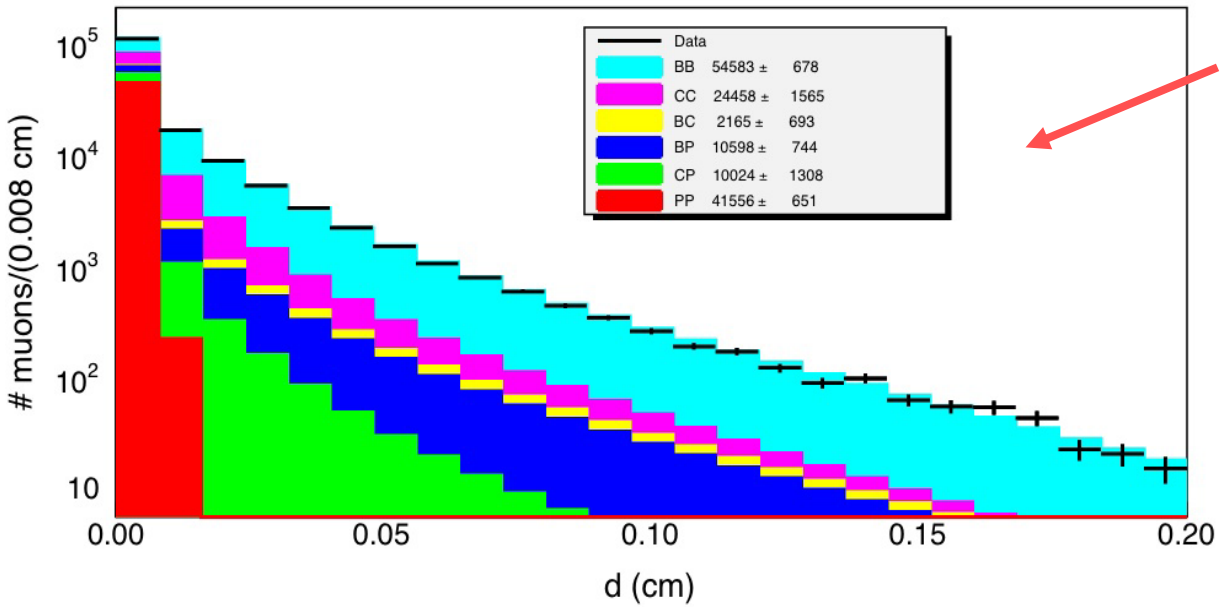
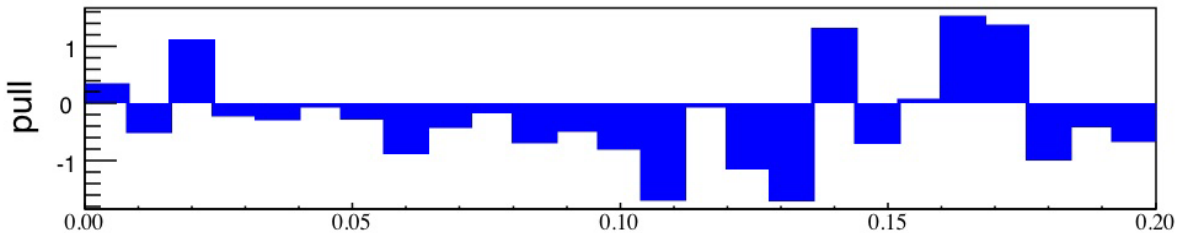
Scope of today talk

- Walk you trough the main steps of the analysis one last time
- Elaborate where there have been misunderstandings/difficulties
- Then, this is it. We are exhausted.



QCD

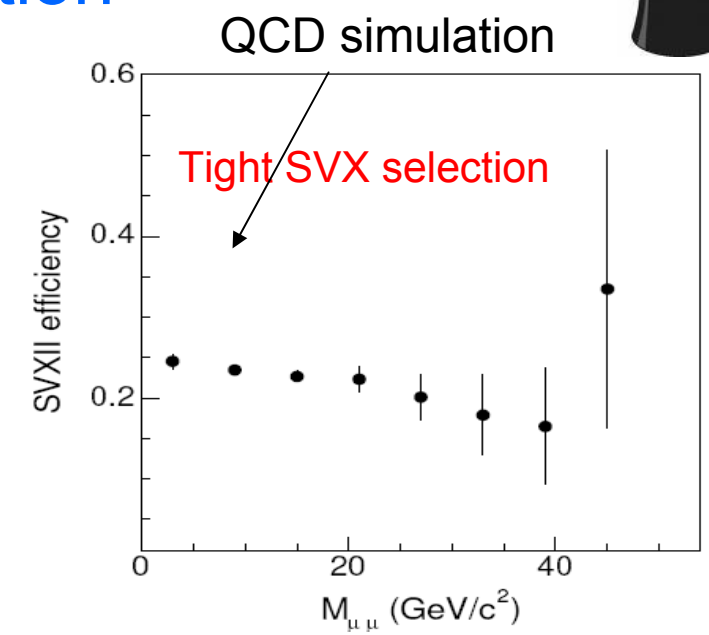
Correlated bb xcross measurement PRD 77, 072004 (2008)

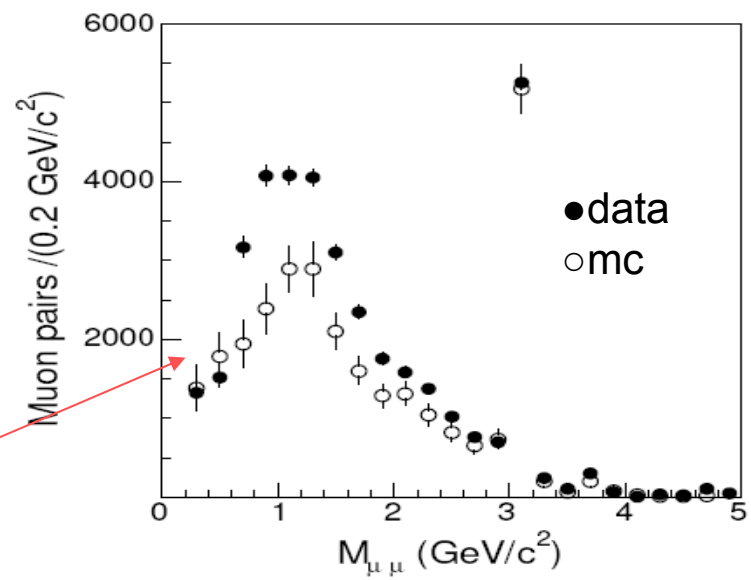


- The measurement uses tight SVX requirements (L00, L0, and 2 out of the remaining 4 SVX layers)
- Ad hoc selection chosen to fit the data with the templates from various sources
- The tight selection requires that both initial muons are generated inside the beam pipe
- According to the simulation, 96% of the QCD events have two muons originated inside the beam pipe

Efficiency of the SVX selection

- We can evaluate the efficiency of the tight SVX selection by using control samples of data
- The efficiency of the tight SVX selection for prompt muons (Y, D-Y) is geometrical $\varepsilon = 0.257 \pm 0.004$
- For heavy flavor the efficiency is $\varepsilon = 0.237 \pm 0.001$ (high p_T h.f. hadrons) – verified with J/ψ mesons from B decays, J/ψ K, and muons accompanied by D^0 mesons
- The average efficiency in this data set should be $\varepsilon = 0.244 \pm 0.002$ but is found to be $\varepsilon = 0.1930 \pm 0.0004$





No SVX requirement

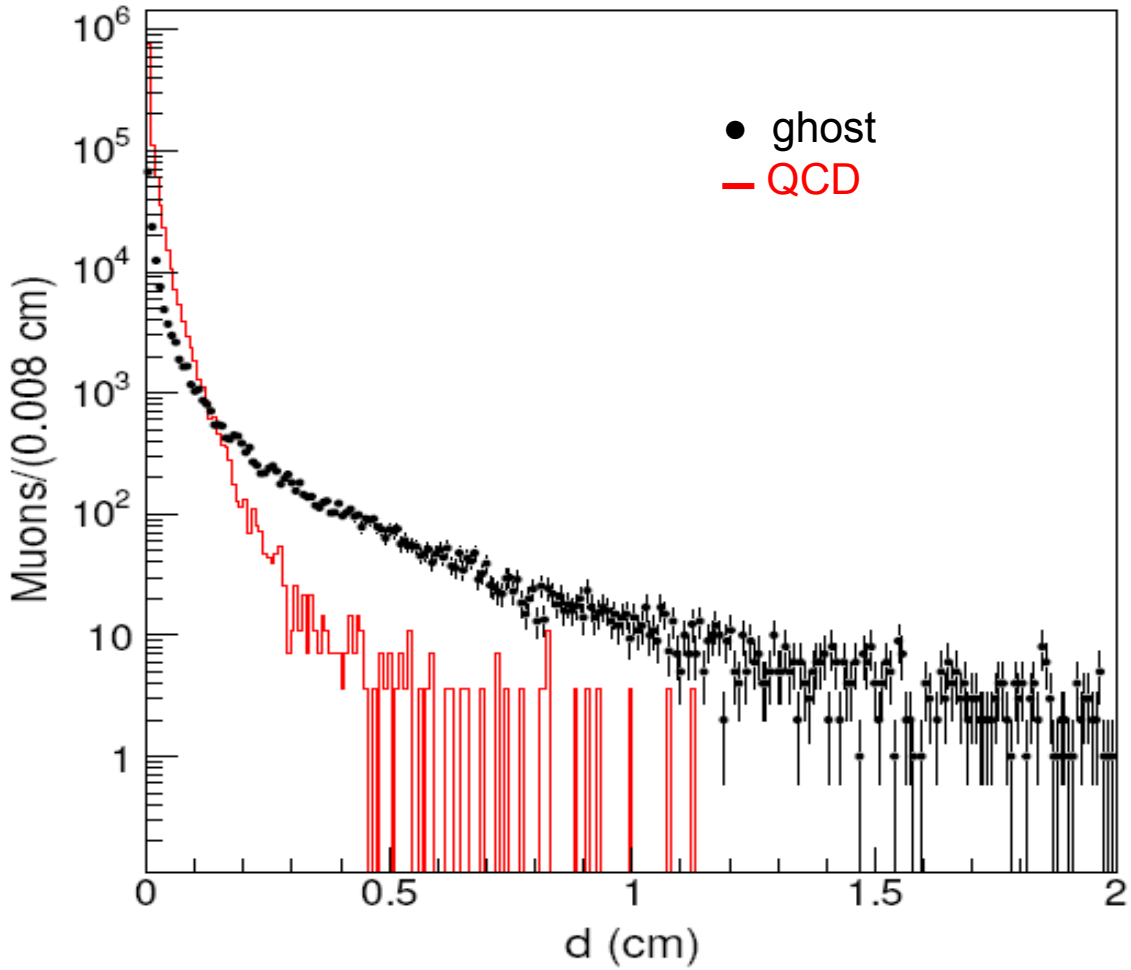
Ghosts – events in which one muon is produced outside of the beam pipe

Type	No SVX	Tight SVX	Loose SVX
All	743006	143743	590970
All OS		98218	392020
All SS		45525	198950
QCD	589111 ± 4829	143743	518417 ± 7264
QCD OS		98218	354228 ± 4963
QCD SS		45525	164188 ± 2301
Ghost	153895 ± 4829	0	72553 ± 7264
Ghost OS		0	37792 ± 4963
Ghost SS		0	34762 ± 2301

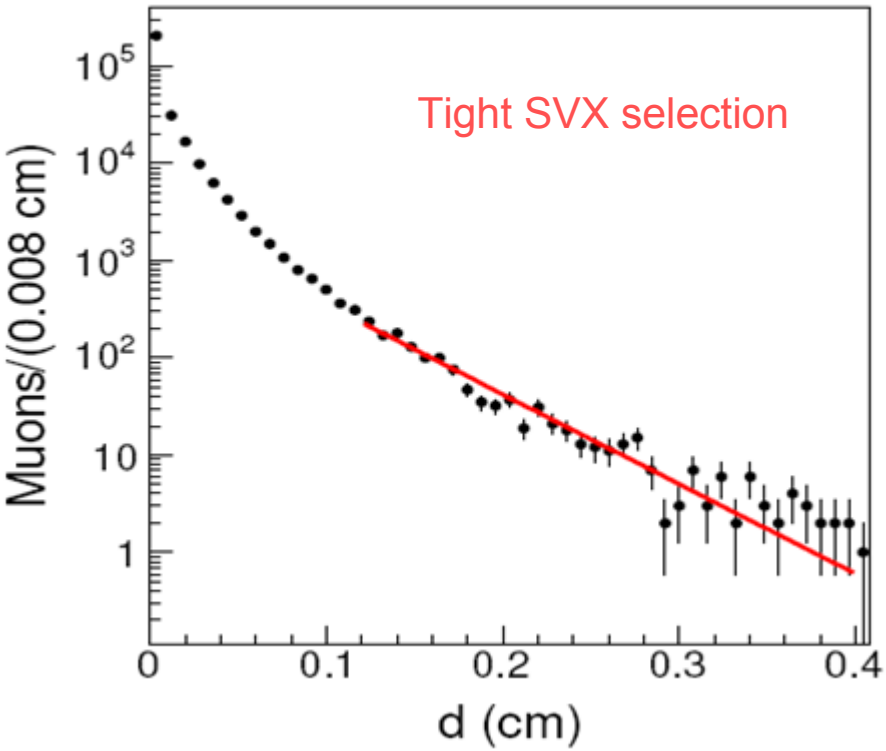
assuming that ghosts are totally removed by the tight SVX selection

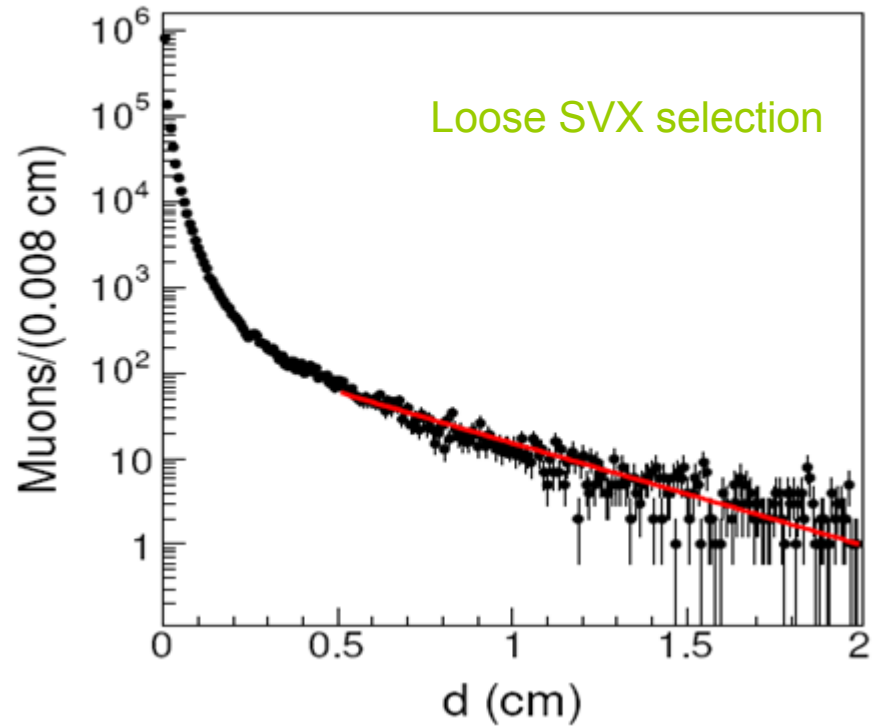
742 pb^{-1}, 221564 ± 11615 $b\bar{b}$ events with no SVX and 194976 ± 10458 with loose SVX requirements

Ghosts have different impact parameter distribution



Lifetime fits





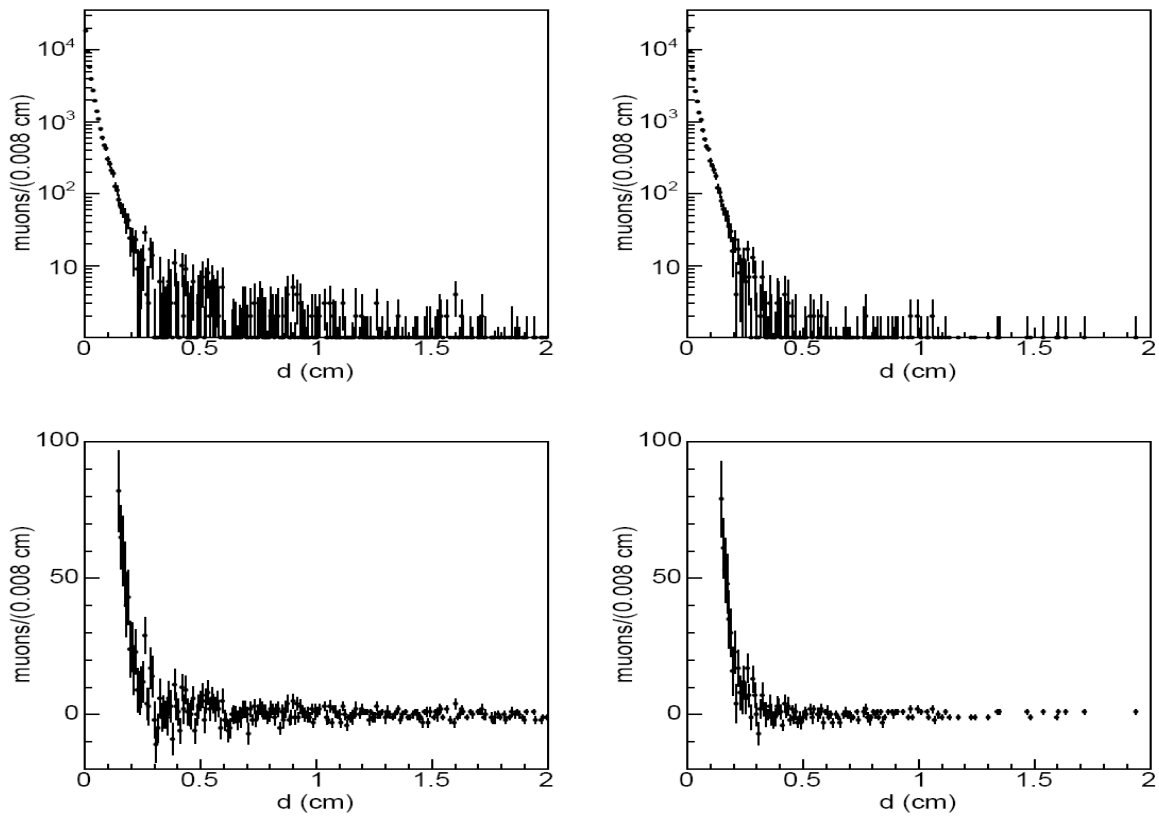
τ = 12.2 ± 0.3 ps

$c\tau$ = 469.7 ± 1.3 μm

PDG: 470.1 ± 2.7

The distribution is sculpted by the loose SXV requirements

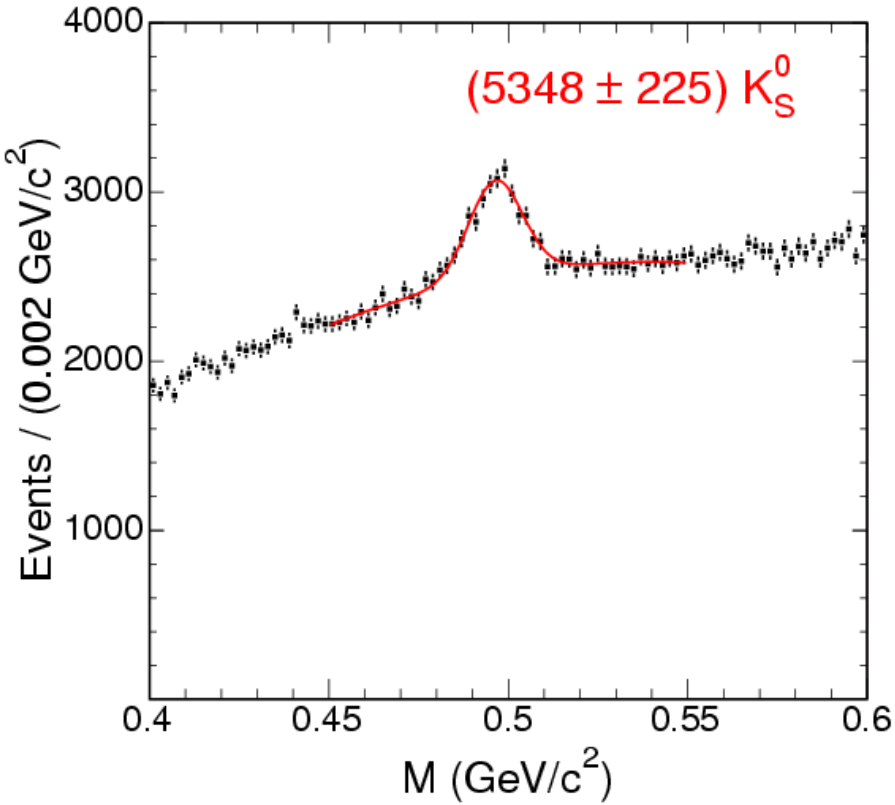
The tail is not a detector effect - CMUP trigger muons accompanying a D0 candidate

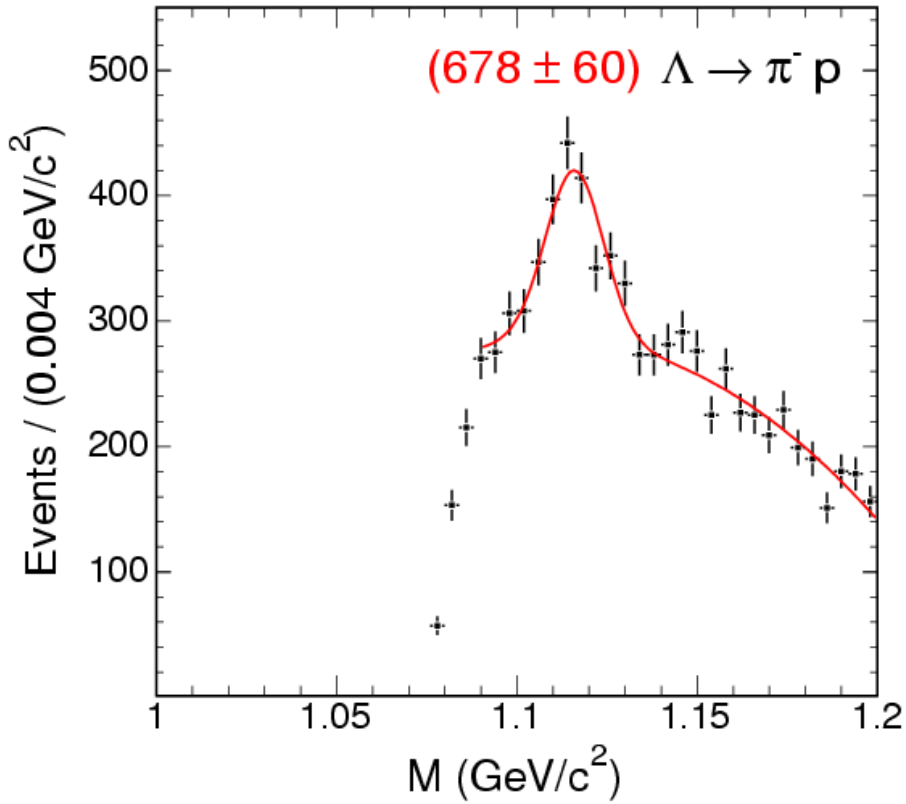


- Candidate ghost events:
  - Secondary interactions in the detectors surrounding the beam pipe
  - Long-lived particles
  - Heavy flavored hadrons with anomalously high Lorentz boost are not viable candidates

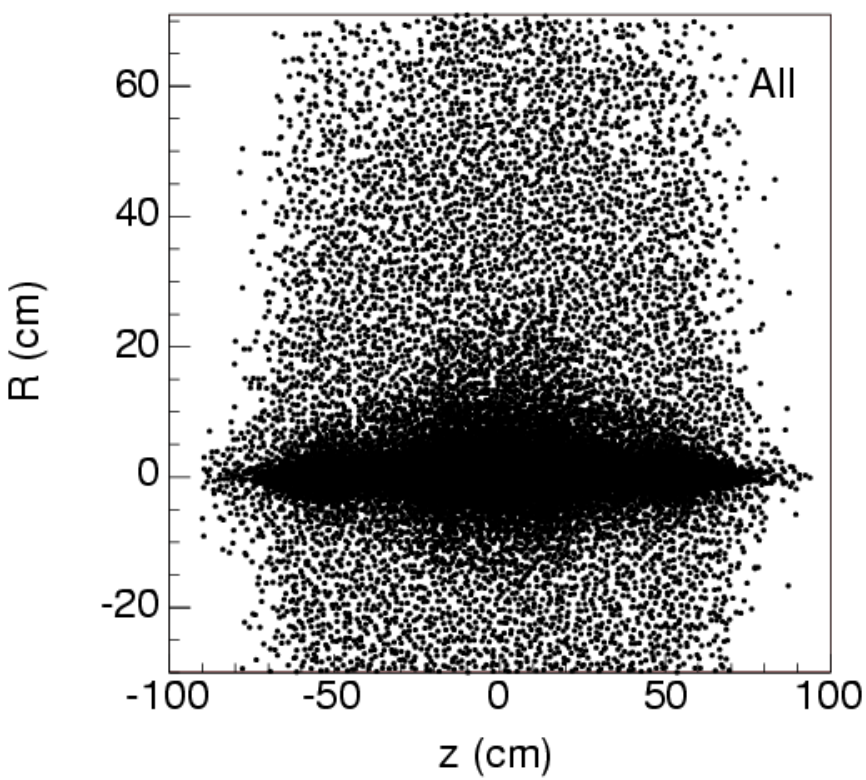
- Pion and kaon in-flight-decays
- prediction: 57000 events (ghosts are 154000 ±4800) – efficiency of tight and loose SVX selection 8% and 44%, respectively
- Out of the 25000 fake-dimuons events that pass the loose SVX selection, 15000 muons are due to kaon in-flight decays; 35000 are pion decays and punchthroughs
- The prediction is based on the Herwig simulation

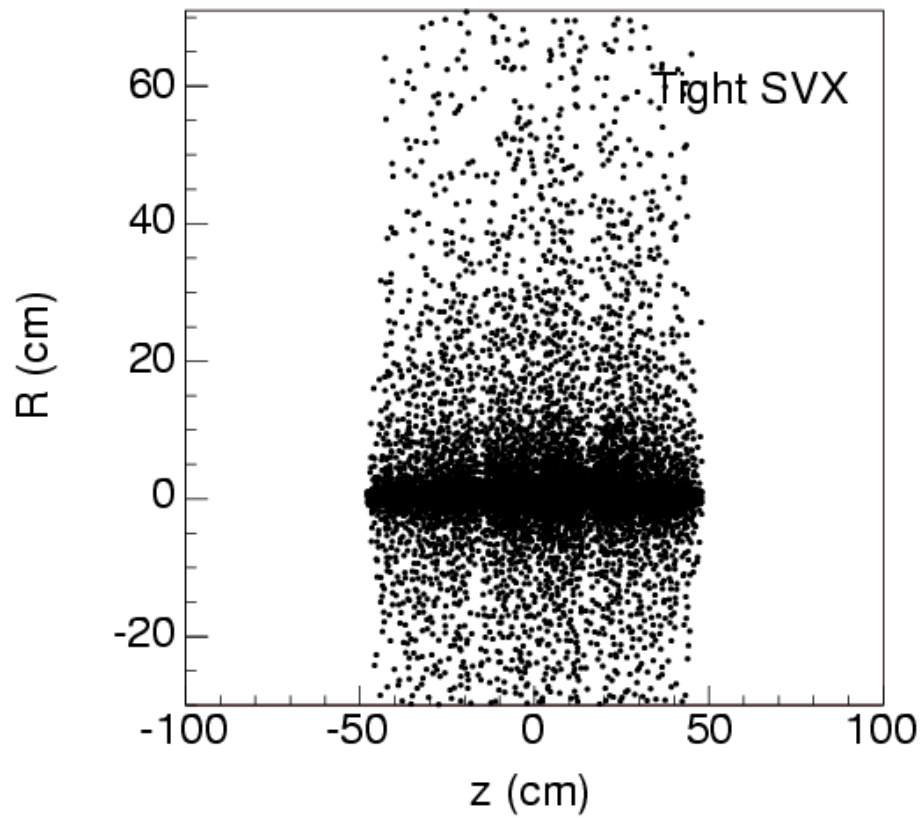
K0S, hyperon contribution





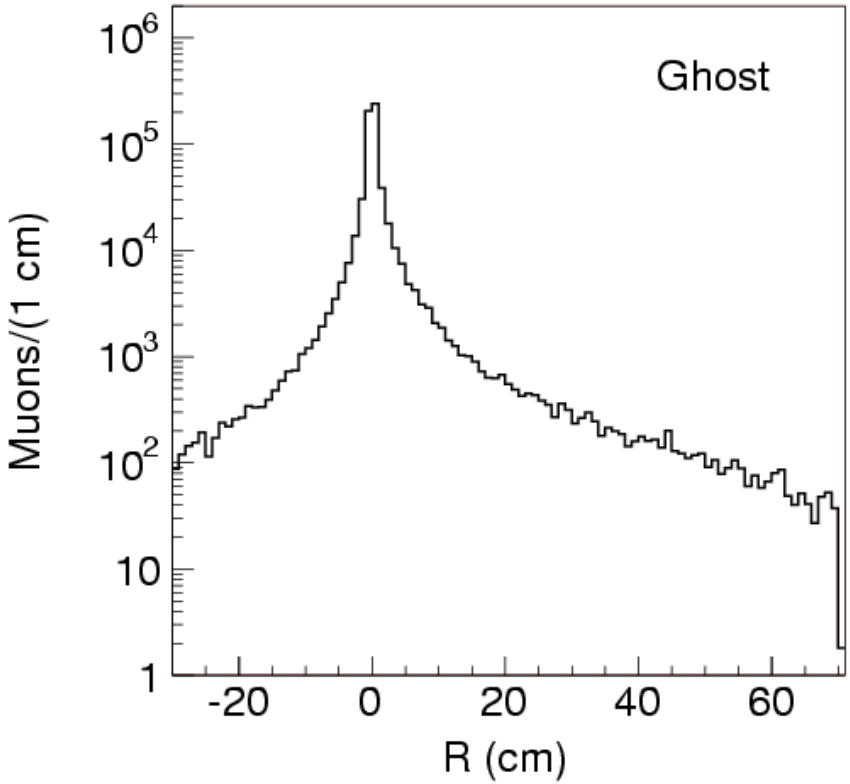
Secondary interactions

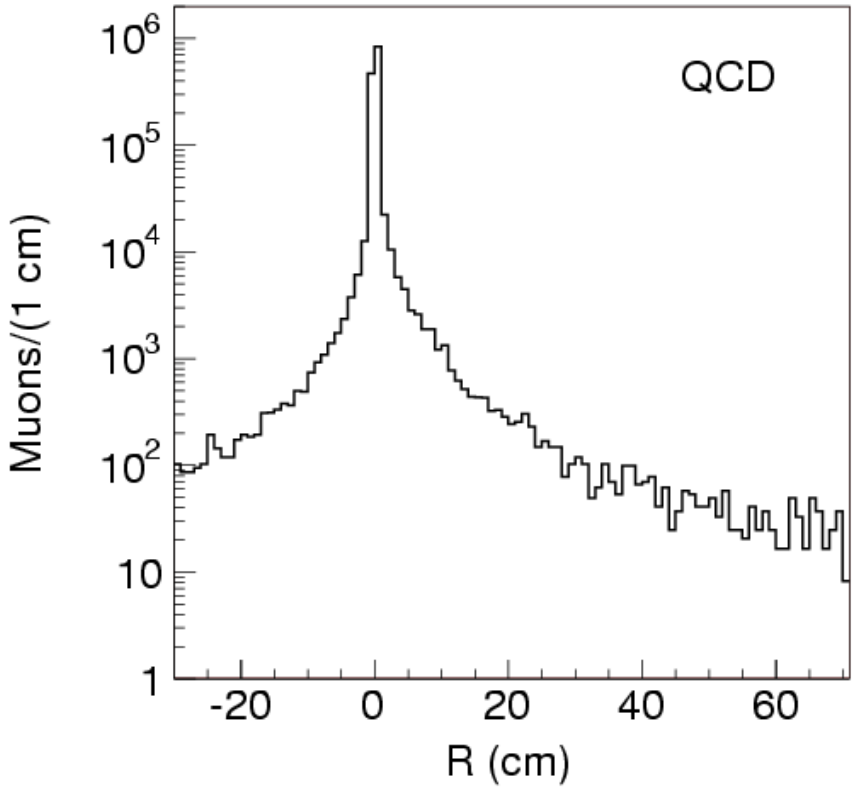




- Combine the initial muons with all tracks with p_T>1 GeV/c
- Vertex-constrain – keep χ^2/NDF <10

Secondary interactions





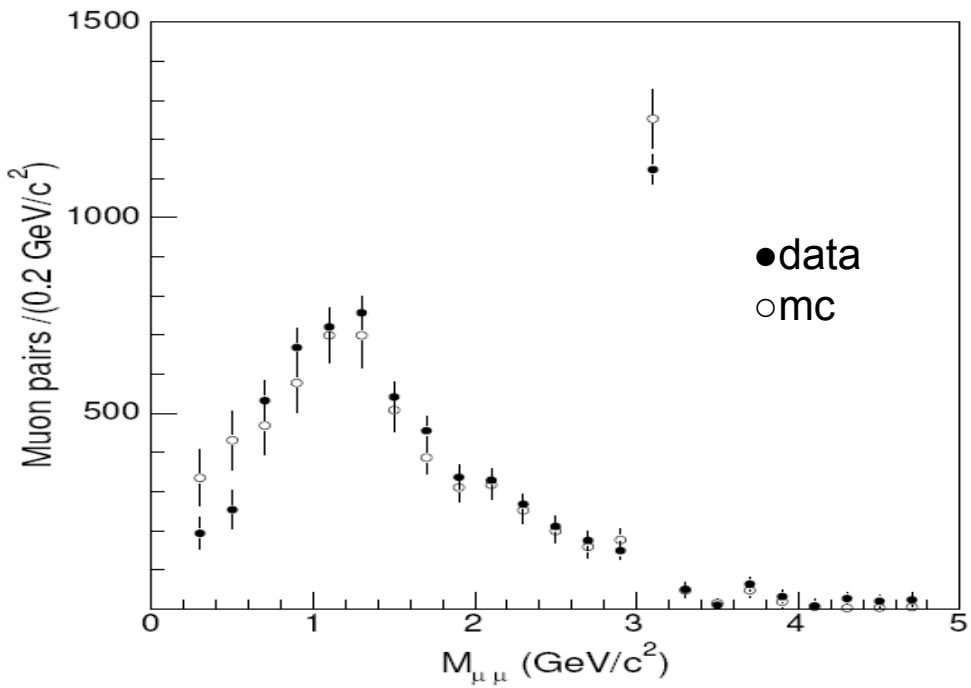
- Expected, but not visible

Request additional muons

- Count CMU+CMP+CMX muons with p_T> 2 GeV/c in QCD and ghost events.
- Remeasure the tight SVX efficiency of initial muons for events that contain an additional muons
- the efficiency of the tight SVX selection, only applied to the initial muons, drops from 0.193 to 0.166
- This tells that a fraction of ghost events is quite special and contains a lot of muons
- It is quite surprising given that ghost events were supposed to arise from IFD, K0S and alikes, or secondary interactions

Request of additional muons

- We use as control sample events in which both muons pass the tight SVX requirements. One half of these events are bbbar and ccbar jets. There is no doubt that we can predict the data.
- 7.1% of the QCD events contain an additional muons, 2.1% are due to b sequential semileptonic decays, 5% are fake muons.
- Ghosts and QCD have different compositions but QCD is a good sample to monitor the fake muon estimate



- 6935±154 in the data and 6998±293 predicted

Request of additional muons

- 16.4% of the ghost events contain an additional muon – we estimate that 7% are fakes and 9.4% real – four times larger than in QCD events
- How could the 5% fakes per event in QCD rise to 16.4 % in ghost events when all distributions such as dx, chi2, and dphi look the same for QCD and ghost events

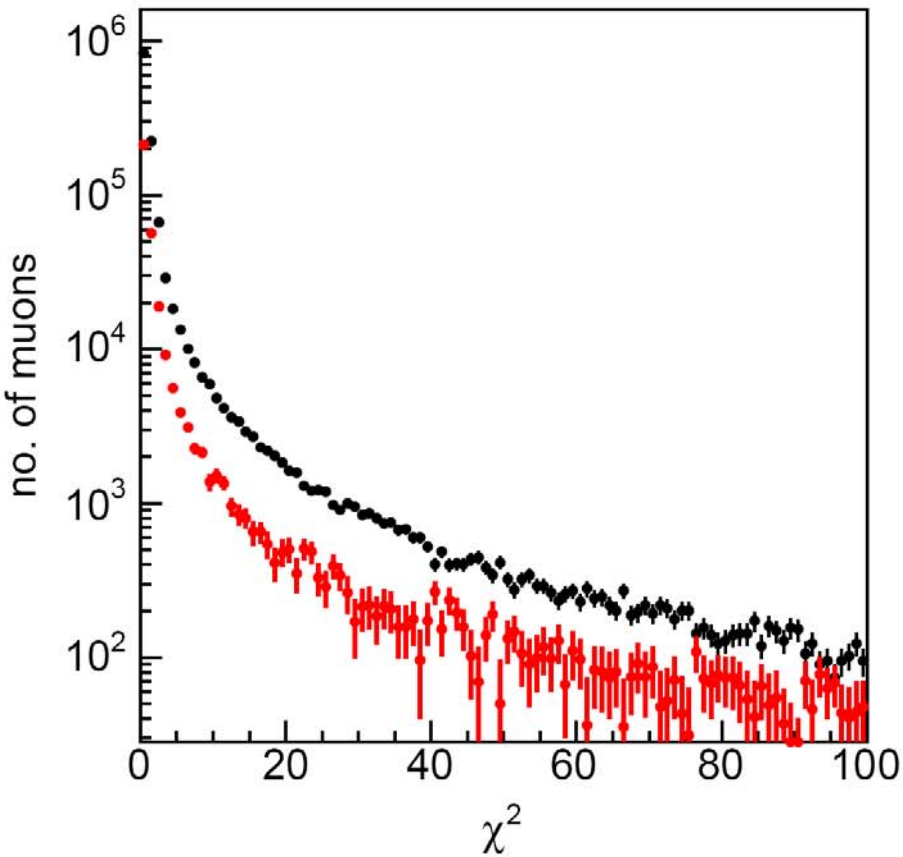
	CMU	CMP	CMUP	CMX
QCD	53%	26%	17%	4%
Ghost	60%	24%	14%	2%

Muon χ^2

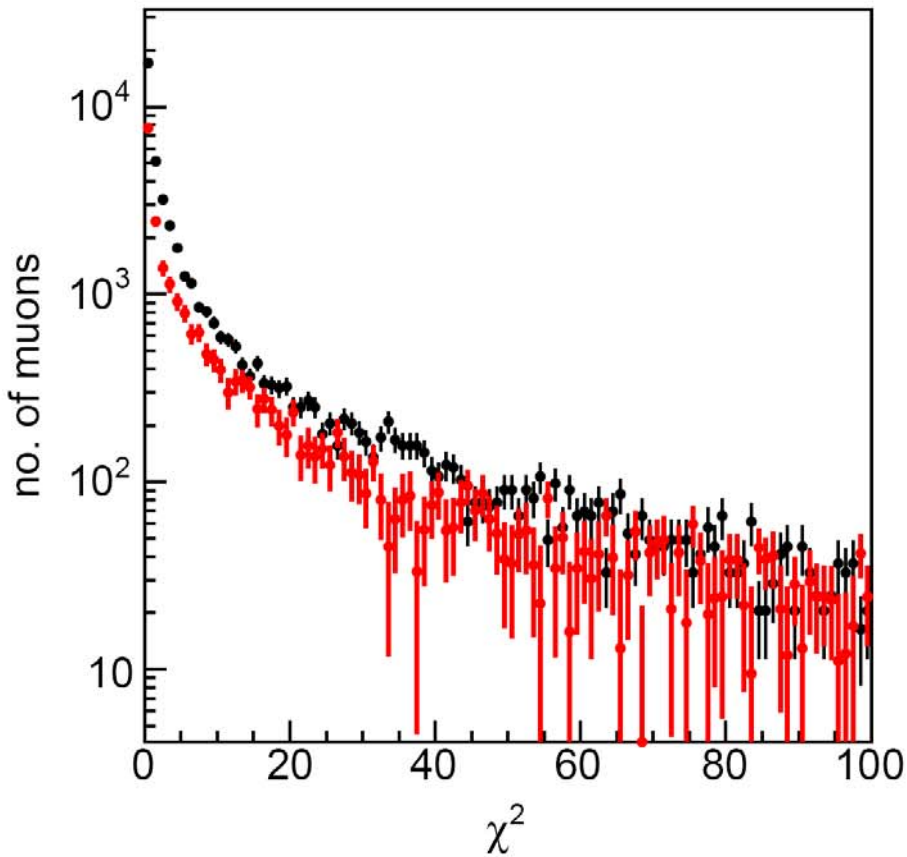
QCD

Ghost

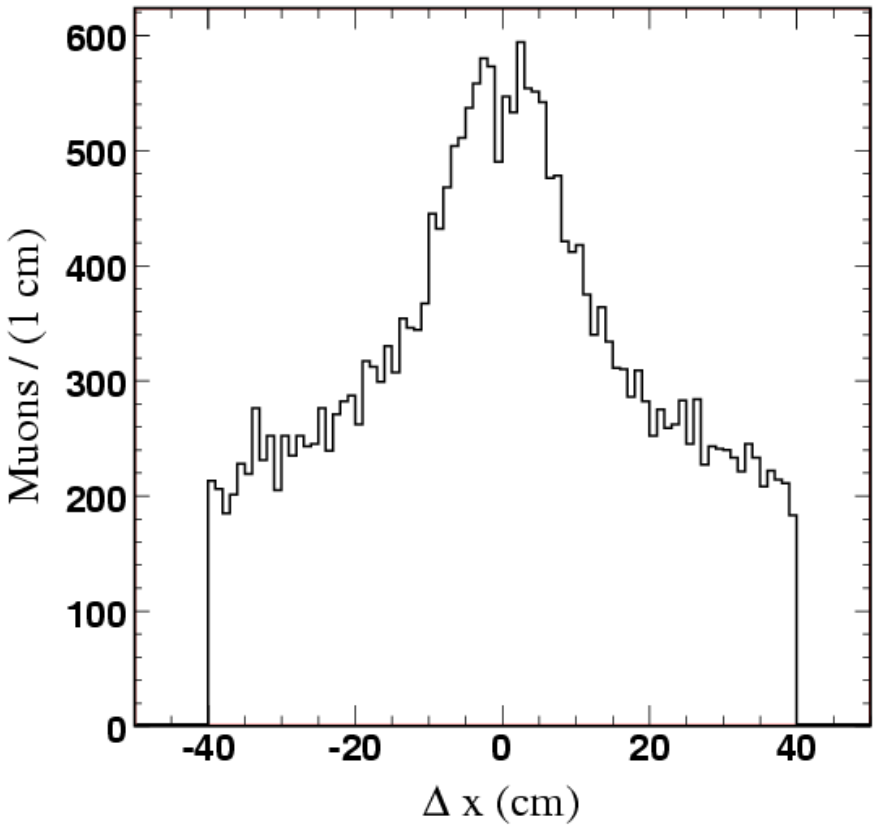
Initial μ's



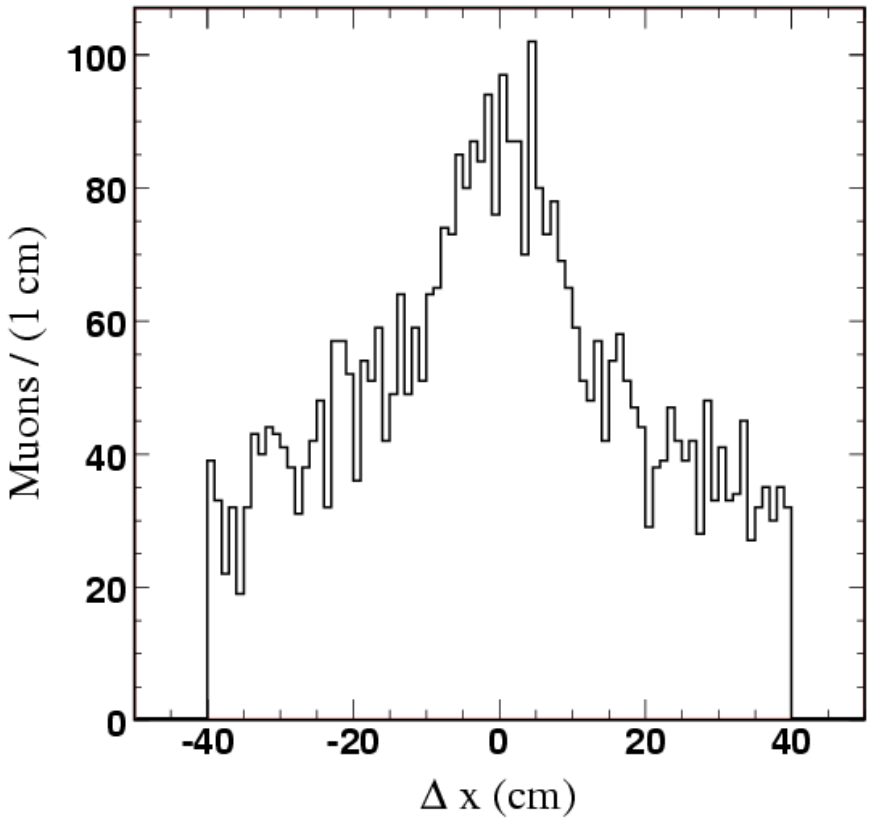
Additional μ's



Dx – additional muons (CMP)

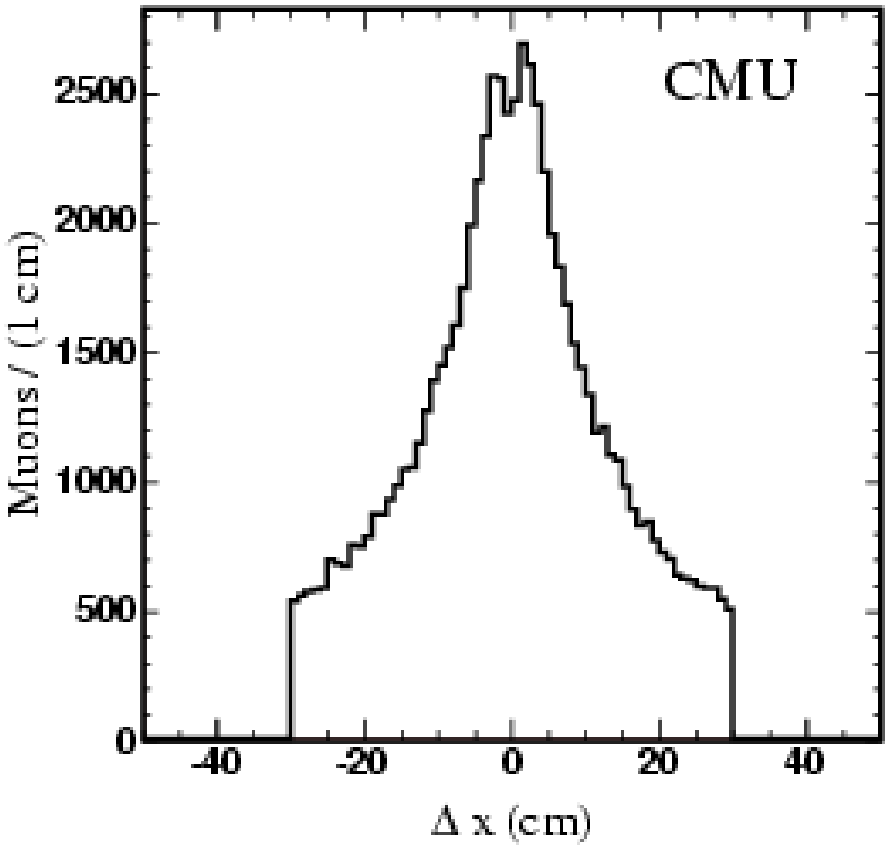


All



Tight SVX

Dx – additional muons (CMU)



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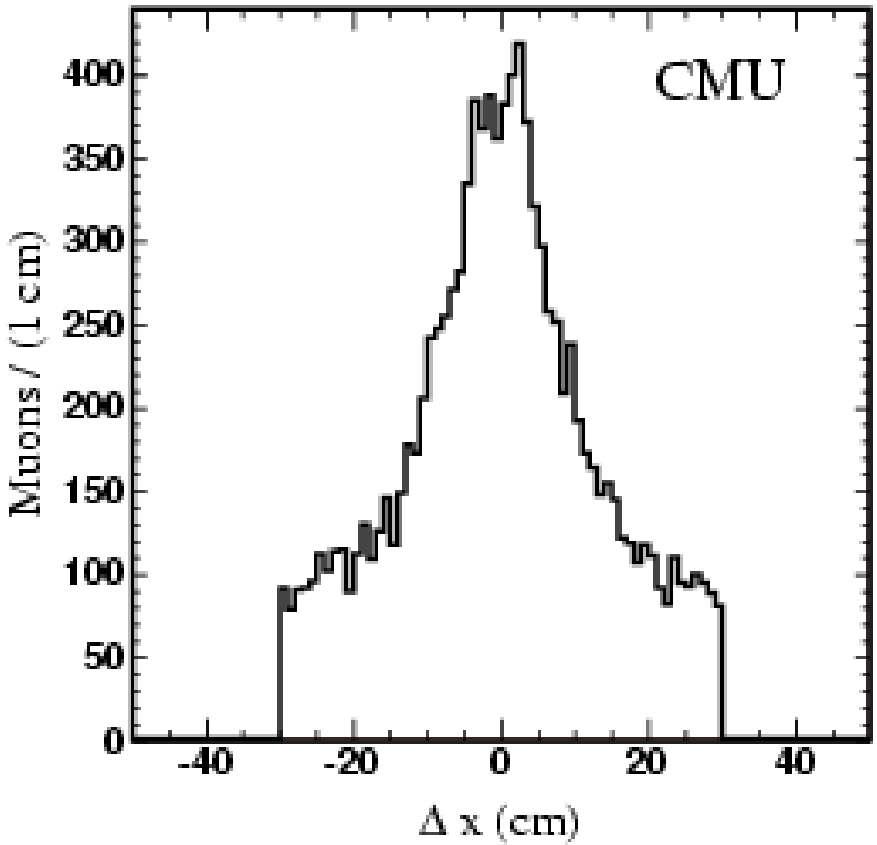
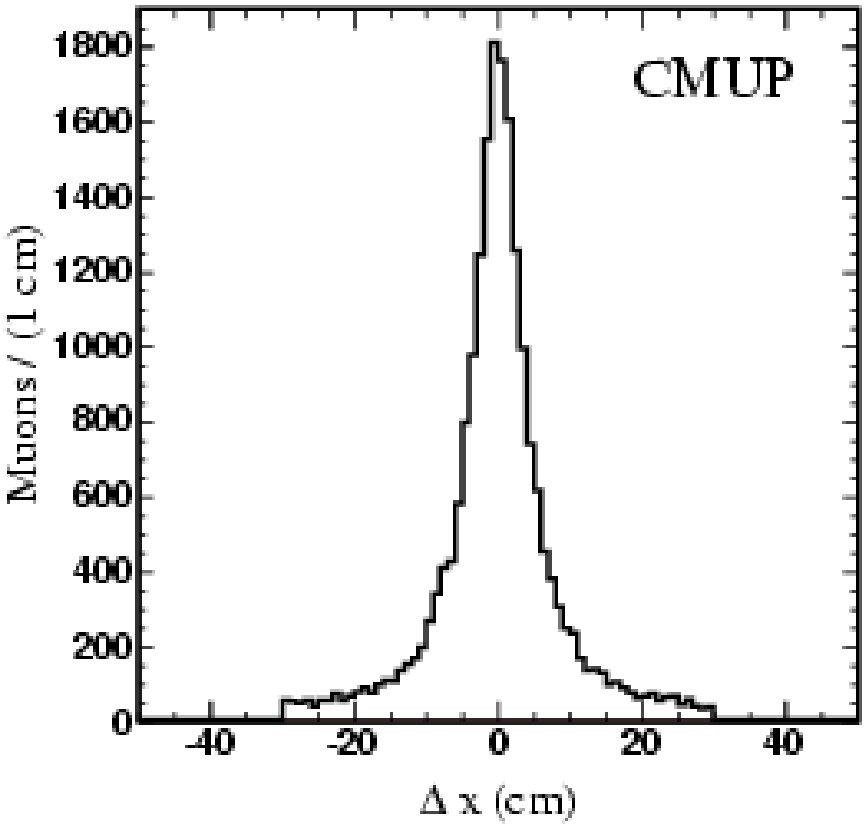
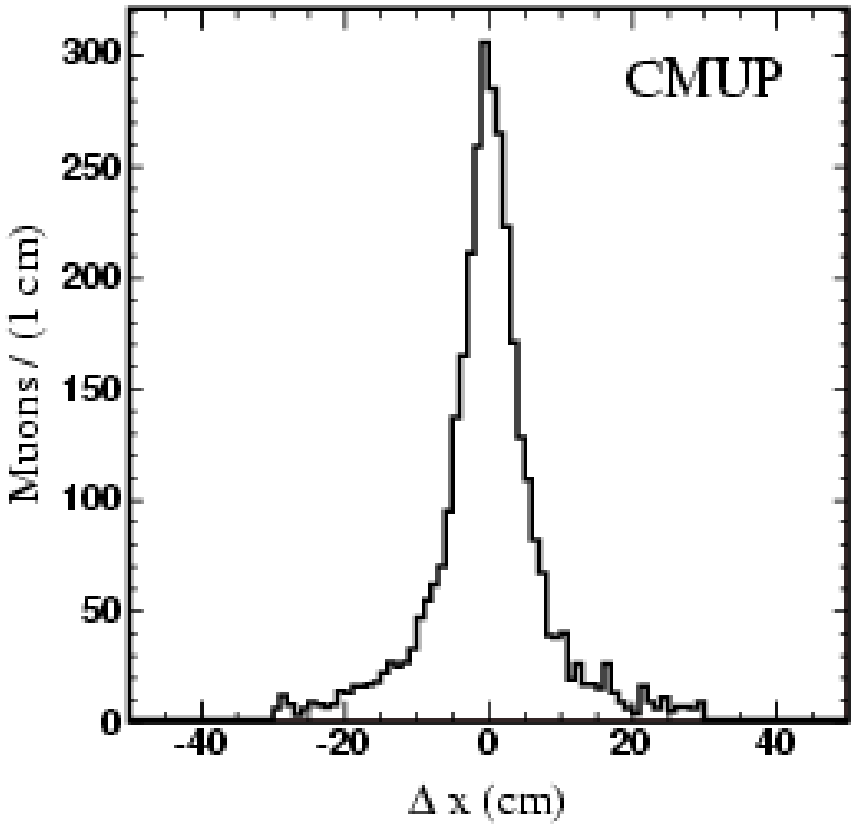


Tight SVX

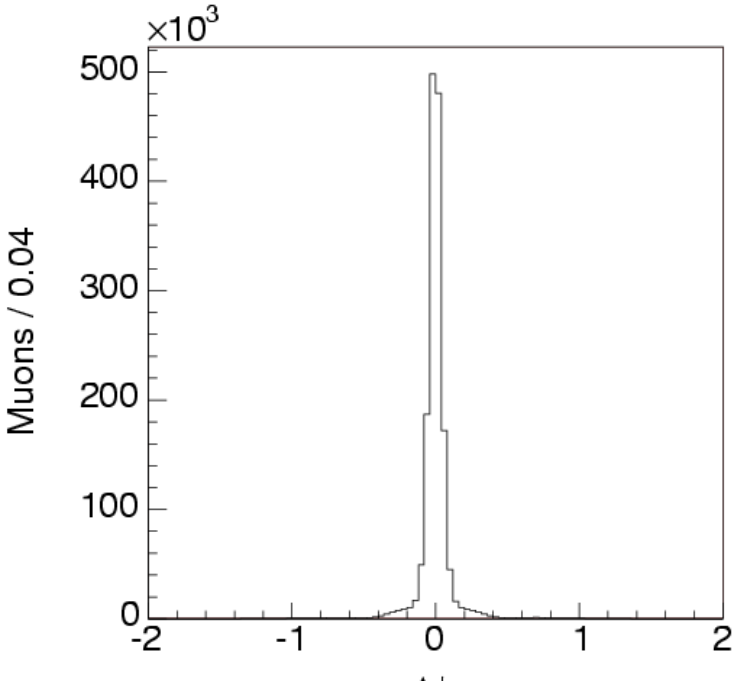
Dx – additional muons (CMUP)



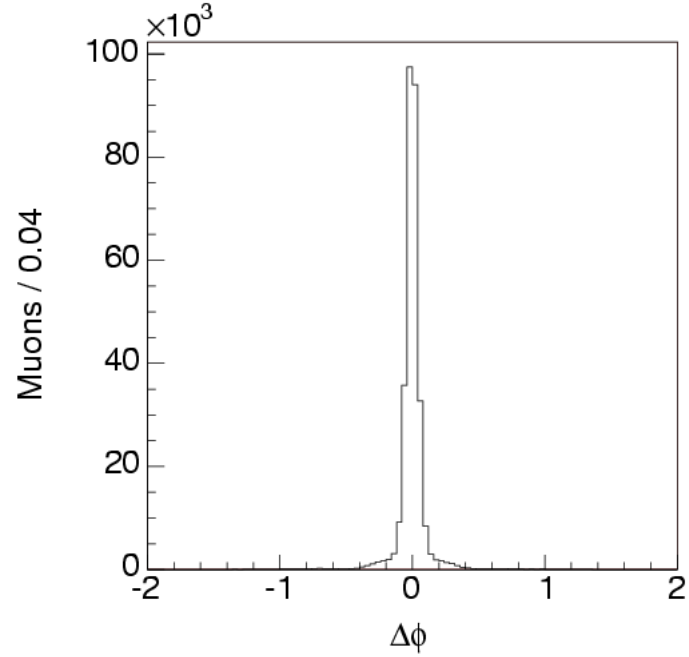
All

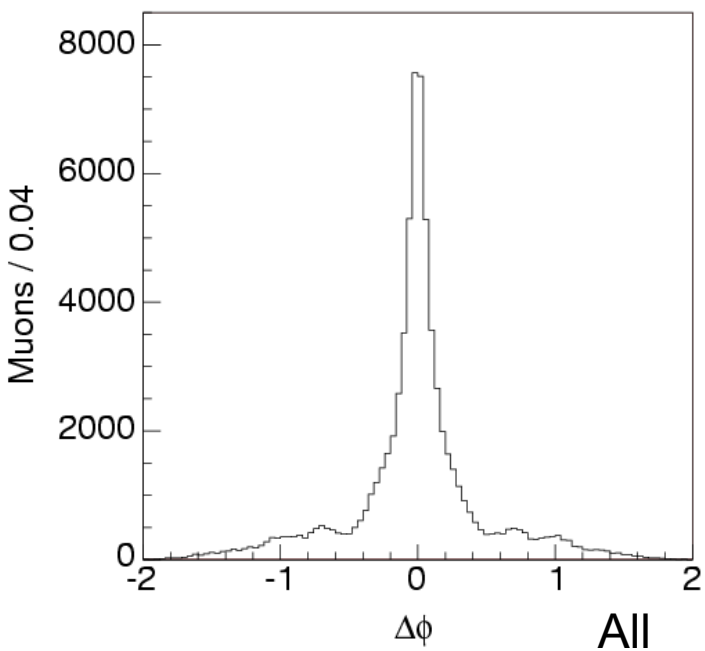


Tight SVX



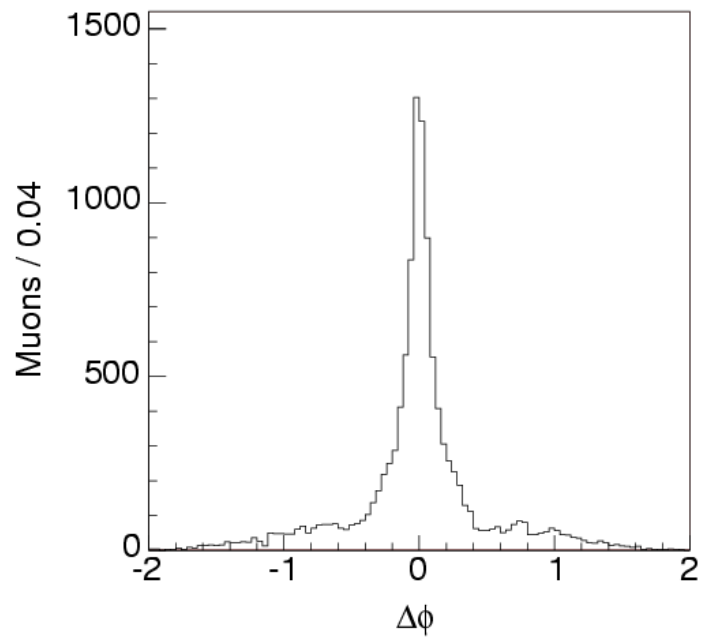
initial





additional

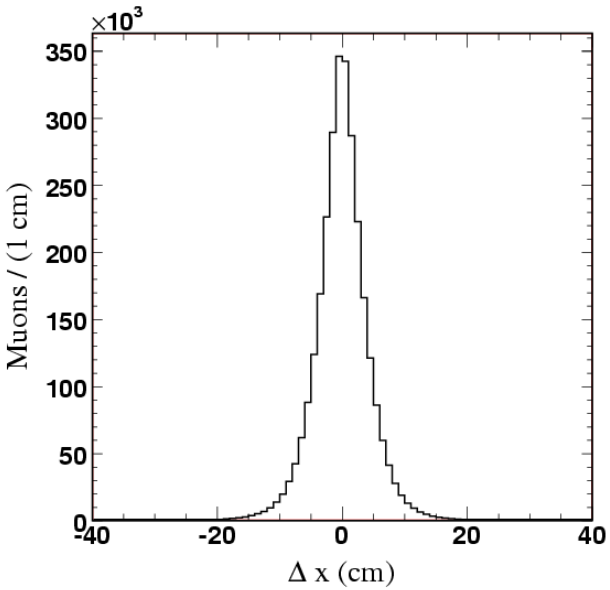
All



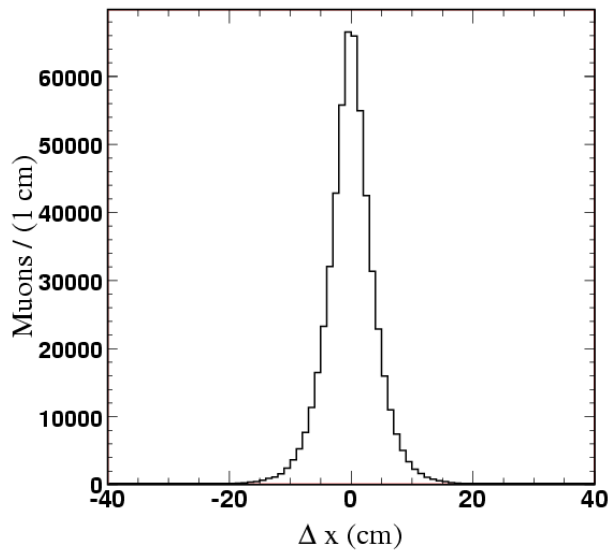
QCD

Dx – initial muons (CMUP)

All



Tight SVX



- The fake probability per track is derived using D0 from D* from B hadrons and yields approximately 0.0012 fake CMUP/event
- The fraction of fakes depends on the signal
- In the bb xsec paper, the fake rate was verified by also selecting muons with χ^2 >9 and refitting the impact parameter distribution – result:
- bbbar has about 1% fakes
- ccbar has 14% fakes – signal 2 times smaller and the number of events without a second c is 4 times larger
- b – prompt has 100% fakes – no signal
- the fakes from the IP fits are consistent with the prediction of 0.0012 fakes/event

Cross-check of…

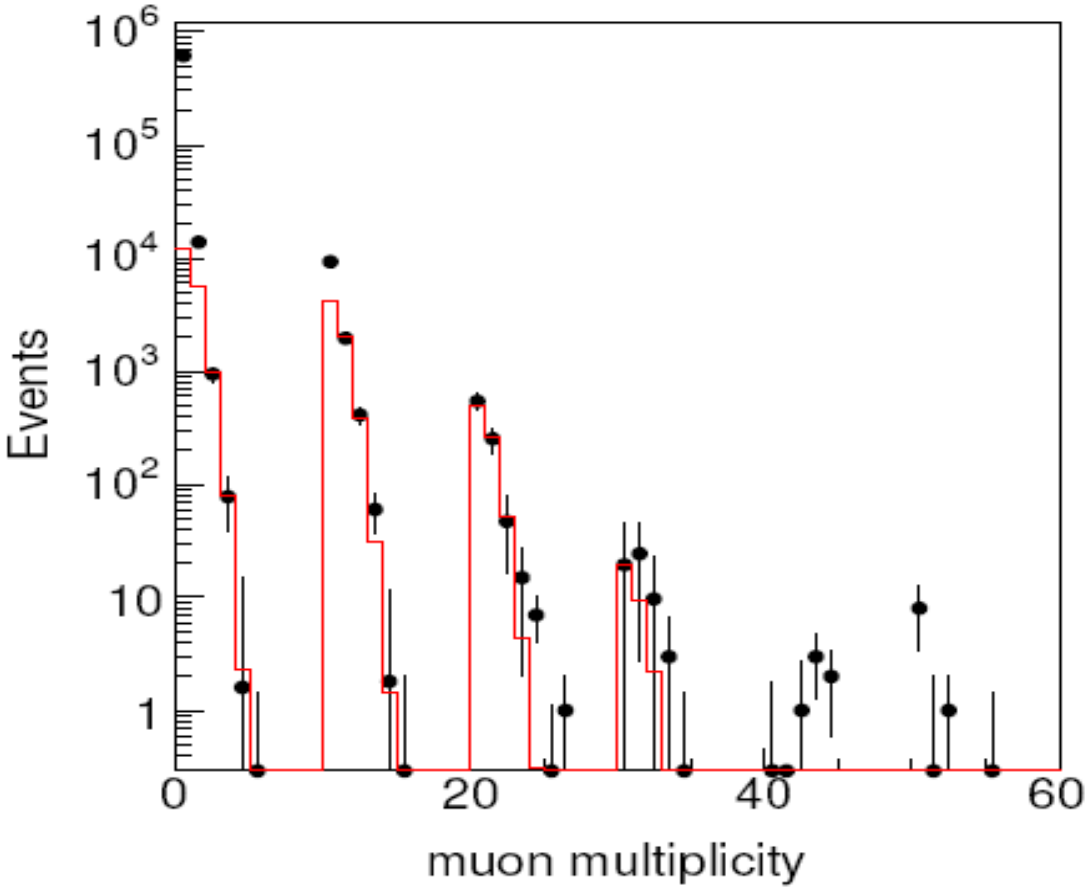
- The fraction of additional muons in QCD and ghost events by using only CMUP additional muons with p_T>3 GeV/c.
- Fake CMUP are negligible at the expense of the muon acceptance that is reduced by a factor of 5

Topology	All	QCD	Ghost	F_π
OS	10812	7380±172	3432±123	216±44
SS	4400	2635±104	1765±123	138±35

Fakes are reduced to 7% of the signal or 0.002/event

The fraction of real CMUP muon in ghost events (1.64±0.08)% is still four times larger than in QCD (0.40±0.01)%

θ <36.8° – additional muon multiplicity



Fake muons removed assuming tracks are π

Toy Monte Carlo: 8 $\tau \to \mu$ with BR=0.174 and ε_μ =0.883 and ε_{kin} =1

4 τ^+ +4 τ^- – toy MC, normalized to data for bins >=11,

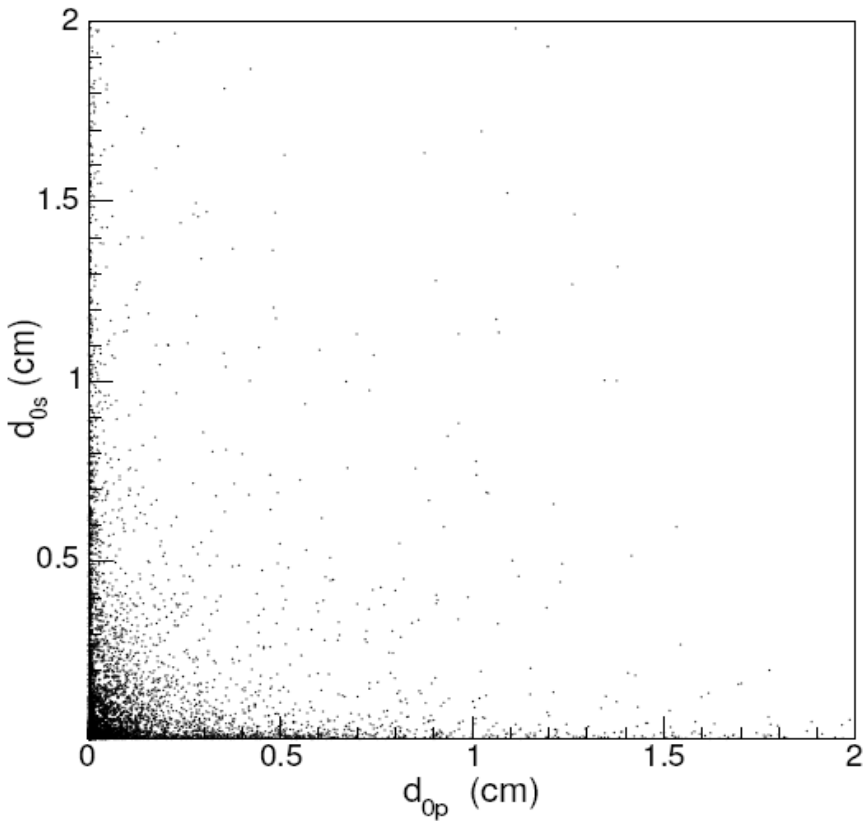
accounts for approximately 13200 (5%) of the ghost events

Phenomenological conjecture

- 5% of the ghost events arise from the decay into 8 τ of a state h_1 that is light compared to its transverse momentum
- Use the conjecture to make other predictions that are verified with the data
- To compare data and predictions we need to simulate h_1 states with large transverse momentum
- It is done with Pythia through processes such as ff->h_1h_1, or pp->H->h_1h_1, where H is a Higgs bosons with a mass ranging from 115 to 300 GeV/c^2 . This is a matter of convenience in generating events
- First thing: this object must have a lifetime much longer than b quark or it would not end up in the ghost sample

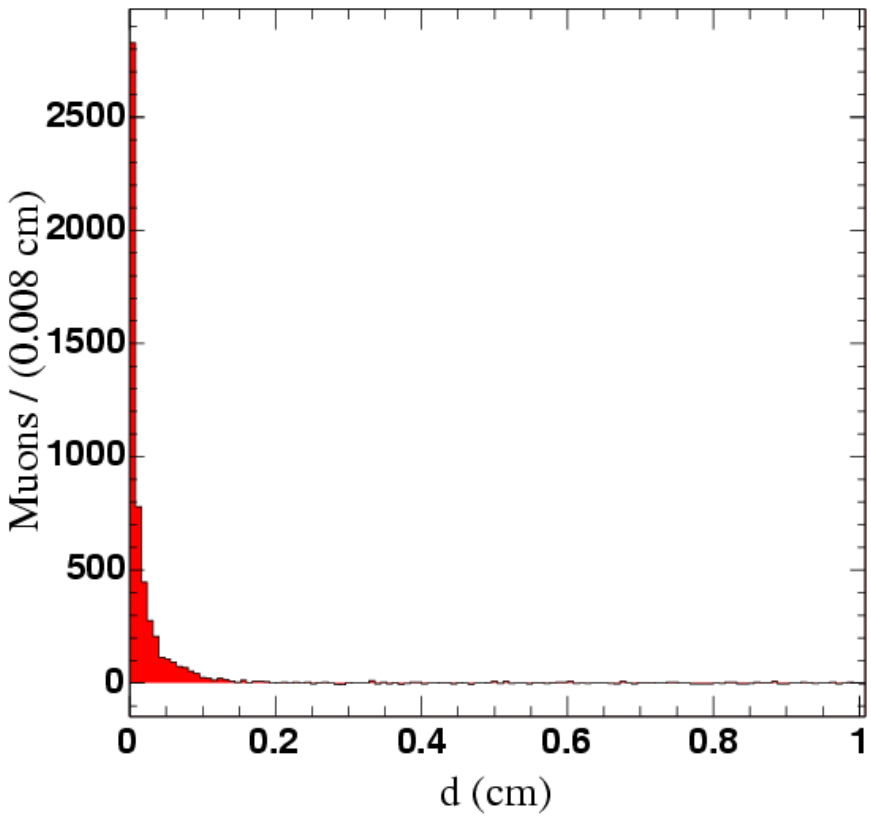
Impact parameter of the additional muons

ghosts



ρ = 0.03

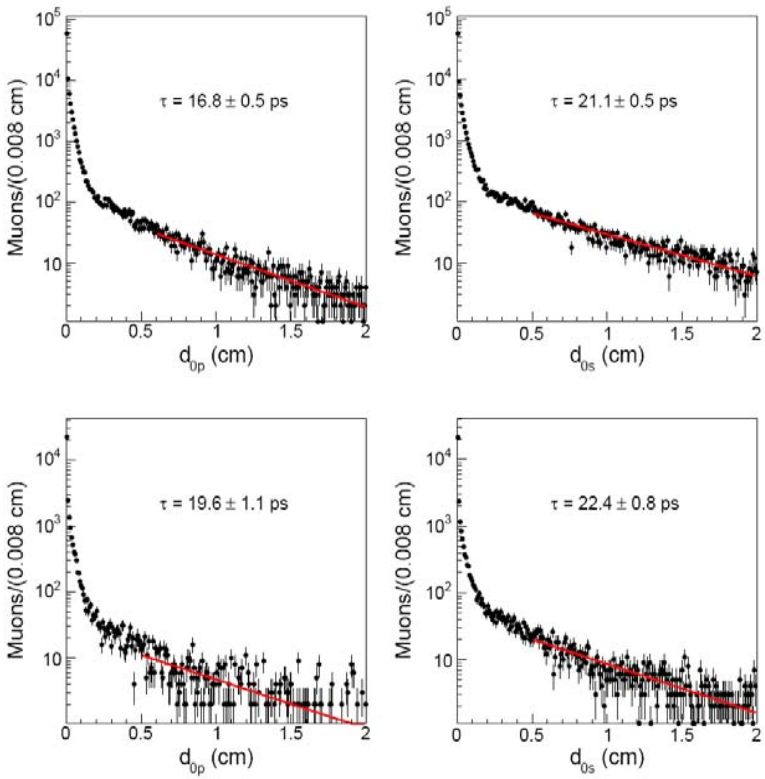
QCD

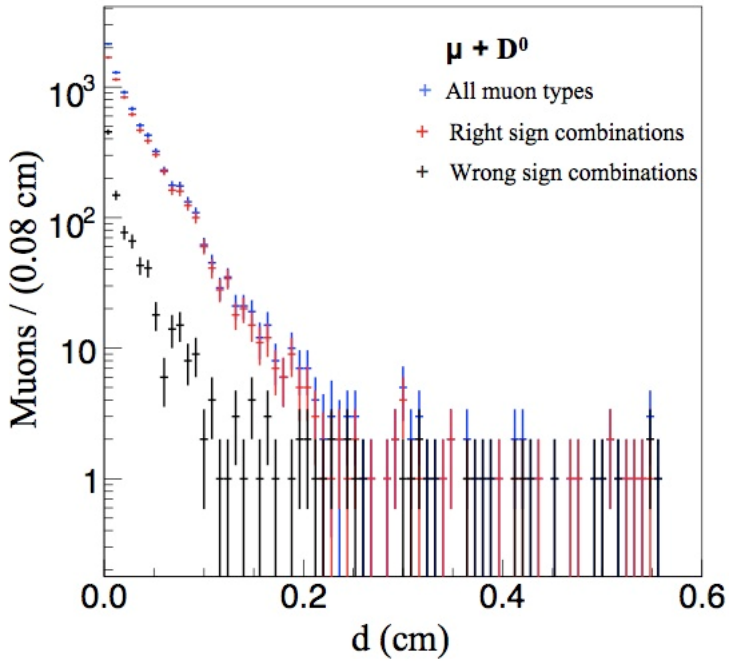


5320 OS-SS
additional muons

Impact parameter of additional muons

- The additional muons are used to measure a lifetime of 21 ps
- Additional muon in QCD events do not have any d tail

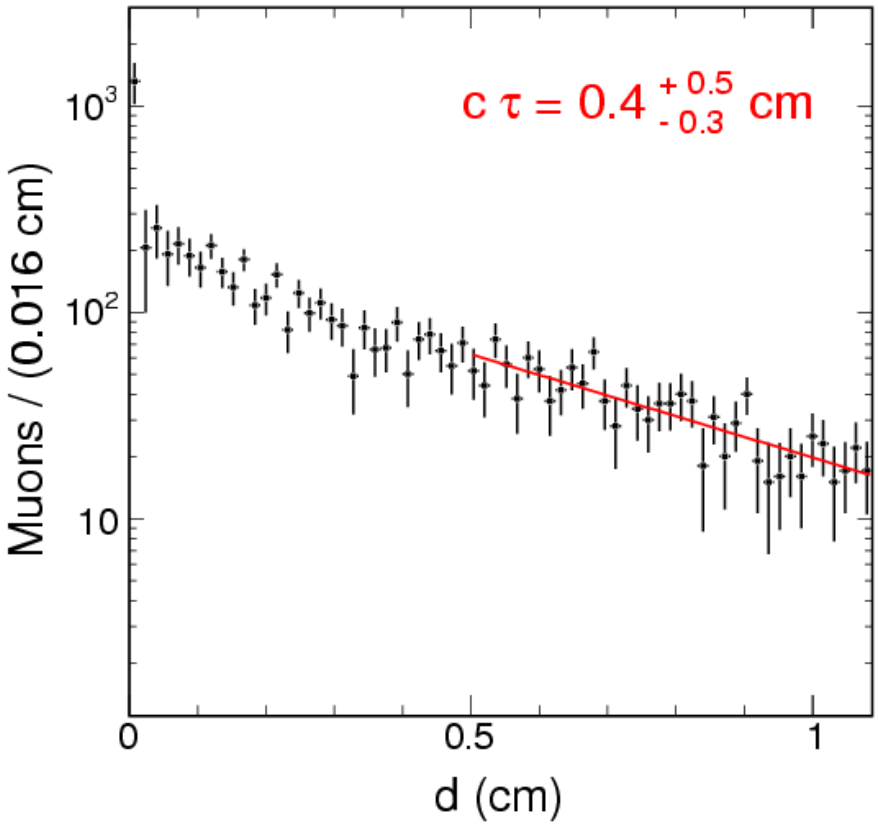


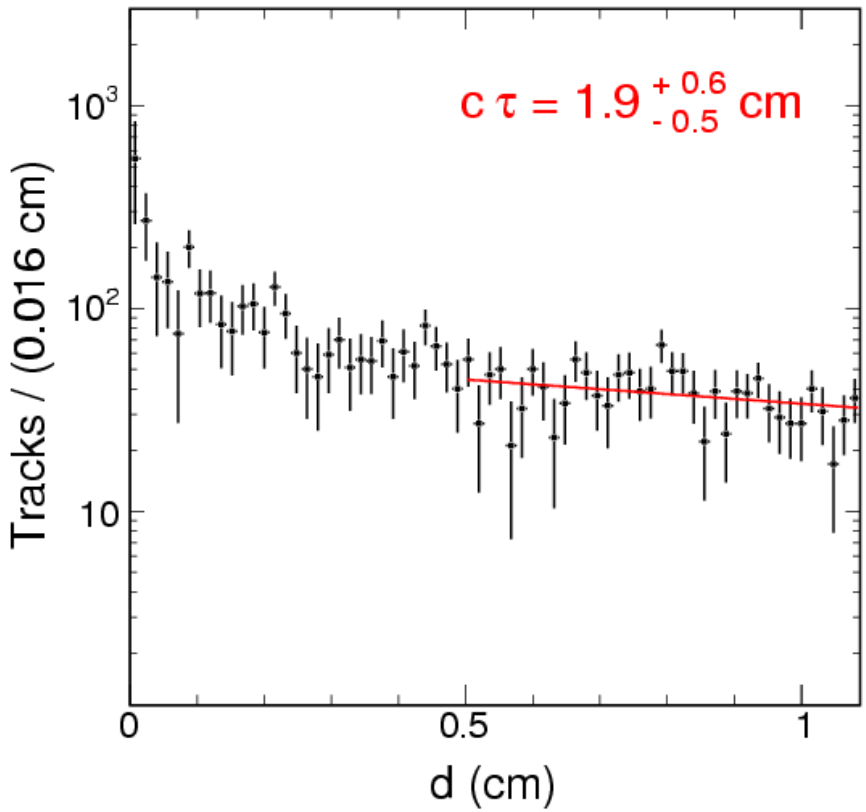


K0S

The lifetime measured with the trigger muon is the same as that of ghost events
Any lifetime larger than 10-15 ps produce the same impact parameter distribution for trigger muons
The fact that in ghost events the lifetime ot the initial muon is 85% of that measured with additional muons is due to the fact that the new particle has a 21 ps lifetime

No SVX requirement

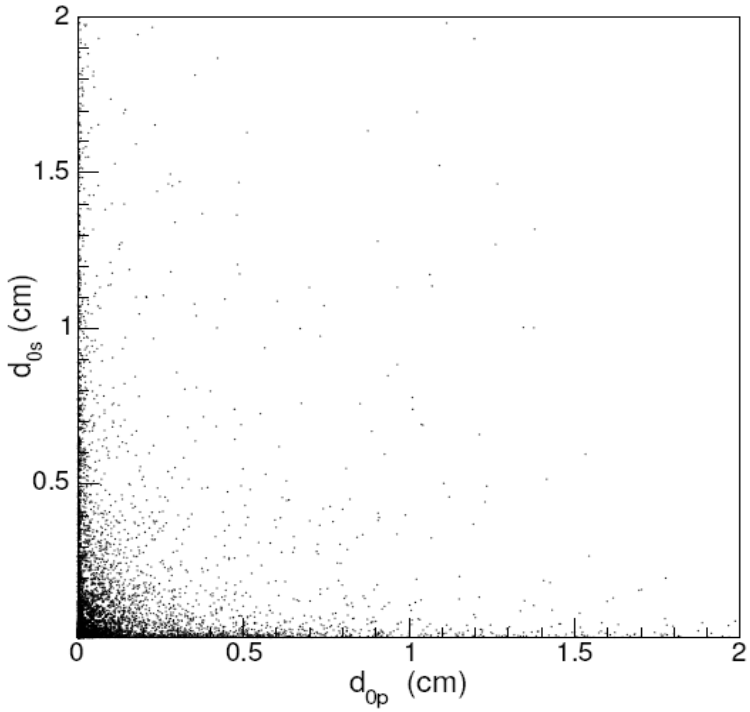




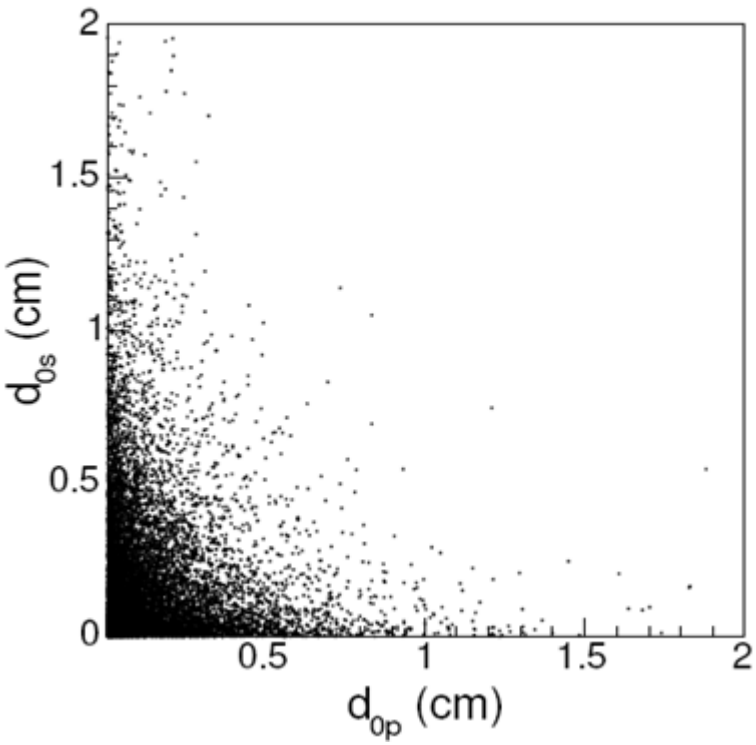
Decay mechanism - impact parameter uncorrelated

This also implies that multi-muons do not arise from secondary interactions

Data



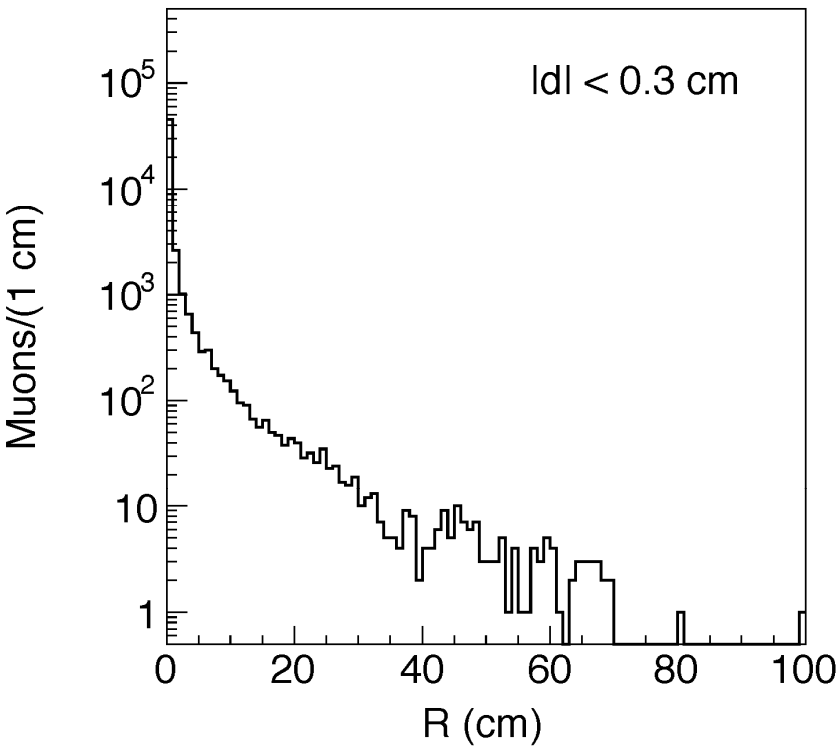
h_1-> 2 h_{2-}> 4 h_3 -> 8 τ simulation

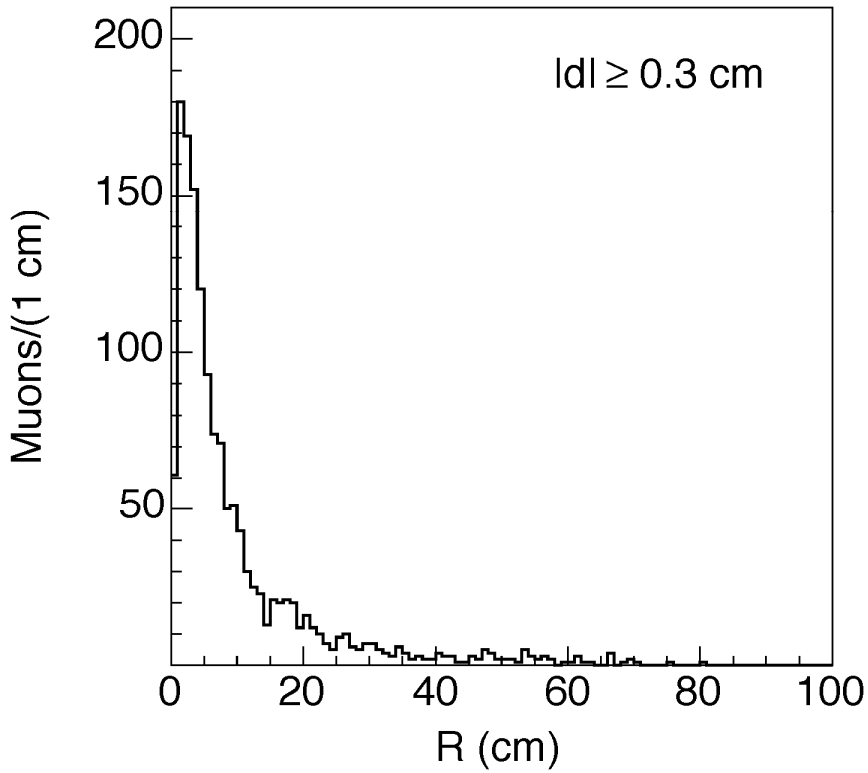


Multi-muons from secondary interactions

Vertex constrain initial and additional muons

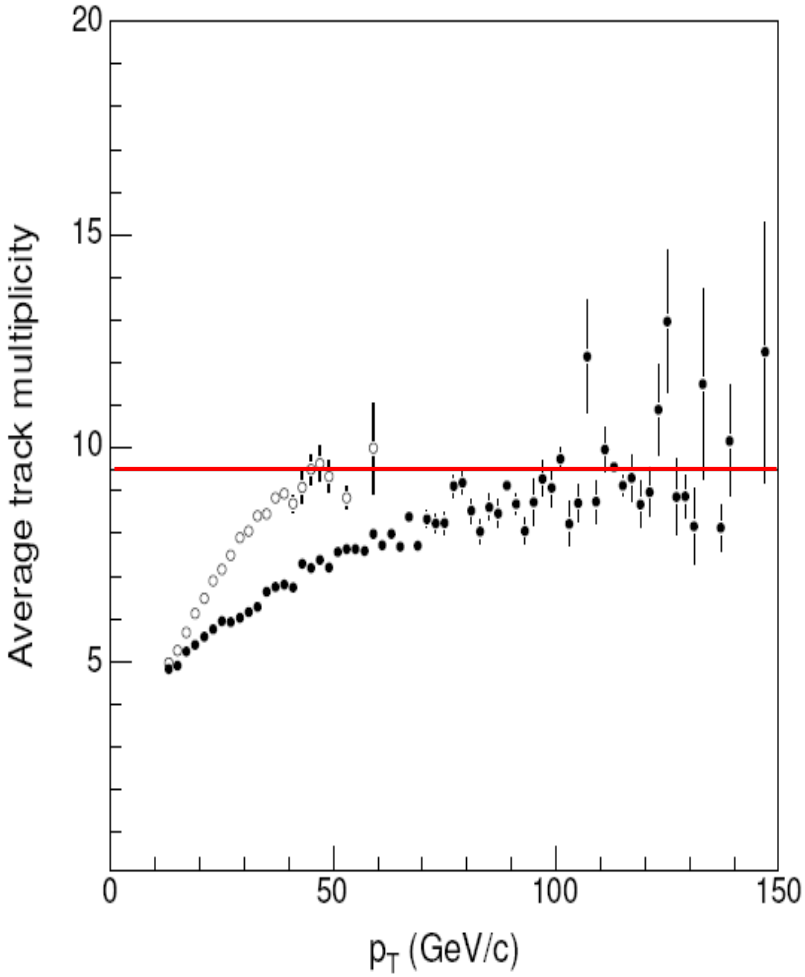
Plot R vs z - on the web page – here the R distribution





A forgotten test of the hypothesis

- Ghost events with 3 or more muons in a 36.8^0 cone are consistent with the presence of 8 τ leptons
- It the hypothesis is correct, these cones must asymptotically contain 9.5 tracks with the same kinematic of the muons
- Compare data to a simulation of the process $p\bar{p} \to H \to h_1\, h_1$, with m_H=115 GeV/c^2 and $h_1 \to 8\tau$
- Use Pythia, ISUB=151 to generate a Higgs boson



Are h_1 a bunch of fake multi-muons or pair produced ?

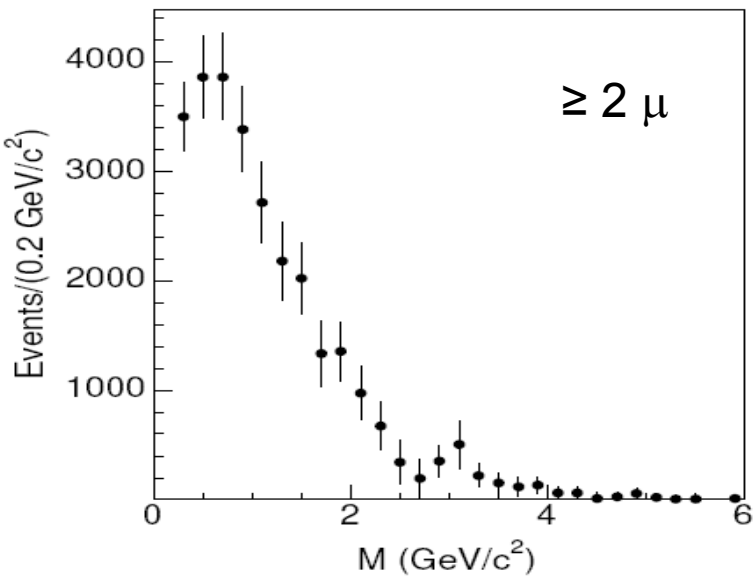
Ghost events

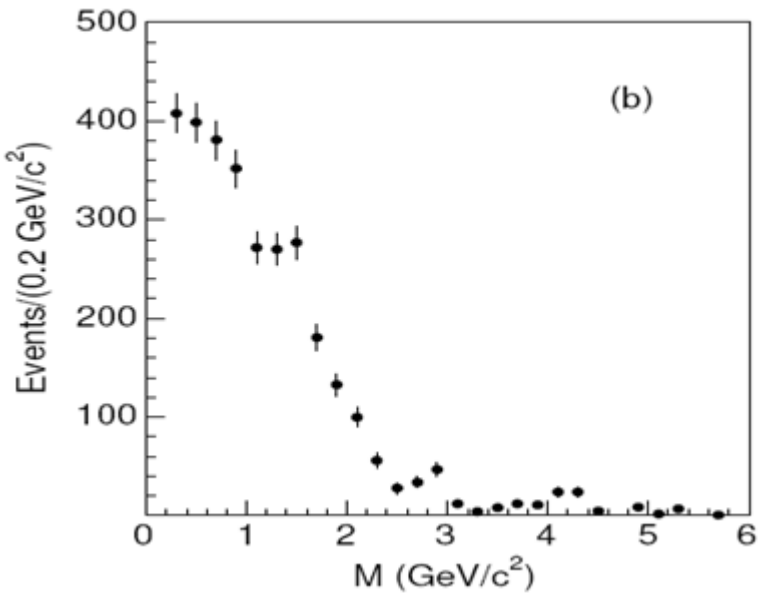
27790±761 cones with ≥ 2 μ a)

4133±263 cones with ≥ 3 μ

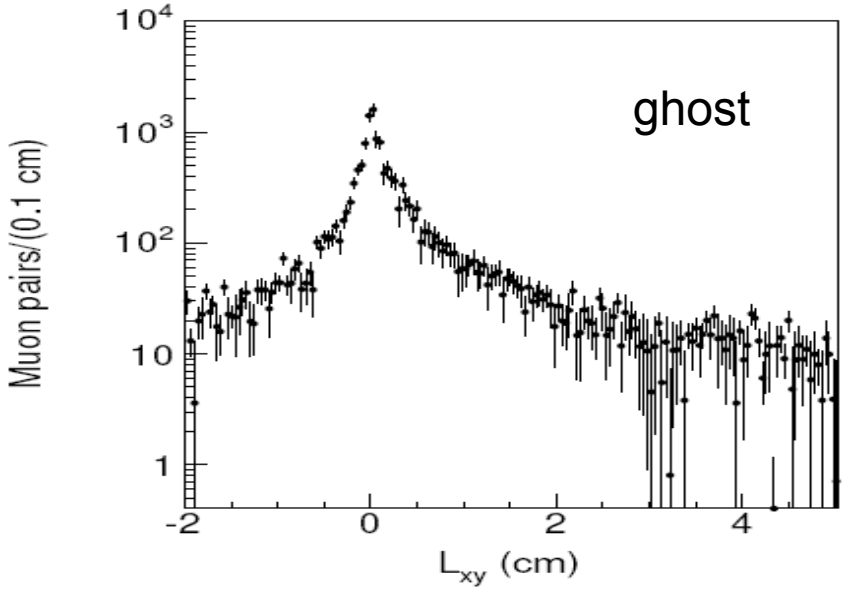
3016 with ≥ 2 μ in both cones b)

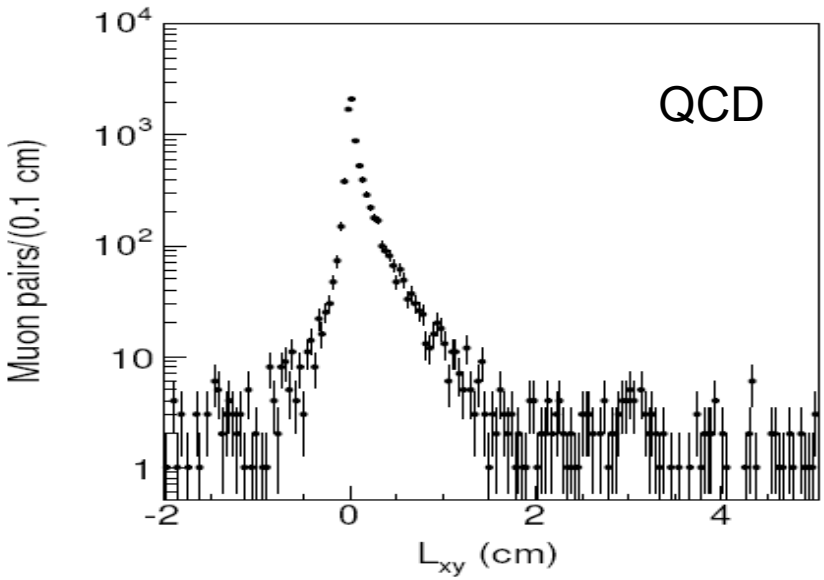
a/b=0.11 is consistent with NP simulations

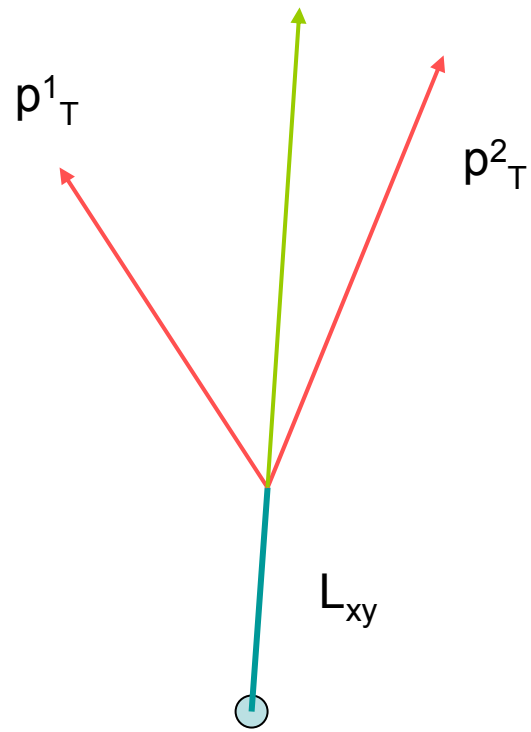




L_{xy} distributions

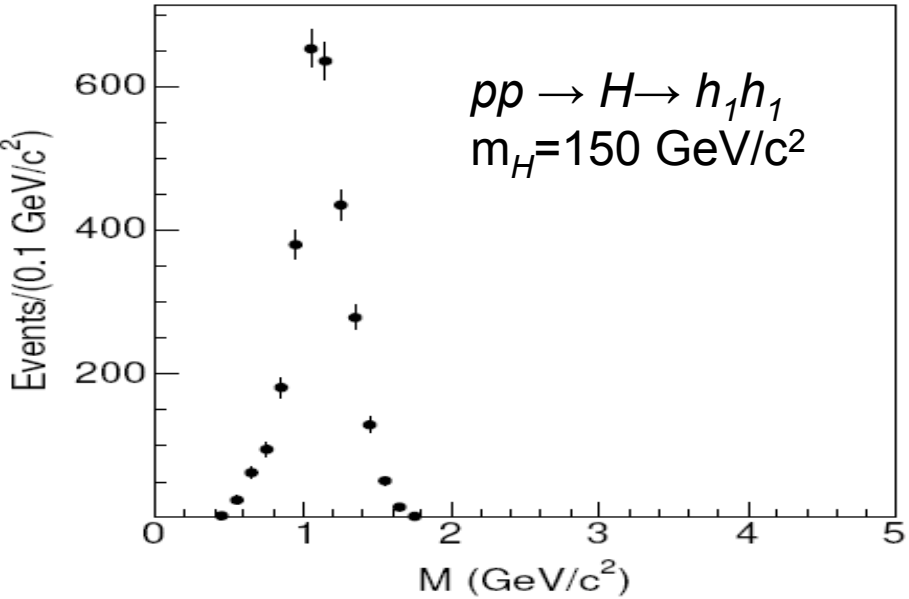


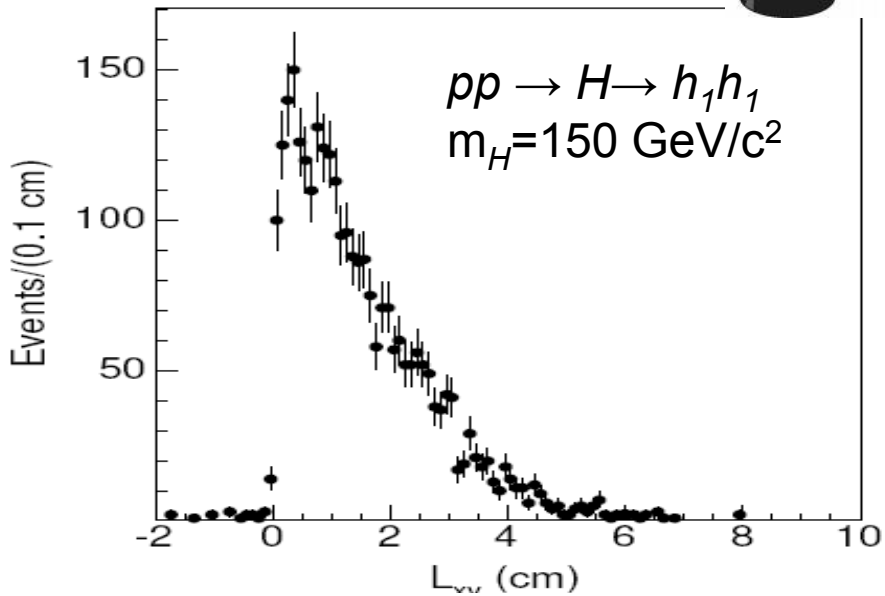


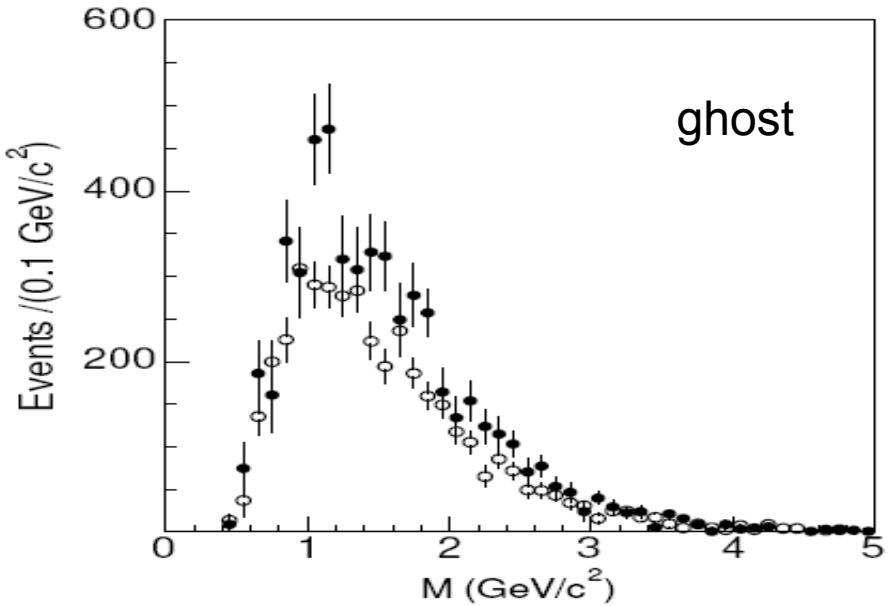


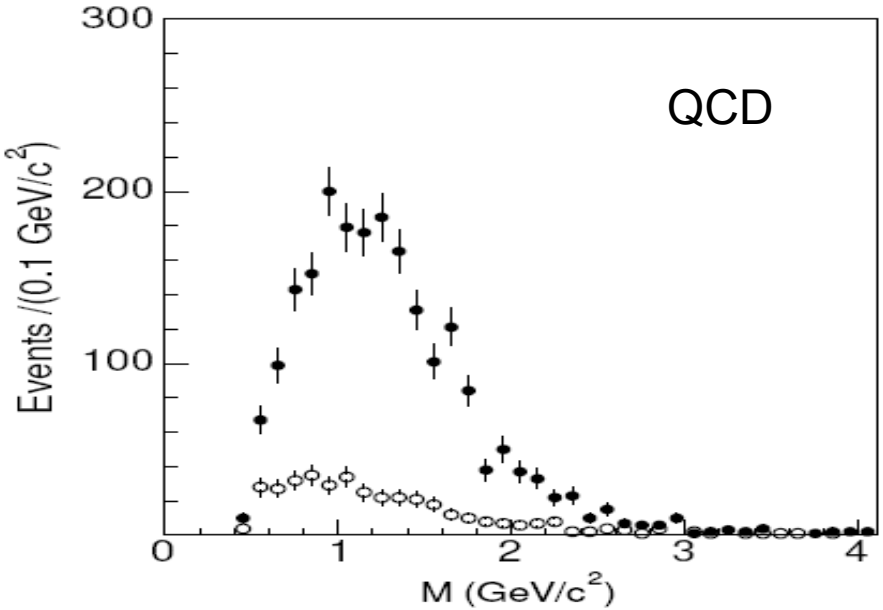
2 μ vertex constrained

$\tau \longrightarrow h^+h^-h^-$









Conclusion

The horse called Paganini