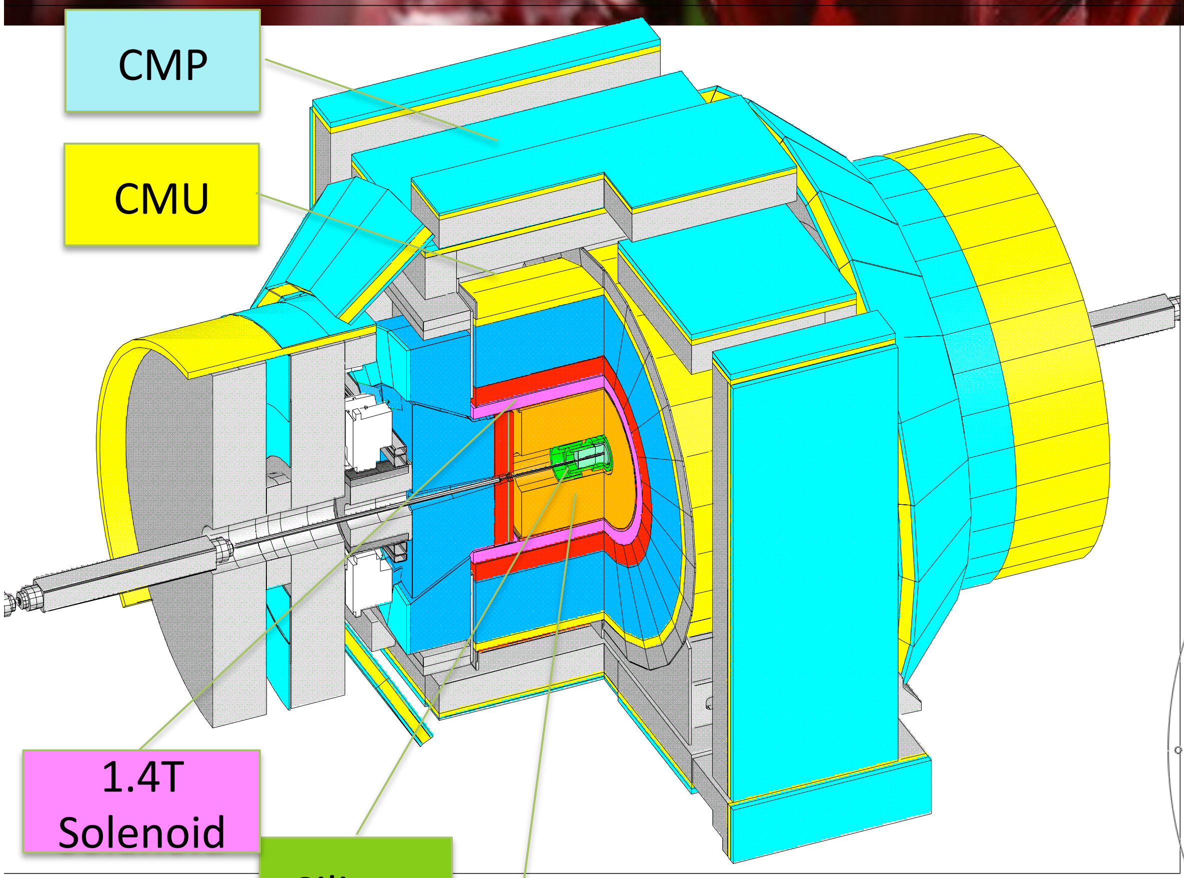
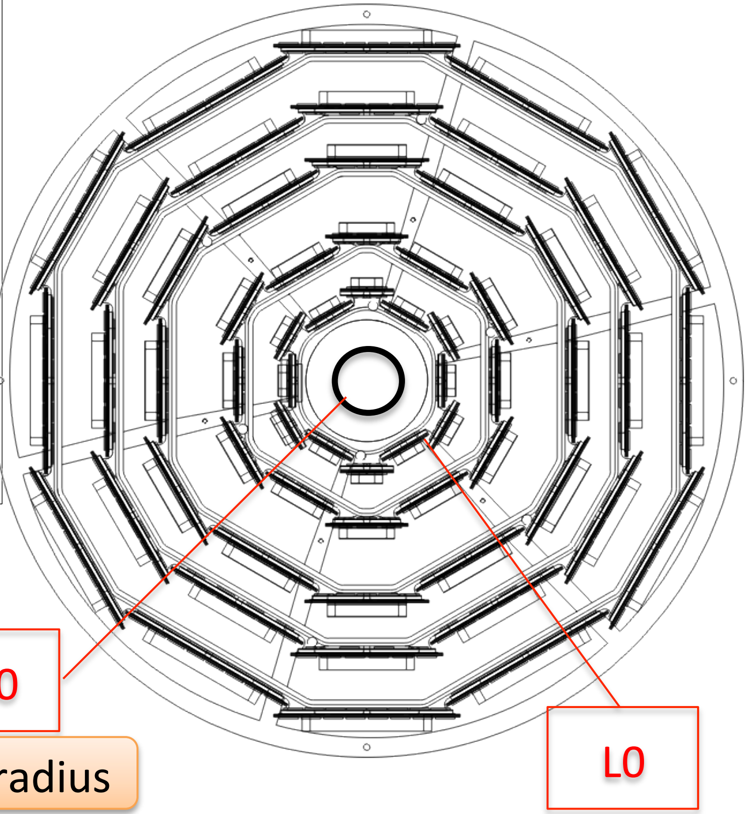
Deserves independent verification

The CDF Detector



r-ϕ view of SVX and L00

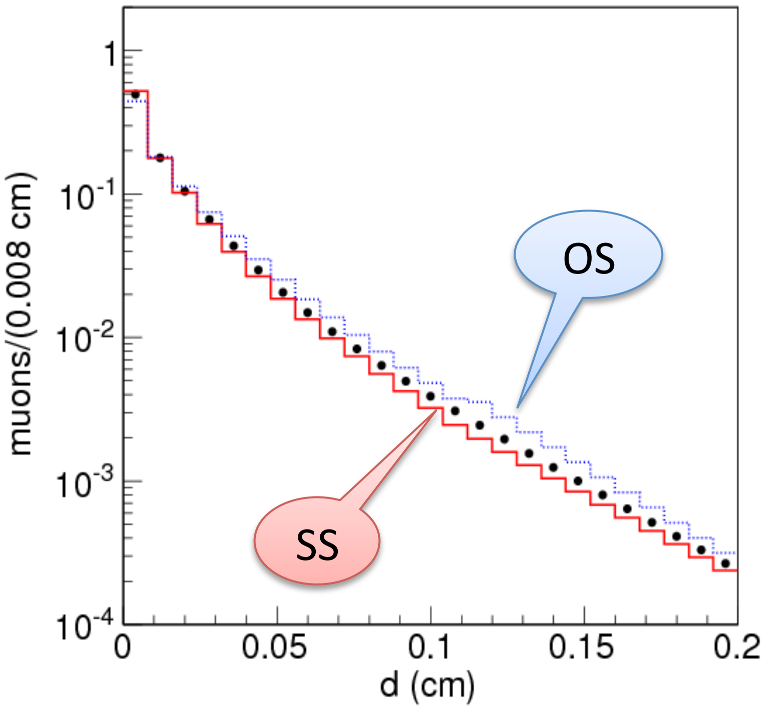


CDF Technique

- Use muon impact parameter distributions to separate $b\bar{b}$ contribution from other sources.
- Select dimuon events with $|\eta|<0.6$ and $p_T>3\text{GeV}/c$ for each muon.
- $5\ \text{GeV}/c^2 < M_{\mu\mu} < 80\ \text{GeV}/c^2$
- Remove events with additional muons
- Plot the IP distributions (d_1,d_2) for opposite sign (OS) and same sign (++, --) muons.
- Simultaneously fit the distributions for muons from b pairs (BB), c pairs (CC), sequential decays (BC), Drell-Yan (PP), and D.I.F.'s or misID's with a muon or in pairs (BB_{FK}, CC_{FK}, and other).

A Note on Templates

- Sequential decays (b→μc→μμx) contribute to OS templates but not SS templates.
- And cc source is only OS.
- Prompt → *Υ* data
- b and c → simulation [tuned in σ($b\bar{b}$) analysis]



Advantages

- Use data-derived templates for these sources (as much as possible).
- Excellent I.P. resolution allows us to disentangle the sources.
- This technique has been used since Run I
  - most recently to measure bb production xsec: PRD 77, 072004 (2008).
  - Previous A_{SL}: http://www-cdf.fnal.gov/physics/new/bottom/070816.blessed-acp-bsemil/
- Measurement of $\overline{\chi}$ is good preparation for an A_{SL} measurement

$\bar{\chi}$

- $\bar{\chi}$ is the average mixing probability

$$\bar{\chi}_b = \frac{\Gamma(B^0 \to \bar{B}^0 \to \ell^+ X)}{\Gamma(B \to \ell^\pm X)} = f_d \chi_d + f_s \chi_s$$

- And is related to R:

$$R = \frac{N^{++} + N^{--}}{N^{OS}}$$

- Difference in $\bar{\chi}$ from LEP (0.1259±0.0042) and Tevatron (0.147±0.011)

CDF RunI: PRD 69, 012002 (2004)

Relation of R to $\overline{\chi}$

- R has contributions from mixing, and other decay processes such as
  - $b \rightarrow c \rightarrow \mu$ decays
  - $b \rightarrow \psi X$, $b \rightarrow \chi_c X$, and other $b \rightarrow c\bar{c}q$ decays
- We account for these effects with a parameter *f*, determined from simulation to be *f*=0.176±0.011
- We obtain the relation:

$$R = \frac{f\left[\overline{\chi}^2 + (1-\overline{\chi})^2\right] + 2\overline{\chi}(1-\overline{\chi})(1-f)}{(1-f)\left[\overline{\chi}^2 + (1-\overline{\chi})^2\right] + 2\overline{\chi}(1-\overline{\chi})f}$$

$\bar{\chi}$ Measurement

- Use dimuon triggered data from 1.44/fb of int. lumi.
- Same selection requirements as described for A_{SL} measurement.
- Require that both muons have a hit in one of the two innermost silicon layers
  - Removes a large fraction of poorly understood events
  - Reduces overall statistics.
- Fit the OS, ++, and – impact parameter distributions simultaneously
- Determine R from BB component of the fit.

The Fit Function (for completeness)

$$L = \prod_i \prod_j \left[\ell_{ij}^{n(i,j)} \frac{e^{-\ell_{ij}}}{n(i,j)!} \right]$$

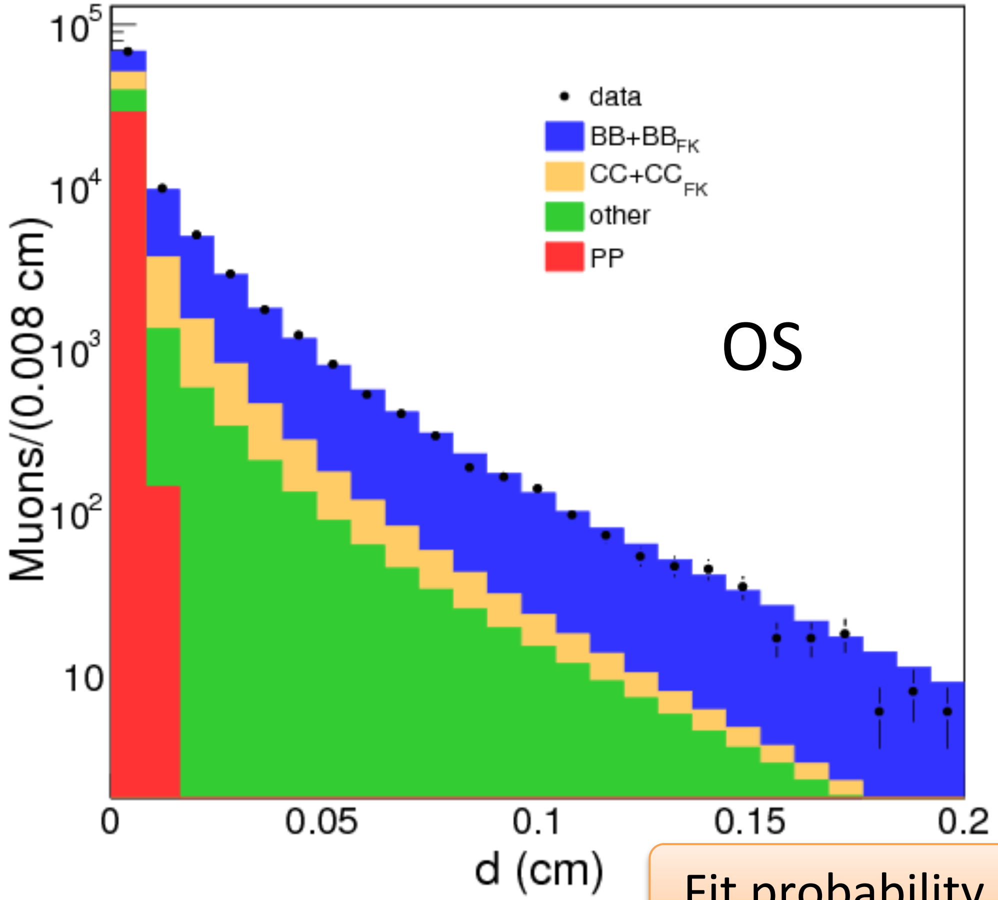
$$\begin{aligned}
\ell_{ij} = & BB^{XS} \cdot S_b^{XS}(i) \cdot S_b^{XS}(j) + BB_{FK}^{XS} \cdot S_b(i) \cdot S_b(j) \\
& + \left(CC + CC_{FK}^{XS}\right) \cdot S_c(i) \cdot S_c(j) + PP^{XS} \cdot S_p(i) \cdot S_p(j) \\
& + \frac{1}{2} \left[BP^{XS} \cdot (S_b(i) \cdot S_p(j) + S_p(i) \cdot S_b(j)) \right. \\
& + CP^{XS} \cdot (S_c(i) \cdot S_p(j) + S_p(i) \cdot S_c(j)) \\
& \left. + BC^{XS} \cdot (S_b(i) \cdot S_c(j) + S_c(i) \cdot S_b(j)) \right]
\end{aligned}$$

$$\frac{1}{2} \left[\frac{(CP - BP)^2}{CP + BP + (0.14 \cdot BP)^2} + \frac{(BC - 0.046 \cdot BB)^2}{BC + (0.046)^2 \cdot BB + (0.013 \cdot BB)^2} \right]$$

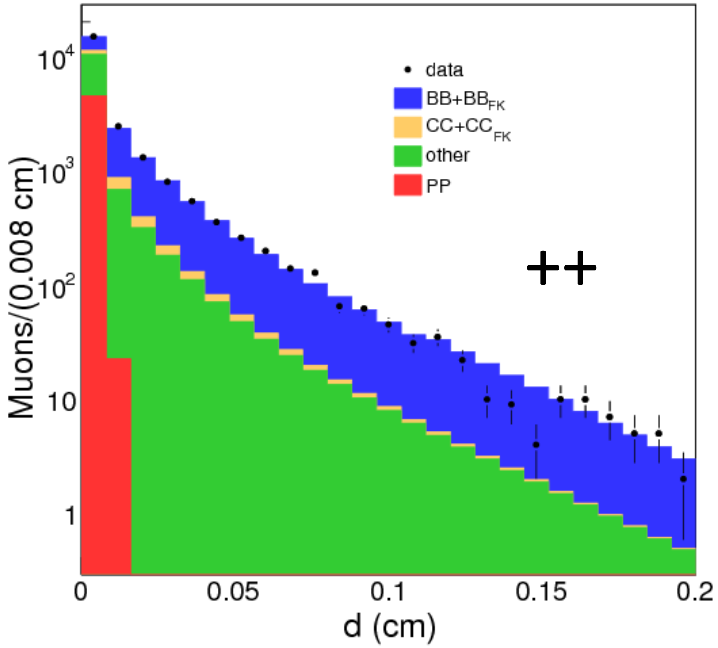
$$\begin{aligned}
CP^{LS} &= (1.05 \pm 0.05) \cdot CP^{OS} & \qquad CP^{++} &= (1.2 \pm 0.1) \cdot CP^{--} \\
BP^{LS} &= (0.87 \pm 0.07) \cdot BP^{OS} & \qquad BP^{++} &= (1.15 \pm 0.05) \cdot BP^{--} \\
BC^{LS} &= BC^{OS} & \qquad BC^{++} &= BC^{--}
\end{aligned}$$

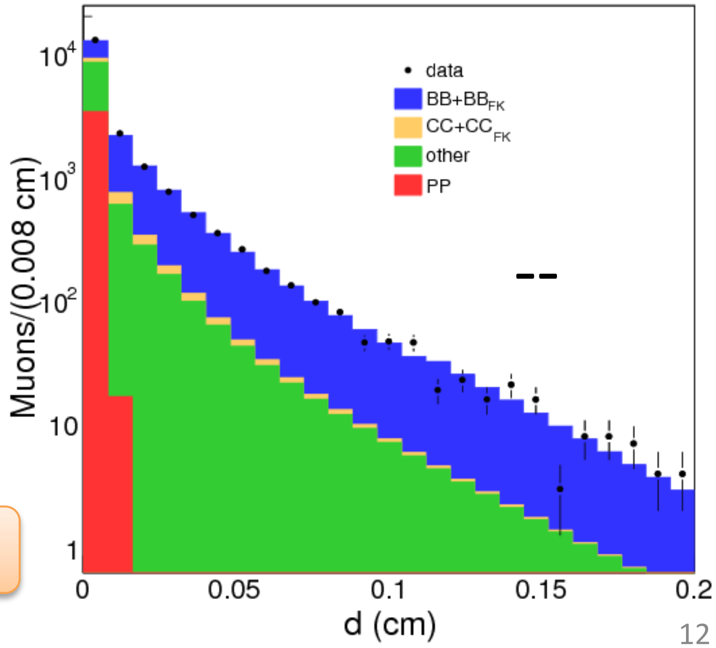
Fit Results

1D projections of 2D fits



Fit probability 78.5%





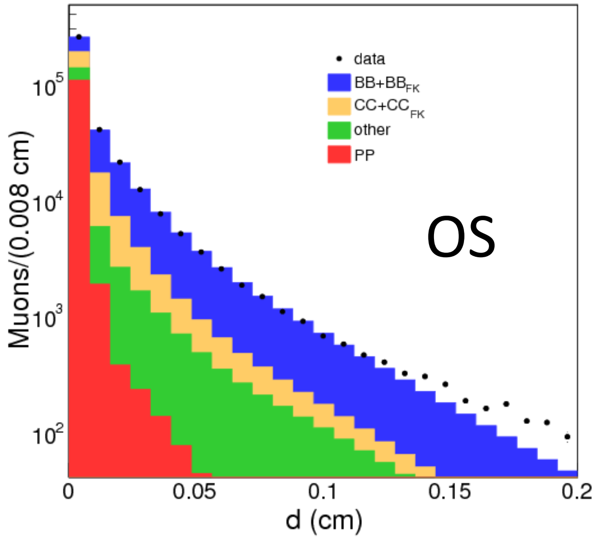
$\bar{\chi}$ Result

- R=0.467±0.008 (stat only)
- Varying the templates within their uncertainties yields a systematic error of 0.007
- R = 0.467±0.011 (stat and sys)
- Yields $\bar{\chi}$ = 0.126±0.008 (0.005 is due to R and 0.006 to *f*)
- Compare to LEP average $\bar{\chi}$ = 0.1259±0.0042

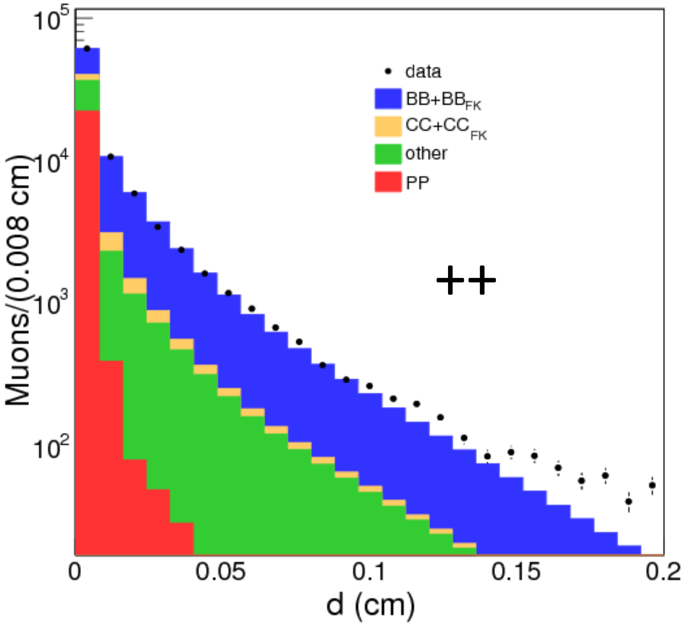
Additional Checks on $\bar{\chi}$

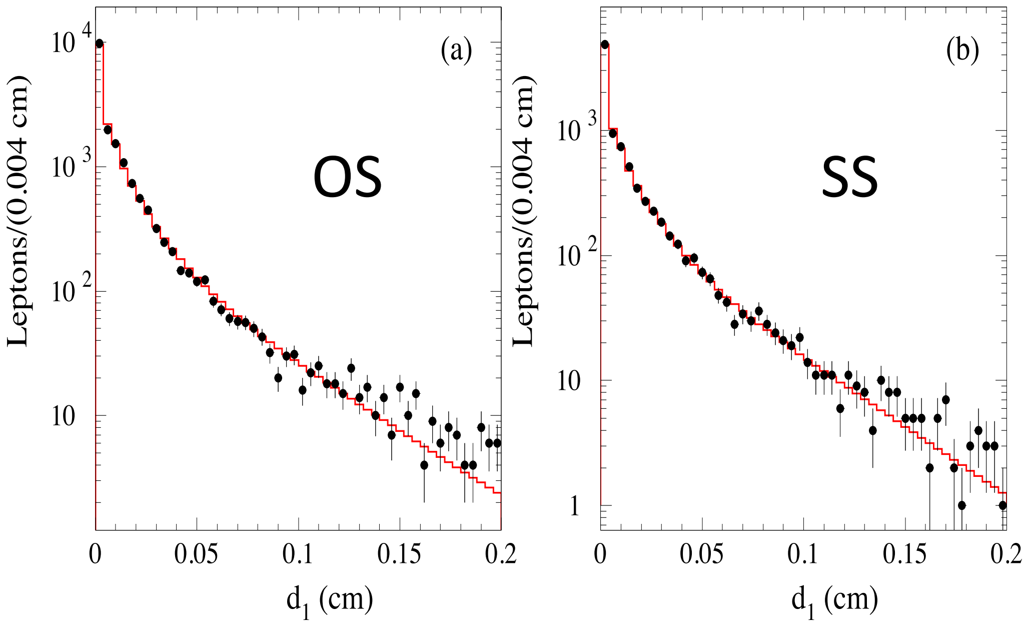
- To investigate difference w.r.t. earlier Tevatron measurements, we revert to “standard” silicon hit requirements.
- This lets in a class of muons missing from the simulation; we refer to them as “ghosts”.
- The ghosts are dominated by punchthrough, and it is important to correctly account for them.
- The ghost template is derived from 0.7/fb of data and applied to the other 0.7/fb of data.

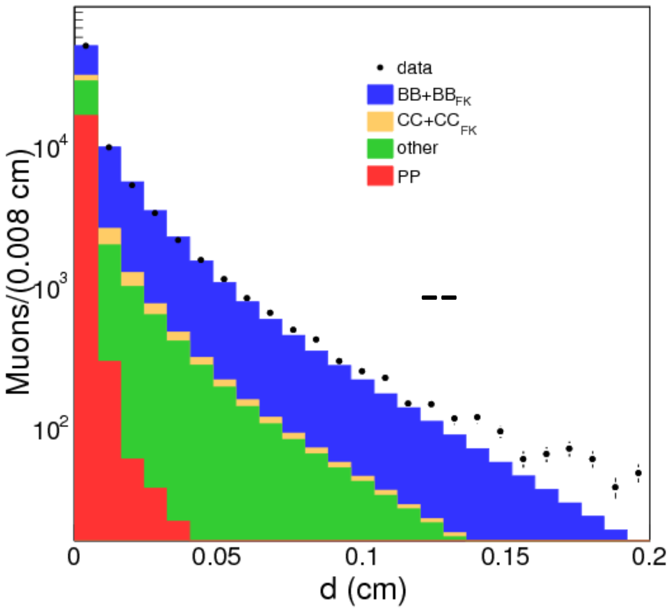
Fit result without “ghosts”



Fit probability 0.02%

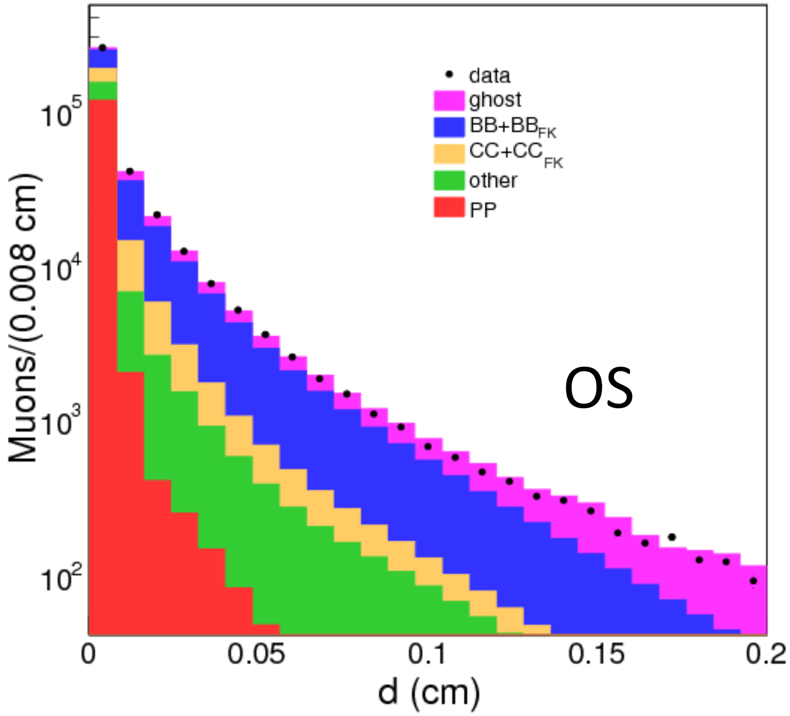


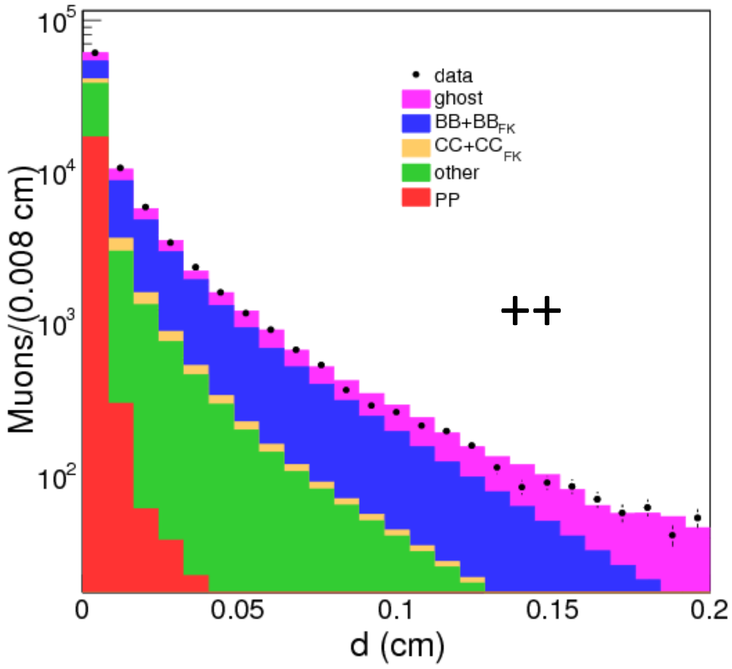


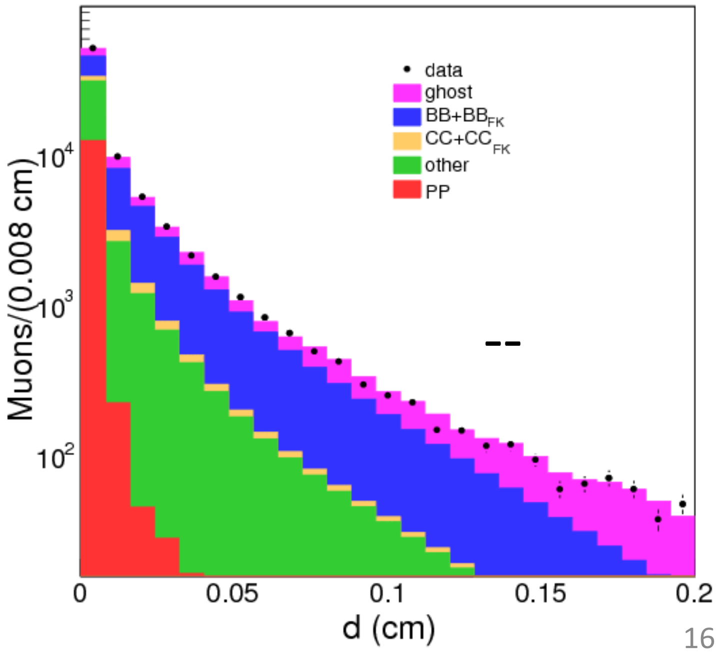


CDF RunI: PRD 69, 012002 (2004)

Fit result with ghosts







Consistent result

R=0.466±0.007 (stat only)

Fit probability
49.1%

Prospects for A_{SL}

- Measure the dimuon asymmetry defined as

$$A_{SL} = \frac{N^{++} - N^{--}}{N^{++} + N^{--}}$$

- Using 6/fb of data, like sign sample is about 1.2 million events, about 1/3 the size of the D0 sample.
- Will yield 70% larger statistical errors than D0.
- Systematic errors should scale similarly.

Conclusion

- The new $\bar{\chi}$ result is in agreement with the LEP measurements, possibly settling a long standing difference.
- Previous disagreement related to class of poorly understood muons (ghosts).
- Data-derived templates for ghosts allows us to extract $\bar{\chi}$.
- These techniques are being used to measure A_{SL} in 6/fb of data.

BACKUP

Magnetic Field

- CDF does not reverse solenoid polarity
  - Central tracker has tilted drift cells intended for one field direction
  - We evaluate tracking asymmetry with data (see CPV in charm decays talk by Angelo Di Canto on Tuesday).
  - CDF muon chambers are not in a magnetized region
    - We don’t see an asymmetry in muon ID.