Tevatron Timing and Z Collision Distribution for use in the Gamma+MET Analysis

Jonathan Asaadi, Dave Toback, Ron Moore, Max Goncharov, Adam Aurisano

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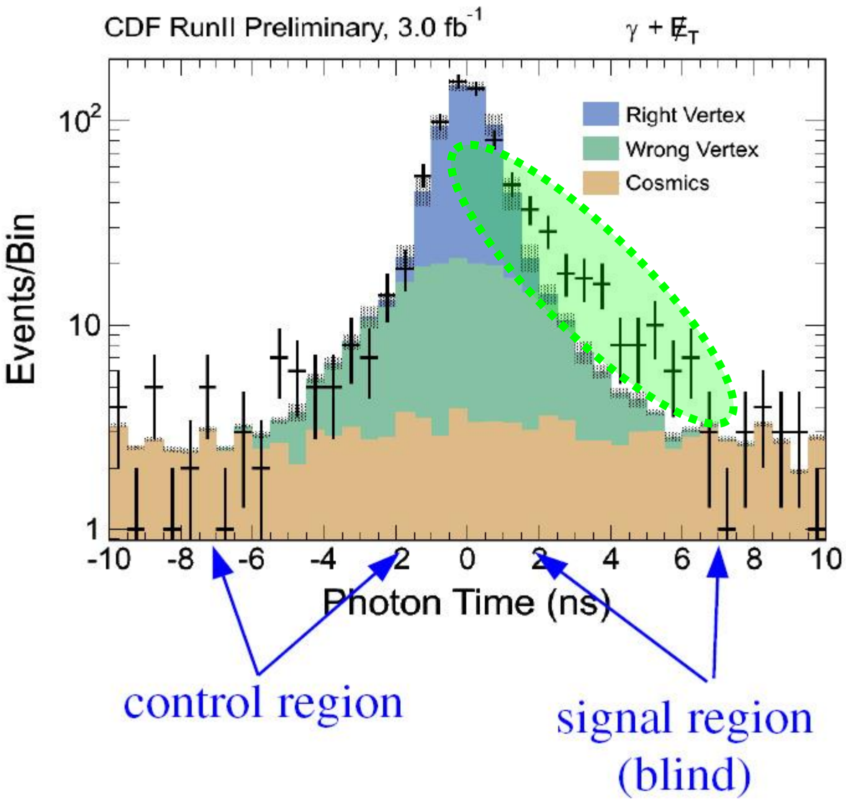
Preliminary Gamma+MET Study Excess

- An earlier study found an excess in the exclusive Photon + MET sample
  - Photon E_T > 45 GeV
  - MET > 45 GeV
  - Veto Jet E_T > 15 GeV
  - Veto Lepton E_T > 10 GeV
- ***Could this be new physics?***



What if it isn't "new" physics...but it just looks like it?

Maybe this could just be some prosaic background that doesn't affect other analyses significantly and gives us a bias that causes the timing to be different than expected

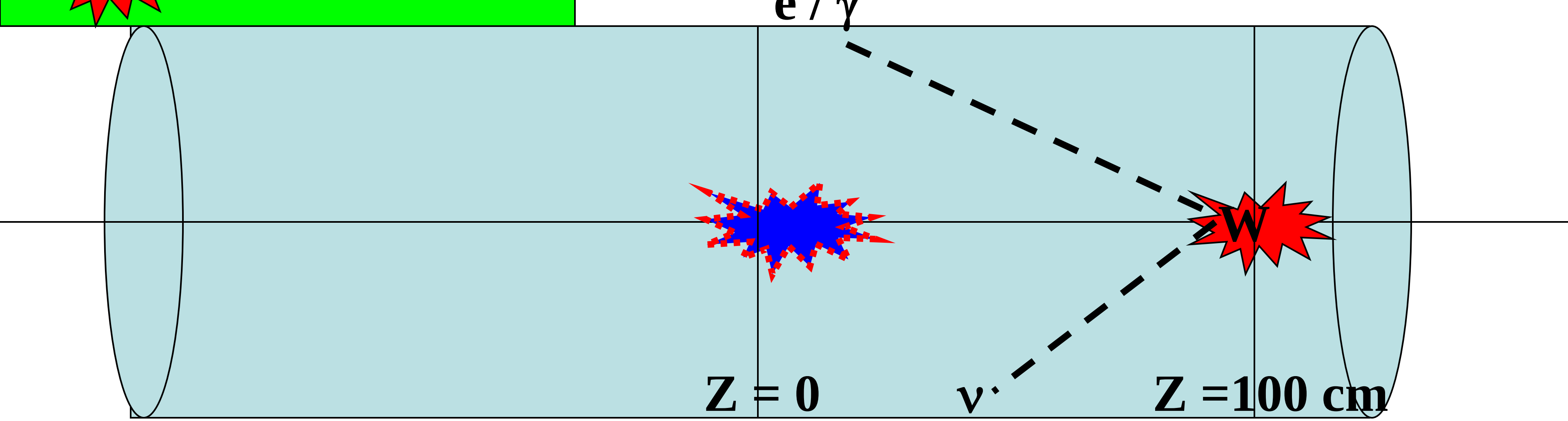
(Not as exciting...but still needs to be investigated!)

Why do we care about Collision Distributions?

Vertex Selected for Event

Collision Point

Since we are doing an analysis in exclusive Gamma+MET we have a real problem with selecting the wrong vertex



A process can be biased towards large Z for numerous reasons:

- Electrons coming from large Z are more likely to fake a photon
- Photons identified with a wrong vertex are more likely to have their E_t ‘promoted’

If a physics process is biased to large Z this can bias us to larger times

At larger Z we are likely to select the wrong vertex in the first place

Thus we need to understand the collision distributions in both time and position in order to understand the time distribution we expect for the Photon+MET sample

Trying to Understand Our Backgrounds

$$W \rightarrow e + \nu$$

$$Z\gamma \rightarrow \nu\nu + \gamma$$

$$\gamma\gamma$$

Non-Collision Background

In order to determine if this is new physics we must test all possible backgrounds and see if they have sufficient production with large times

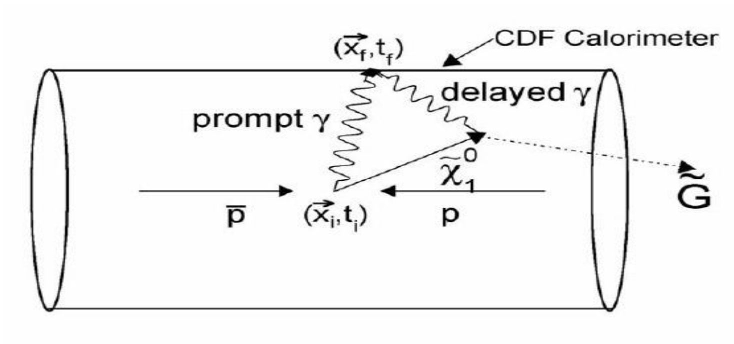
If our understanding of the <u>collision distributions</u> aren't correct, perhaps this excess is a collision background and we just didn't realize

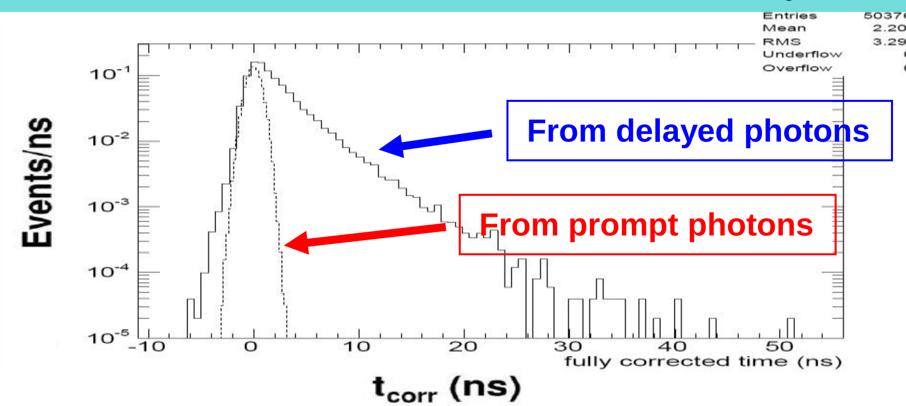
If we take into account all the backgrounds and there is still an excess, perhaps it is new physics

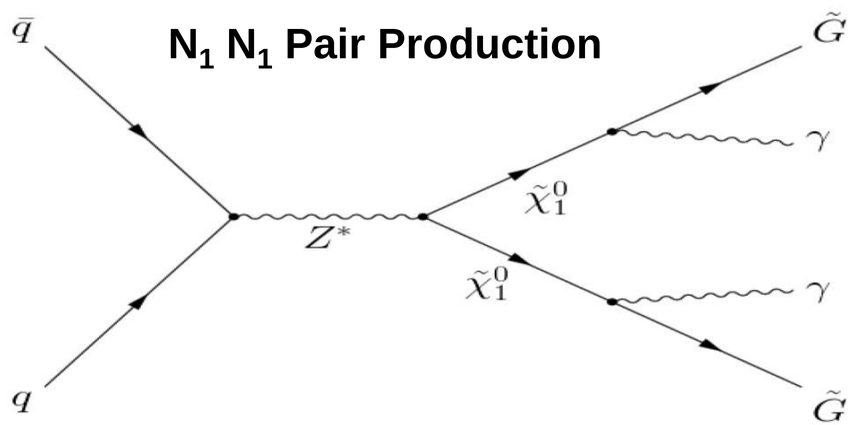
New Physics

In some forms of SUSY the Next to lightest stable particle (NLSP) is long lived before decaying to photon and the lightest stable particle (LSP)

This means that you would have events where the photons would appear to arrive at the detector "delayed



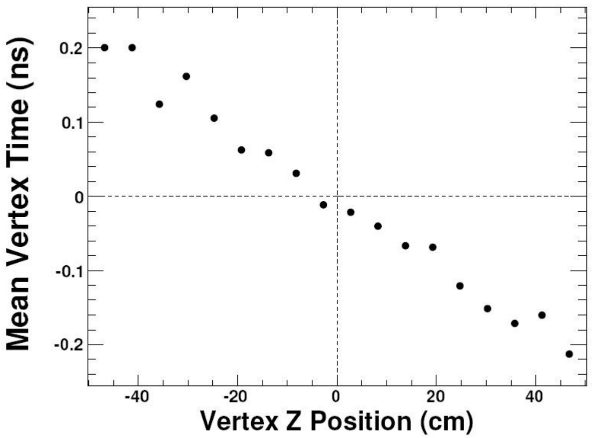




Studying the Accelerator

Through discussions with experts we learned some things about our beam that are not in our MC Simulation

What we already knew: The longitudinal width (σ_p) for the protons and antiprotons are different from one another. This gives rise to a correlation between the vertex position Z and the timing distribution.



$$ct = z\,\frac{\sigma_{\bar{p}} - \sigma_p}{\sigma_{\bar{p}} + \sigma_p}$$

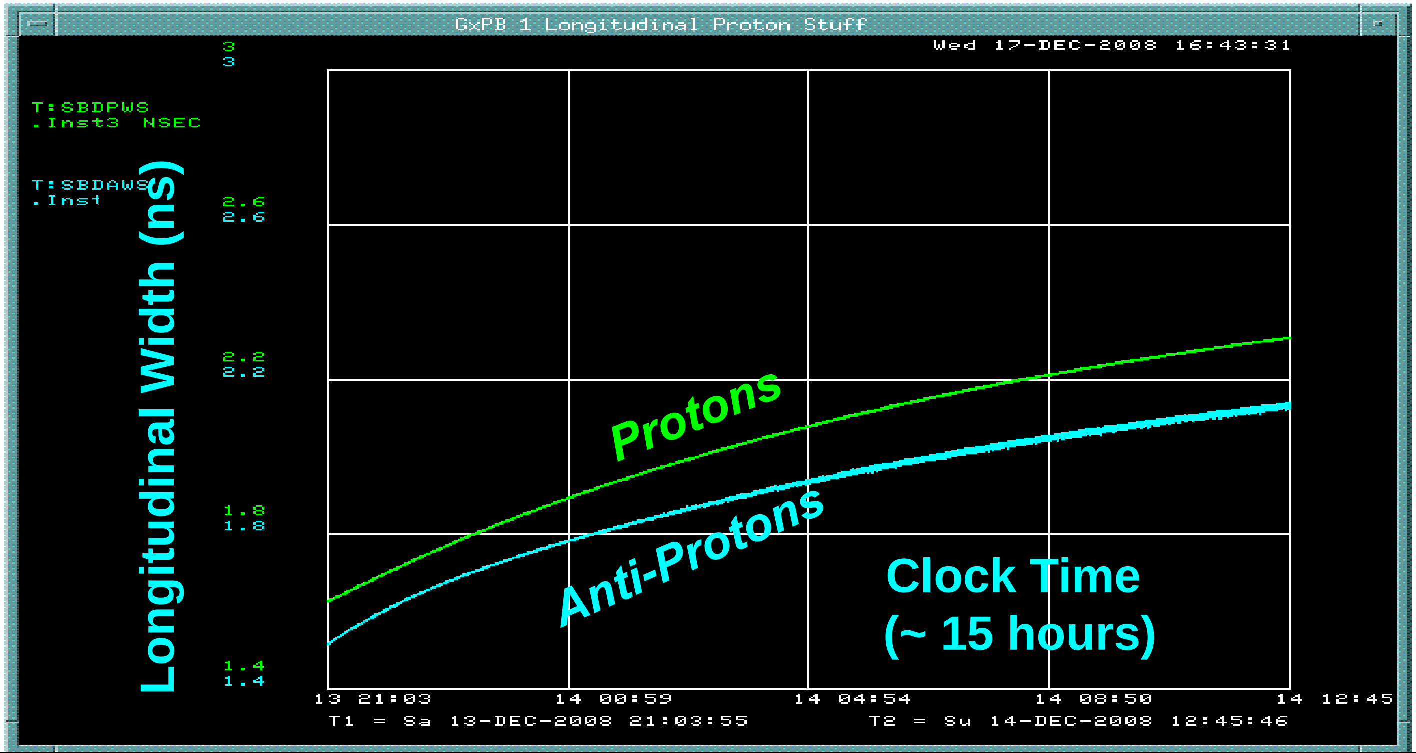
Not in CDF MC…but we already knew that

CDF Note 8015 and Phys. Rev. D 78 (2008) 032015

What we didn't know: The longitudinal profile (σ_p) for the protons and antiprotons **becomes longer** during the course of a store

We want to know how this affects the collision position and time as well as the correlation between the two. In particular look at the change in the means and RMS's of these distributions

Longitudinal Width Changing Over the Course of a Store

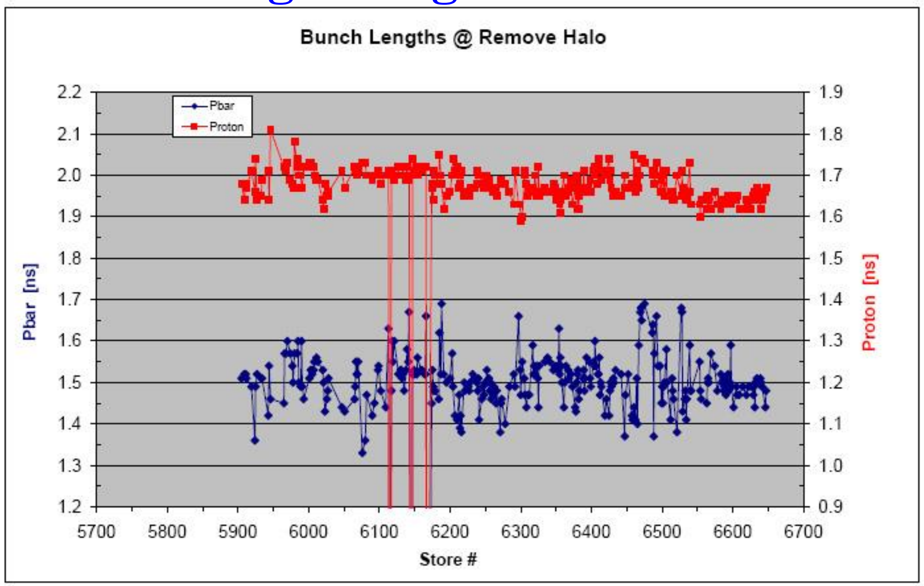


Particle	Longitudinal Width Beginning of the store	Longitudinal Width End of the store
Anti-Protons	1.5 ns (44.97 cm)	2.1 ns (62.96 cm)
Protons	1.7 ns (50.96 cm)	2.3 ns (68.95 cm)

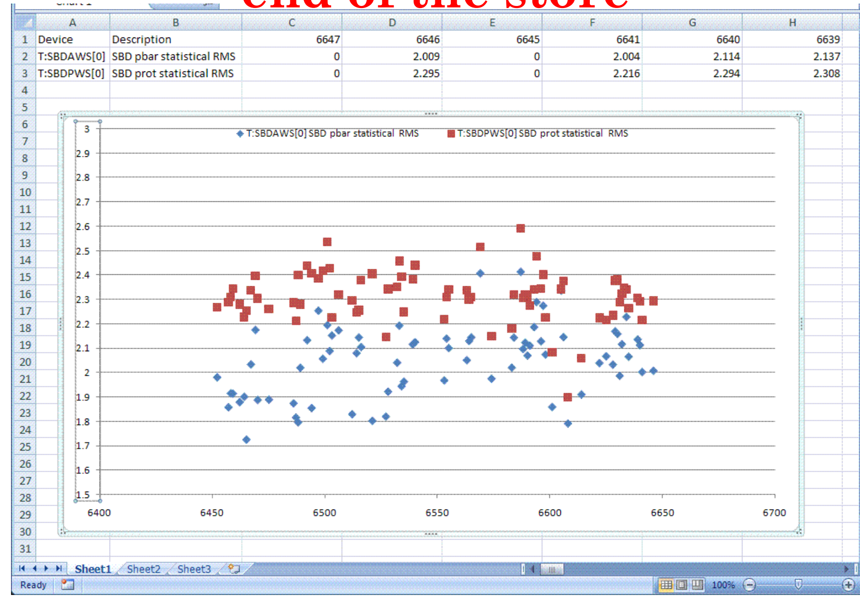
Note: These numbers are typical but a little on the low side

Even more complicated than we first thought

Average Longitudinal Width by Store measured at the beginning of the store



Average Longitudinal Width by Store measured at the end of the store



The ending bunch length depends on the store length, so there's more store-to-store variation than for the starting bunch lengths.

These example plots show that the longitudinal width can vary Store-by-Store as well

Monte Carlo

In order to study how these things may effect our understandings of the collision vertex and timing information we wrote a simple Monte Carlo

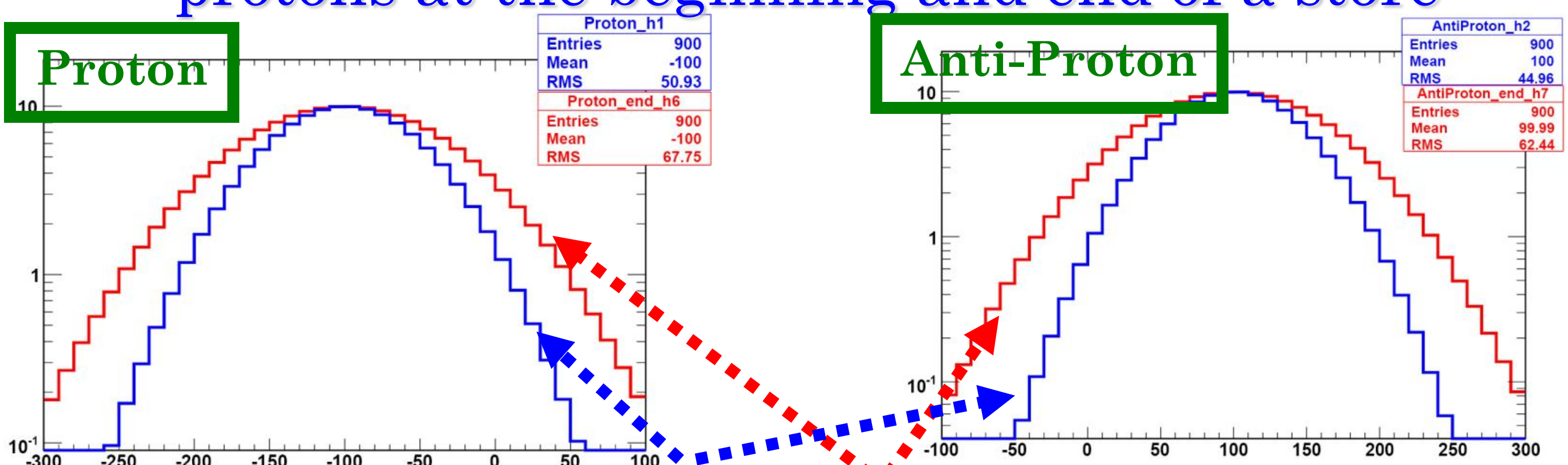
Two Important Effects to take into account

I) Widening of the Longitudinal Profile of the Protons and Anti-Protons

II) The "Hourglass Effect" of the transverse beam profile

Explanation to come

We model typical longitudinal width for the protons and anti protons at the beginning and end of a store



Longitudinal Width at the Beginning of the Store

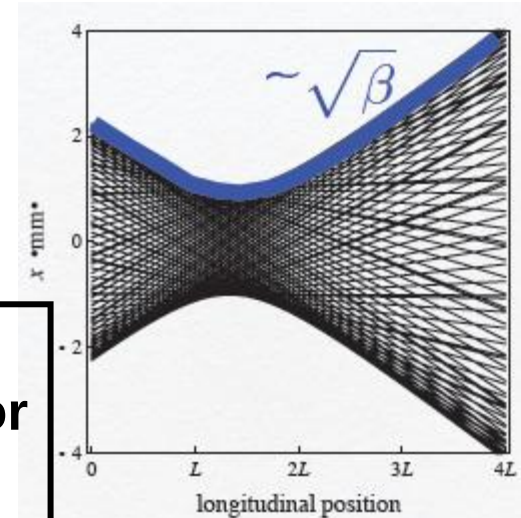
Longitudinal Width at the End of the Store

Hourglass Effect

Hourglass Effect: The transverse beam profile in the interaction region is shaped like an hourglass

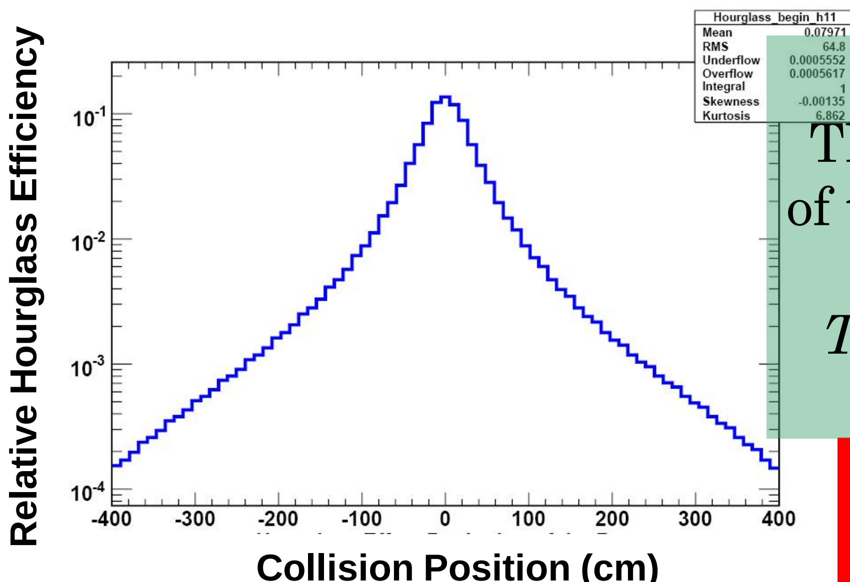
→ This effect comes from the focusing of the beam

$$\left(1+ z^2 / \beta^{*2}\right)^{-1}$$



We assume a typical value for β* ~ 28 cm

The Model of Hourglass Effect in Longitudinal Profile



Translation:

The Hourglass focusing affects the density of the beam in the x-y plane → which affects the luminosity.

This means that we get an extra efficiency term as a function of Z

Now we include the hourglass effect in our simulation: Which affects the position, but not timing distribution

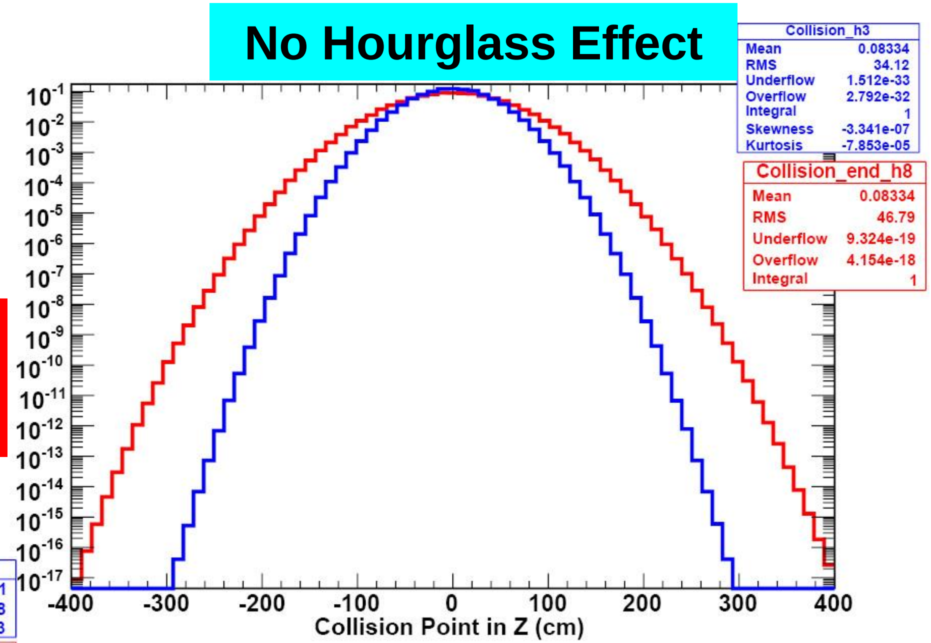
Inclusion of the Hourglass Effect

Comparing before and after inclusion of hourglass effect

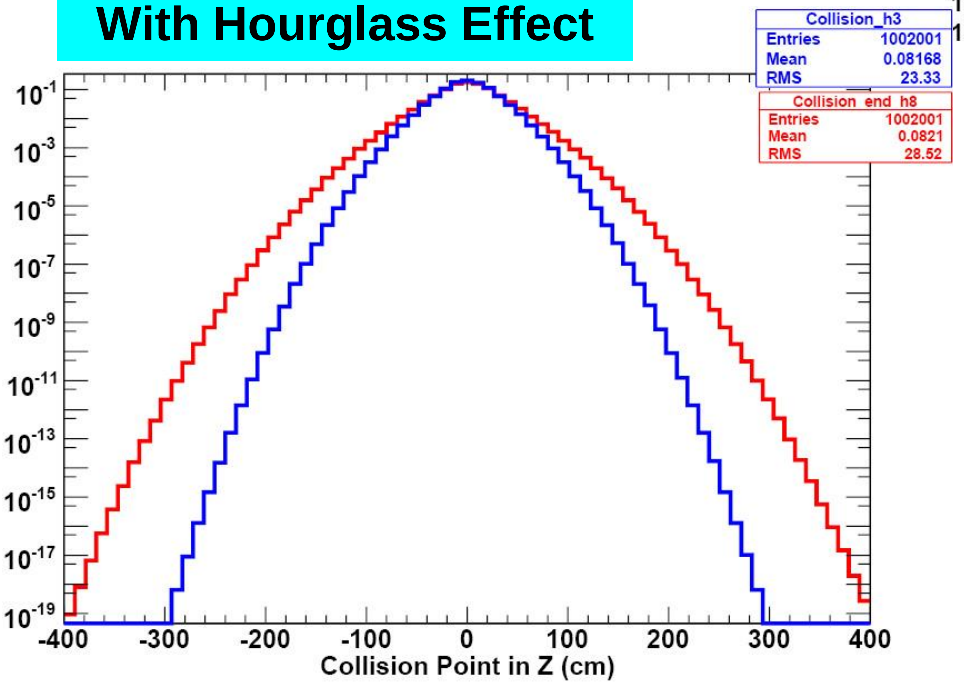
$Z_{collision}$ RMS = 34.12 cm at the Beginning of the Run

$Z_{collision}$ RMS = 46.79 cm at the End of the Run

No Hourglass Effect



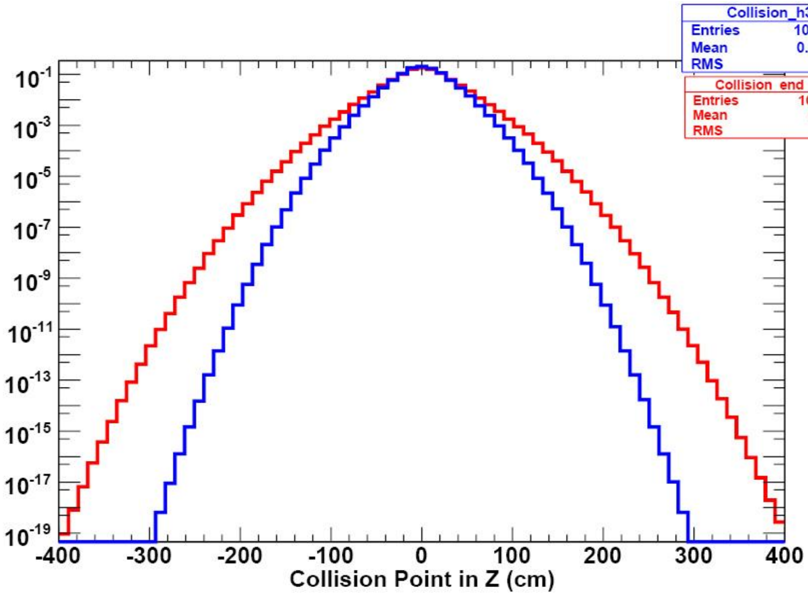
With Hourglass Effect

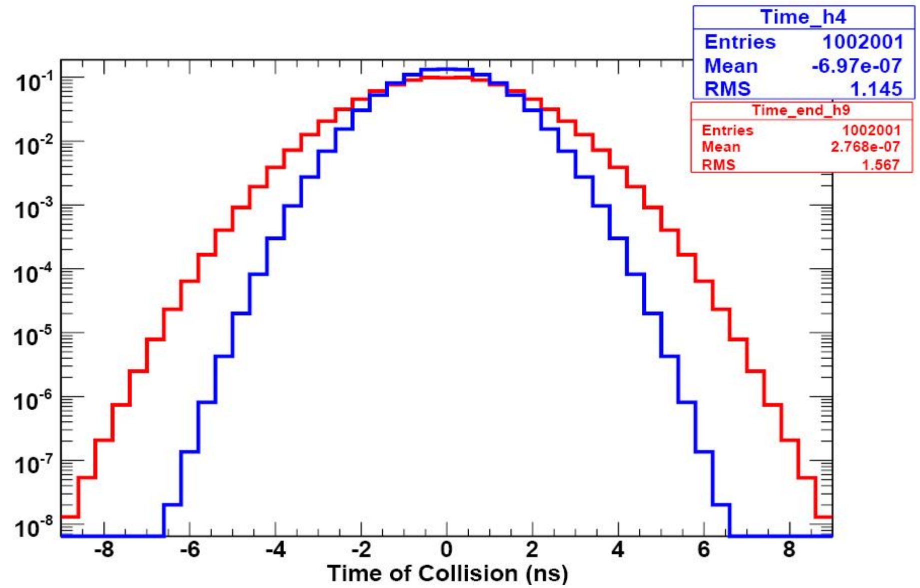


$Z_{collision}$ RMS = 22.33 cm at the Beginning of the Run

$Z_{collision}$ RMS = 28.52 cm at the End of the Run

Simulation Results





$Z_{collision}$ **RMS = 22.33 cm at the Beginning of the Store**

$Z_{collision}$ **RMS = 28.52 cm at the End of the Store**

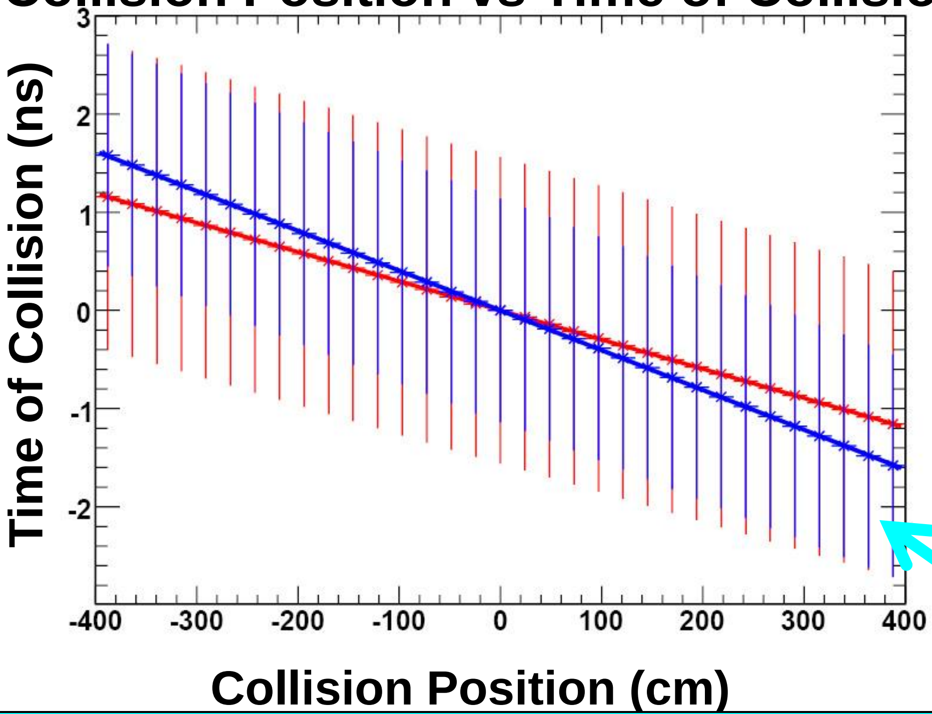
$t_{collision}$ **RMS = 1.15 ns at the Beginning of the Store**

$t_{collision}$ **RMS = 1.57 ns at the End of the Store**

In CDF Monte Carlo $Z_{collision}$ RMS ~ 28 cm and $t_{collision}$ RMS ~ 1.28 ns and are held constant throughout the Store

Collision Position vs. Time of Collision

Profile Plot of
Collision Position vs Time of Collision



Beginning of a store
Slope: -4.05 ps/cm

End of a store
Slope: -2.98 ps/cm

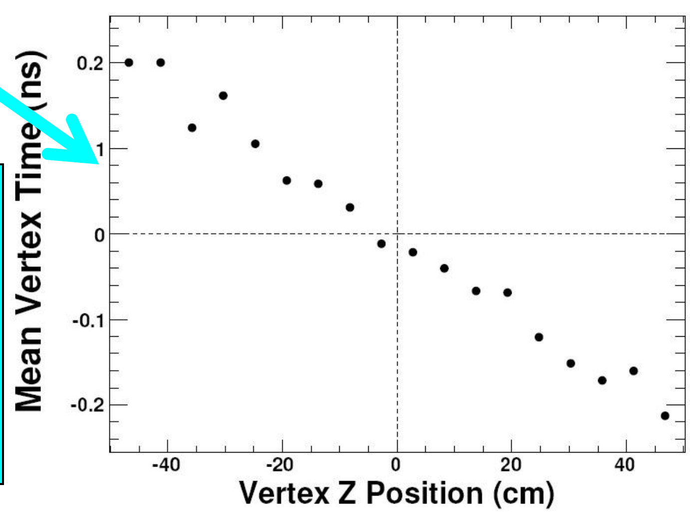
The slope becoming smaller matches our expectation since the slope goes as

$$ct = z\,\frac{\sigma_{\bar{p}} - \sigma_{p}}{\sigma_{\bar{n}} + \sigma_{n}}$$

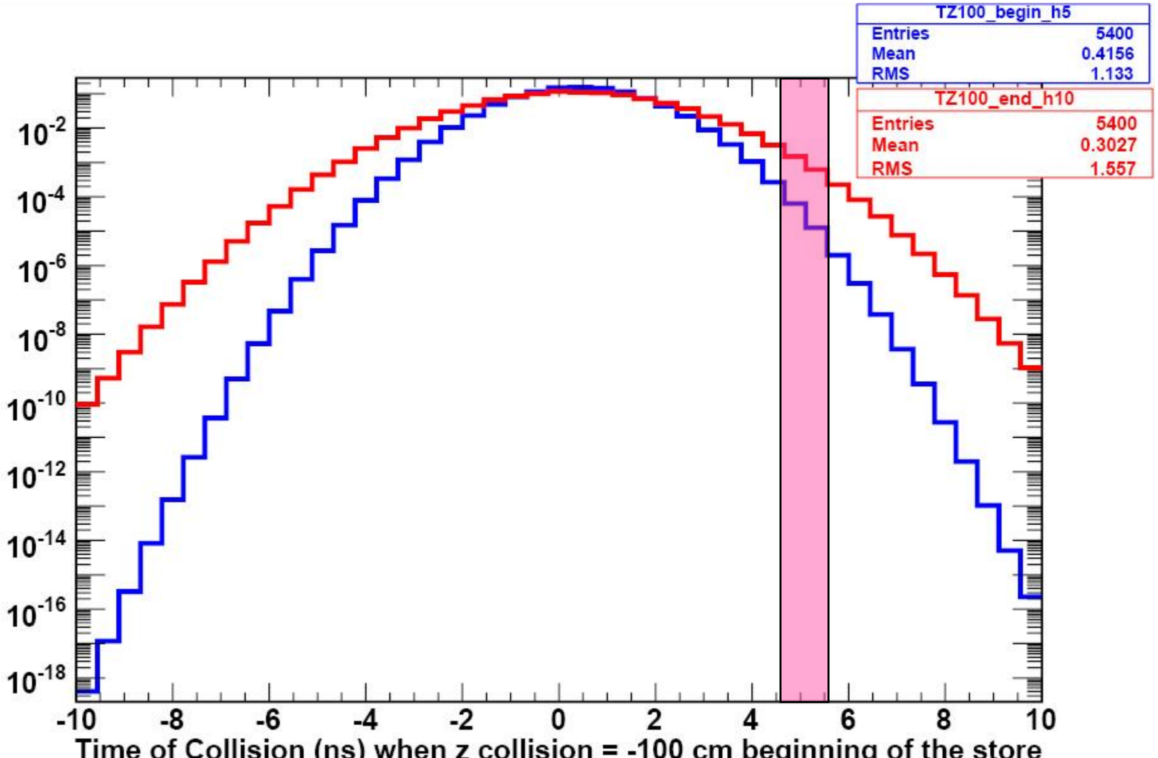
Two Important Effects:

1) The **slope gets smaller** over the course of the store

2) The **RMS of the Timing distribution gets larger** over the course of the store



Look at the timing distribution at Z collision ~ - 100 cm



When $Z_{collision}$ ~ -100 cm

$t_{collision}$ RMS = 1.13 ns
$t_{collision}$ Mean ~ 0.41 ns
at the Beginning of the Run

$t_{collision}$ RMS = 1.56 ns
$t_{collision}$ Mean ~ 0.30 ns
at the End of the Run

At Z = -100 we find the following:

1) The mean and RMS of the collision times change
2) The rate at t ~ 5 ns goes up by a factor of 100

Need to incorporate this into our MC to estimate it's full effect in producing large time gamma+met events

Collision Time & Z for Various Beam Scenarios

	START OF STORE					END OF STORE			
		σ_p = 1.7 ns	σ_A = 1.5 ns				σ_p = 2.5 ns	σ_A = 2.1 ns	
	Mean T [ns]	RMS T [ns]	Mean Z [cm]	RMS Z [cm]		Mean T [ns]	RMS T [ns]	Mean Z [cm]	RMS Z [cm]
nominal	0.00	1.13	0.00	23.1		0.00	1.62	0.00	29.2
beam loading	0.07	1.13	-0.35	23.1		0.07	1.62	-0.27	29.2
proton β* offset	-0.02	1.13	3.54	23.3		-0.03	1.62	4.26	29.4
both β* same offset	-0.02	1.13	5.34	23.3		-0.04	1.62	6.43	29.4
opposite β* offsets	-0.01	1.13	1.73	23.6		-0.01	1.62	2.10	29.8
different β* #1	0.00	1.13	0.00	23.1		0.00	1.62	0.00	29.2
different β* #2	0.00	1.13	0.00	24.0		0.00	1.62	0.00	30.4
pbar cog = -1 ns	0.53	1.13	7.03	23.6		0.56	1.62	5.38	29.6
uniform longitudinal	0.00	4.84	0.00	48.9					

nominal: equal β* = 28 cm at z = 0 cm, no longitudinal offsets

beam loading: Δ_P = -0.1 ns Δ_A = -0.05 ns (something typical for bunch 36)

proton β* offset: β*_z0 = + 10 cm for protons, 0 cm for pbars

both β* same offset: β*_z0 = + 10 cm for both protons and pbars

opposite β* offsets: β*_z0 = + 10 cm for protons and β*_z0 = -10 cm for pbars

different β* #1: β* = 25 cm for protons, 35cm for pbars

different β* #2: β* = 35 cm for protons, 25cm for pbars

pbar cog = -1 ns: Δ_A = -1 ns (unlikely)

uniform longitudinal: both bunches flat in z (completely unrealistic)

Studies have not turned up any other effects that have significant impact on the vertex and timing distributions

Slide taken from Ron Moore

Collision time, z fairly insensitive to realistic beam, optics changes

Conclusions / Next Steps

Conclusions

- The changing of the longitudinal profile is a real and significant effect that can have **major** impact on the final timing distribution
  - This is a qualitative (not quantitative) result right now…
- We have not been able to identify any additional effects that may have a contribution the vertex and timing distributions

Next Steps

- Incorporate these results into Monte Carlo and study their impact
- Working on writing a CDF note with all the details and background information
- We are continuing our work to reproduce the results from the preliminary Gamma+MET analysis

Back-Up Slides

Why do we care about Collision Distributions?

- We are performing a search in the Exclusive Photon+MET Channel and using timing information for the photons

What we are really interested in is the time of flight corrected time!

- The time of flight corrected time depends on getting the vertex right → this is true in any photon analysis…it is just worst for us since we are using **exclusive photon + MET**!
  - Thus we need to understand the collision distributions in both time and position
  - Understanding these distributions will allow us to understand the time distribution we expect for the Photon+MET sample

Toy Monte Carlo

Than we calculate a weighted collision position ($Z_{collision}$) and the timing of that collision (with t = 0 when $Z_{collision}$ = 0 cm)

$$Z_{Collision Position} = \sigma_{Longitudinal} \cdot Z$$

$$\sigma_{Longitudinal} = \frac{1}{1+\left(z\right)^2 / \beta^*} \exp\left(\frac{z^2}{2\sigma^2}\right)$$

We also take into account the "hour-glass" effect of focusing the beam and we use the nominal value for β*~ 28 cm

"Luminosity Distribution During Run II" M.Martens and P.Bagely

Monte Carlo

Comparing before and after inclusion of hourglass effect

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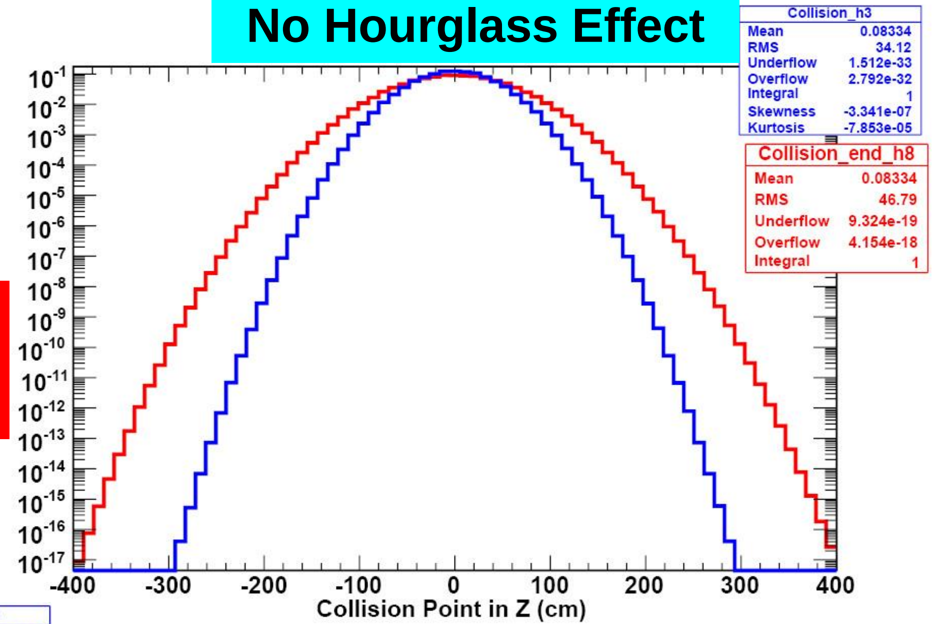
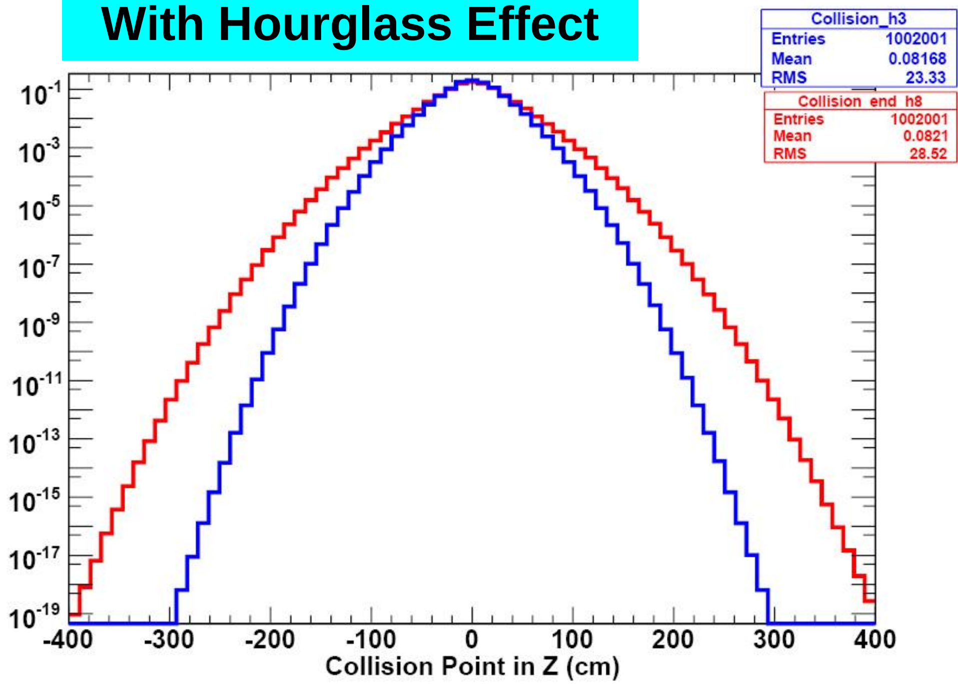


With Hourglass Effect



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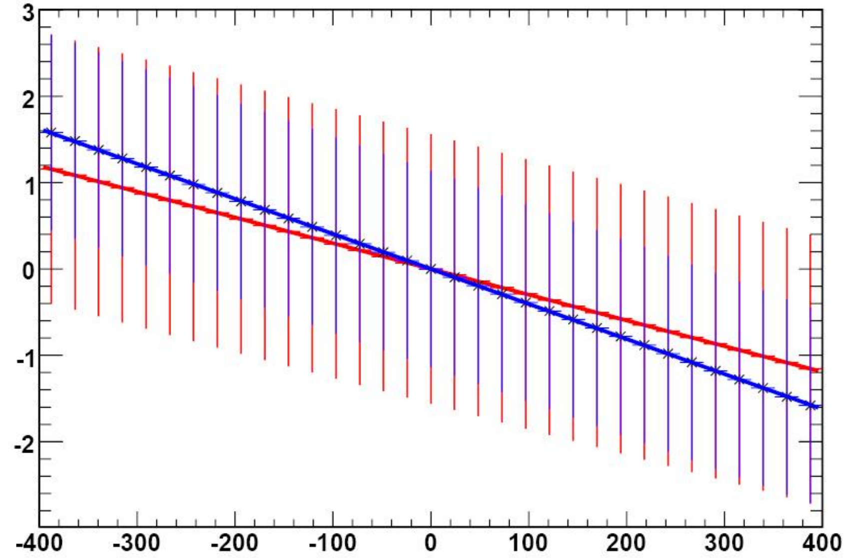
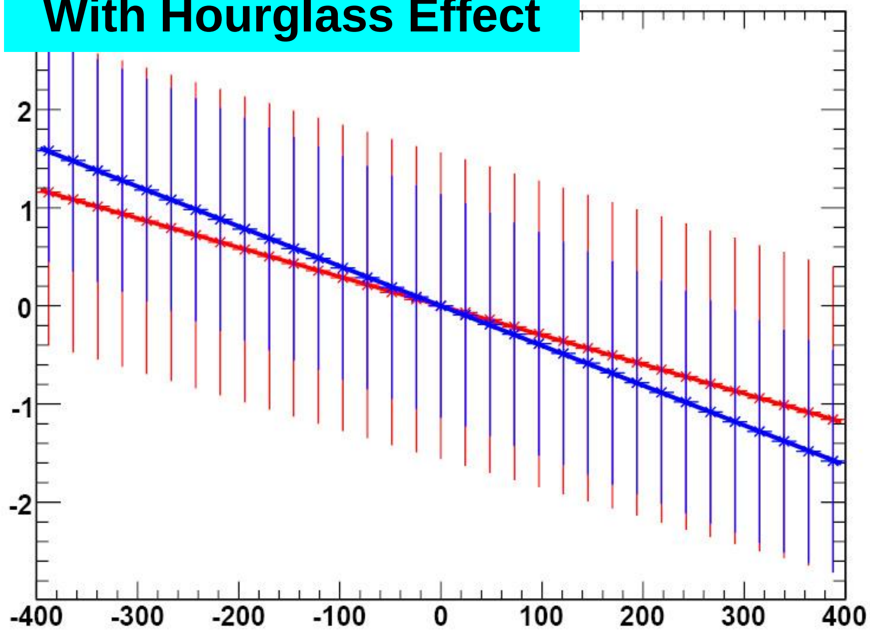


Begin
Fitting results
X-Intercept: 1.322115e-07
Slope: -4.056461e-03

End
Fitting results
X-Intercept: 2.222496e-06
Slope: -2.979712e-03

With Hourglass Effect



Begin
Fitting results
X-Intercept: 1.047204e-07
Slope: -4.053119e-03

End
Fitting results
X-Intercept: 2.031977e-06
Slope: -2.976038e-03

Toy Monte Carlo

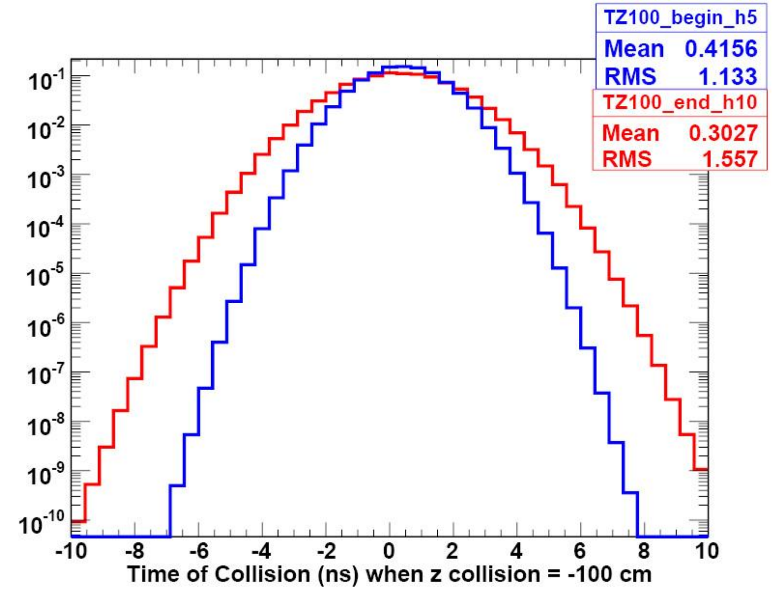
Comparing before and after inclusion of hourglass effect

When $Z_{collision}$ ~ -100 cm

$t_{collision}$ RMS = 1.133 ns
$t_{collision}$ Mean ~ 0.41 ns
at the Beginning of the Run

$t_{collision}$ RMS = 1.557 ns
$t_{collision}$ Mean ~ 0.3027 ns
at the End of the Run

No Hourglass Effect



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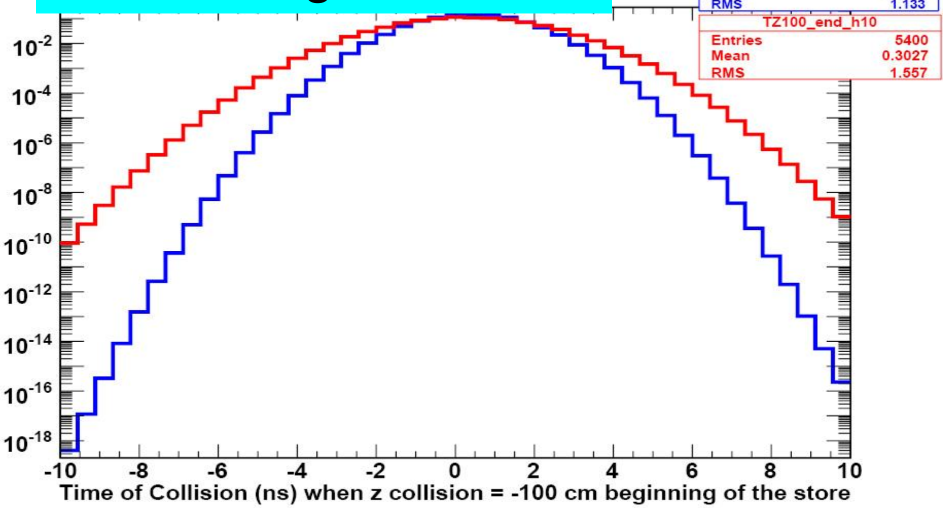
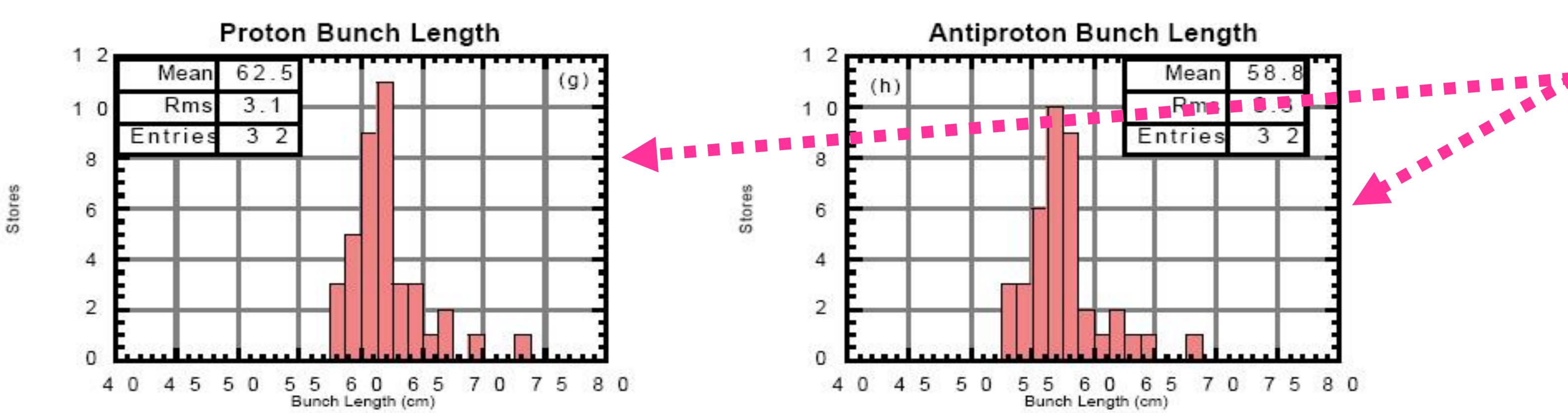


Some Interesting things we found out

Through discussions with experts we found out some factors about our beam that are not in our MC Simulation

1. The longitudinal profile for Protons and Anti-protons is not identical ***(this isn't modeled in our Monte Carlo…but we already knew that)***
2. The longitudinal profile get longer during the course of a run ***(WE DIDN'T KNOW THIS)***
   – As we will show this affects the RMS in $Z_{collision}$ as well as the correlation between time and $Z_{collision}$ (also not in MC)
3. This effects our understanding of what the true vertex time and Z distributions look like
   – Effects our estimates of what the timing distribution looks like when we pick the wrong vertex



Summary of Beam Parameters by store during Run I

Plots taken from: "Luminosity Distribution During Run II" M.Martens and P.Bagely