Di-electron Signal Significance at 62.4 GeV

Zvi

The Basic Idea

- Same method as previous estimate for 200 GeV running
  - MC to simulate HBD response to <pe>=22. (Response means double tagging efficiency and solo retention)
  - Use cocktail generated combinatorial background to measure background reduction due to HBD
  - Define the effective signal, i.e. the signal size with the same statistical significance as the actual data were there no background to subtract.
- Estimate the relationship between the number of events and the signal significance both relative to Run 4 full energy.

Two Big Differences

- HBD improves background rejection
- Lower energy means lower multiplicity - S~multiplicity but BKG~multiplicity^2

PHOBOS paper

PRL **102,** 142301 (2009) PHYSICAL REVIEW LETTERS week ending 10 APRIL 2009

TABLE I. The estimated number of nucleon participants, $\langle N_{\mathrm{part}} \rangle$, and the total charged particle multiplicity, $N_{\mathrm{ch}}^{\mathrm{tot}}$ for Cu + Cu collisions in different centrality bins are presented. All errors are systematic (90% C.L.).

	200 GeV		62.4 GeV		22.4 GeV	
Centrality (%)	$\langle N_{\mathrm{part}} \rangle$	$N_{\mathrm{ch}}^{\mathrm{tot}}$	$\langle N_{\mathrm{part}} \rangle$	$N_{\mathrm{ch}}^{\mathrm{tot}}$	$\langle N_{\mathrm{part}} \rangle$	$N_{\mathrm{ch}}^{\mathrm{tot}}$
0–3	106 ± 3	1541 ± 70	102 ± 3	833 ± 36	103 ± 3	535 ± 23

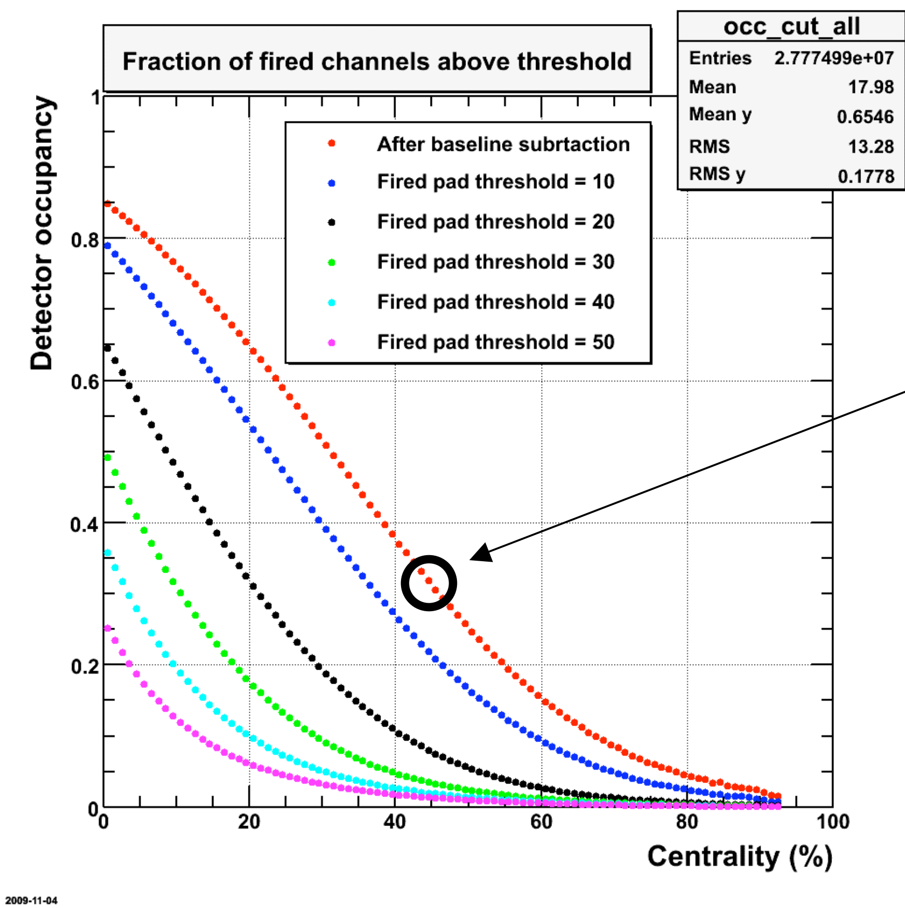
Use the ratio from most central CuCu to estimate how the multiplicity will scale (couldn't find AuAu data)
833/1541=54%

The HBD Side

•<pe>=22 most up to date number as far as I know

•Use simple three (and five) pad sum clustering not the modern methods

•Scintillation is negligible for both 3 and 5 pad sums



$$e^{<\gamma_{scint}>} = P(0) = 1 - occupancy$$

γ_{scint}=0.43 per pad @ 200 GeV so only .23 @ 62.4 GeV and irrelevant in this model

Define the Effective Signal in Run 4

$$\sigma_{Stat} = \sqrt{S + BG}$$

$$\sigma_{sys} = cBG$$

with $c = \sqrt{\sigma_{stat}(likeFG)^2 + \sigma(\mathrm{K})^2} \approx .25\%$

.12% .2%

$$\frac{1}{\sqrt{Se_{ff}}} = \frac{\sqrt{\sigma_{stat}{}^2 + \sigma_{sys}{}^2}}{S}$$

Equivalent sample size if there were no background

$$S_{eff} = \frac{S^2}{S + BG + c^2 BG^2} = \frac{S}{1 + \frac{BG}{S}(1 + c^2 BG)}$$

This is the quantity of merit for us.

HBD and Lower E Effect

HBD will introduce:

$$R = f \cdot \varepsilon \cdot \frac{BG}{BG^{HBD}}$$

With f the increase in stats, ε the electron pair efficiency, and R the reduction of the background.

$$BG^{62GeV} = \frac{f\varepsilon}{R} BG'$$

$$c^{HBD} = \sqrt{\frac{R}{f\varepsilon} 0.0144\% + 0.04\%}$$

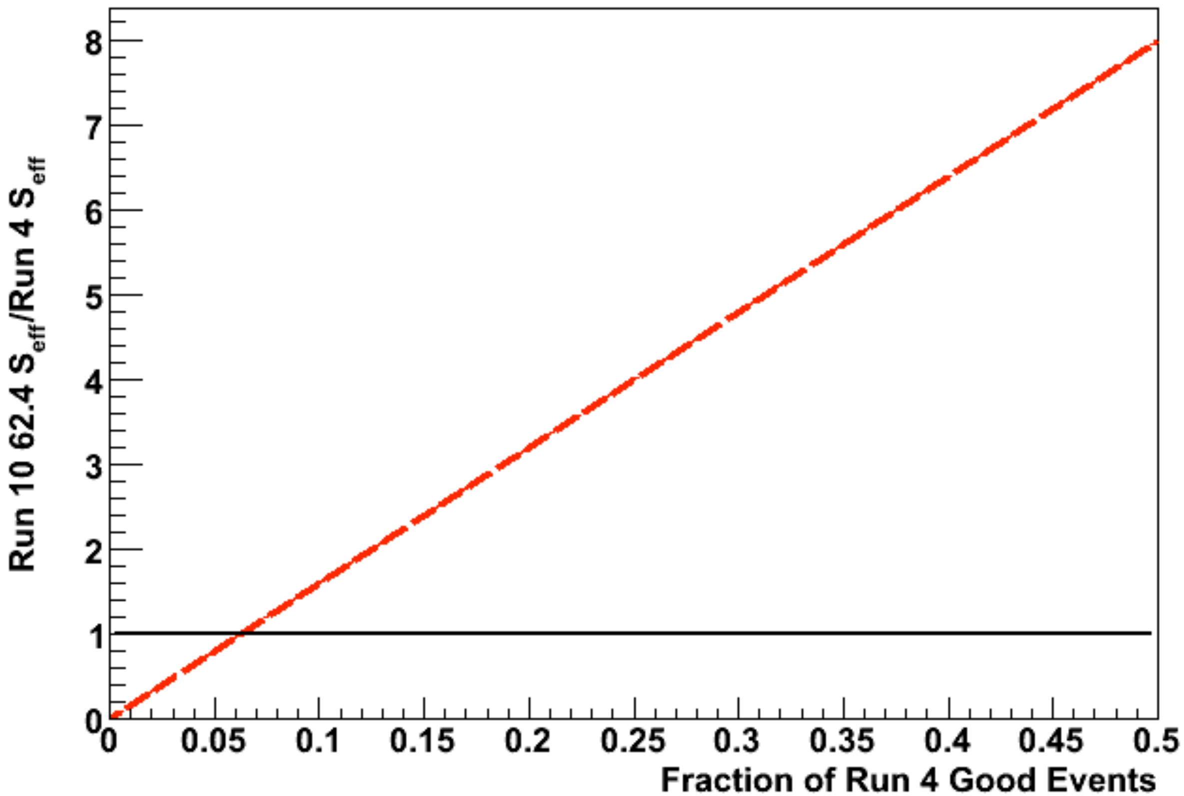
$$S^{62GeV} = FG^{62GeV} - BG^{62GeV} = f\varepsilon S'$$

$$\Rightarrow S_{eff}^{62GeV} = \frac{{S^{62GeV}}^2}{S^{62GeV} + BG^{62GeV} + {c^{HBD}}^2 {BG^{62GeV}}^2} = \frac{S' f\varepsilon}{1 + \frac{1}{R}\frac{BG'}{S'}(1 + {c^{HBD}}^2 \frac{f\varepsilon}{R} BG')}$$

Where BG'=0.54^2*BG and S'=0.54*S; R≈23, ε=0.64

In Run 4, in the bin between 430 and 550 MeV there were 311 signal counts with a signal to background ratio of 1:175.

Put It Together



We need about 6% of the number of Run 4 good events for the same signal significance.

Backups (talk from 7 April 2008)

Update on HBD Predictions

Zvi

Group Meeting 7 April 2008

What will the HBD do for errors in the dielectron continuum?

1. How does the <photo_electrons> affect the ability to distinguish single electron signals from double electron signals (the ones we want to reject)?
2. How does the above double electron tagging capability affect the background reduction?
3. How does the background reduction affect the significance of di-electron measurements?

To answer these questions…

1. Using a Monte Carlo simulate the HBD's response to solo and double electrons, for different <photo_electrons>.

   - For a given solo efficiency, E, what is the double tagging efficiency, ρ.

2. For a given ρ, find the reduction of the combinatorial background, R, using the cocktail to calculate the combinatorial background. Of course R will also depend on E and this should be corrected for, but I'll hold off on that until the next step.

3. Given E we can define the pair efficiency $\varepsilon = E^2$. For a given R and ε what is the improvement of the equivalent statistical significance (i.e. combined systematic and statistical significance) with a working HBD.

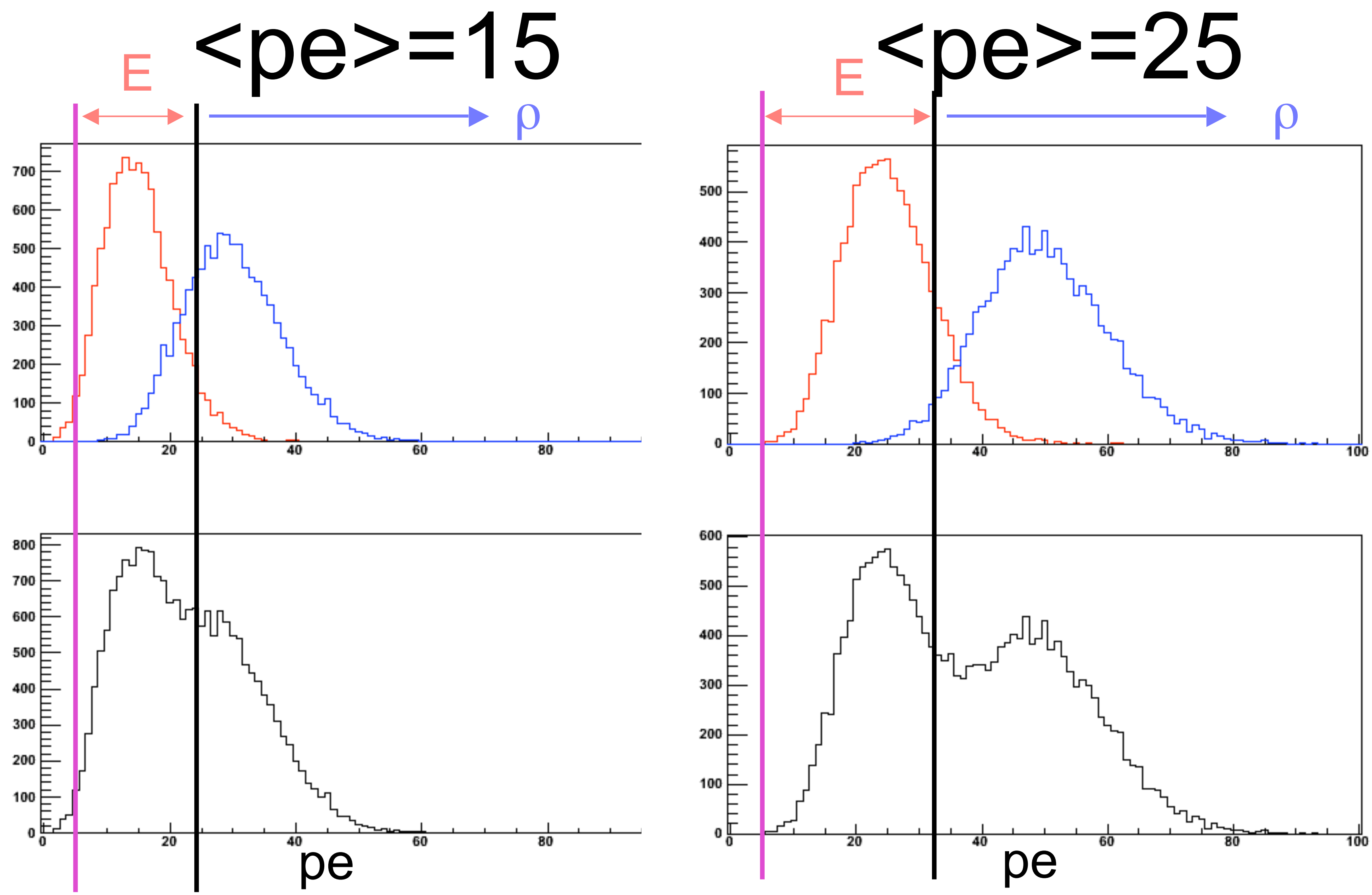
Singles vs Doubles in MC

To estimate the single and double response I used a simple MC which for an inputted <pe>:

• Calculates an actual number of pe via a random number from a Poisson distribution with a mean = <pe>

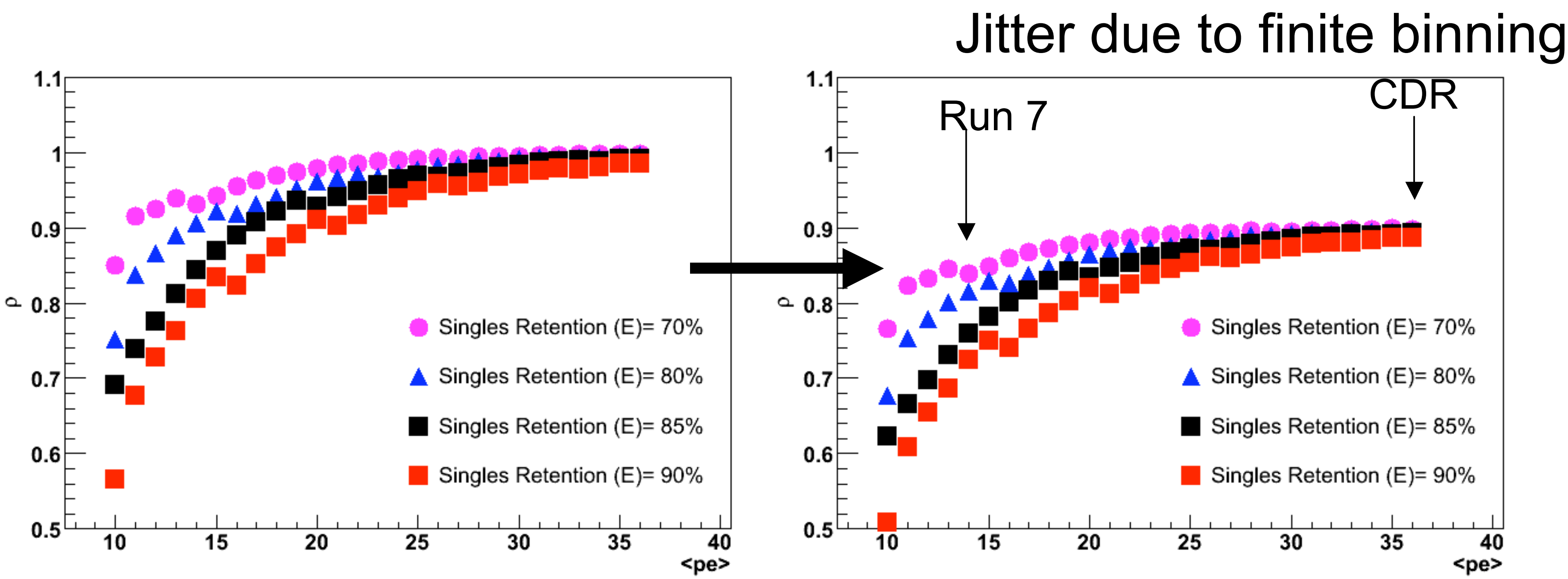
• For each pe calculates an avalanched signal size via a random number from an exponential distribution (centered around 1 to stay in units of pe)

•This values are summed to form the single signal and the same thing is done using a Poission with mean = 2<pe> for the doubles.



Cut is made on the total spectrum at 5 pe on the left, and at a fixed percentage of the singles on the right. E is the fraction of the solo spectrum accepted, ρ is the fraction of the double spectrum rejected.

Cut on Solo Spectrum



Scale the fraction of tagged doubles, ρ, by 90% and plot against <pe> (the input for each MC) on the x axis. Remember that ρ is not the quantity to be optimized because, our signal drops like the efficiency $\varepsilon=E^2$.

Background Estimation

•Estimate the combinatorial background using the cocktail.

•Usually the cocktail is used to simulated physics, i.e. particles that come from the same vertex are paired.

•Here I make random pairs to simulate combinatorial background (following Axel’s method from a few years ago).

•EXODUS generates electrons with kinematics, parent id, etc weighted appropriately.

•If the parent is a pion or an eta apply a rejection of 1- ρ

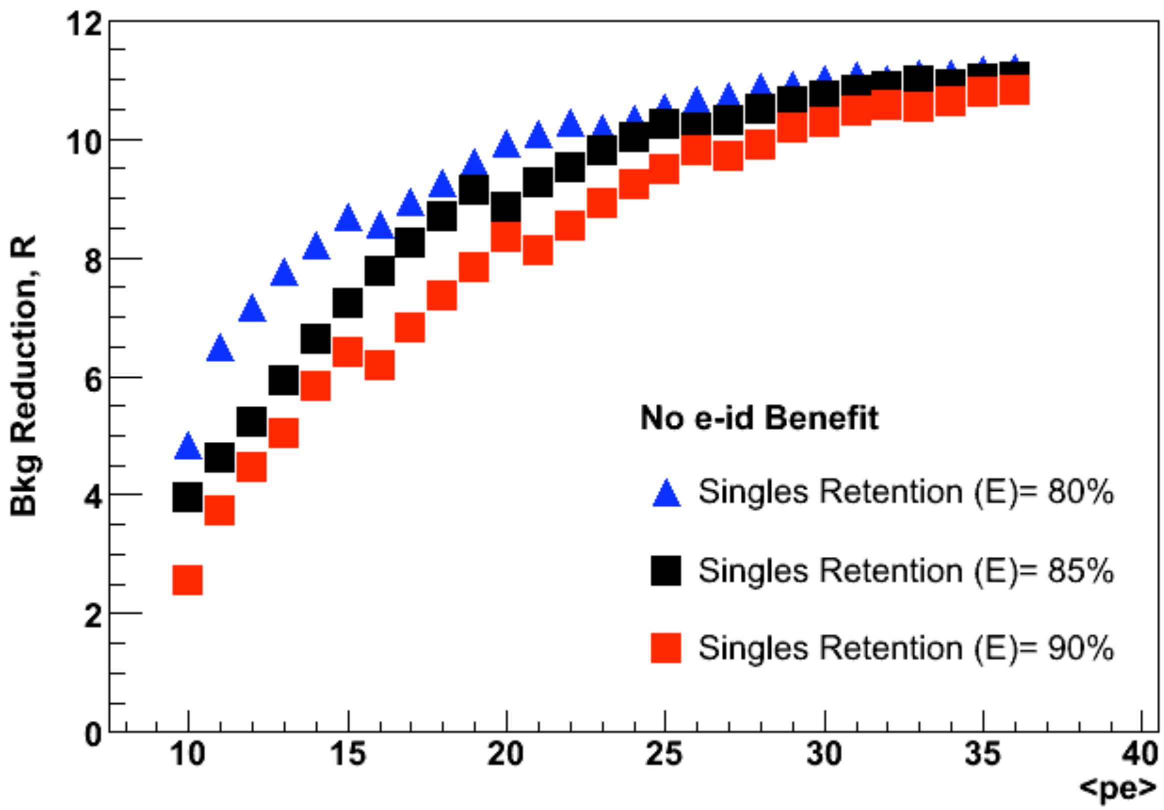
•Add in hadrons, charm, and then make pairs for the background.

•The ratio of the background without the HBD (ρ=0) to with it operating (ρ>0) is R.

A Slight Digression

- The combinatorial background from the cocktail is too low compared to Run 4 data.
- Some calculations for the Run 7 BUP attributed this difference to hadron contamination in the data.
    - In the best case the difference is indeed do to hadron contamination, and (almost) all of this contamination would be rejected by improved e-id using the HBD. This would improve the background reduction (R) by a factor of 2.29
    - In the worst case there would be no background reduction due to improved e-id.

Background reduction



But R(<pe>) is <u>not</u> the quantity of merit because of course it will improve as E decreases but our signal degrades. In the best case of improvement due to eid R->R * 2.29

Define the Effective Signal

$$\sigma_{Stat} = \sqrt{S + BG}$$

$$\sigma_{sys} = cBG$$

with $c = \sqrt{\sigma_{stat}(likeFG)^2 + \sigma(\mathrm{K})^2} \approx .25\%$

.12% .2%

$$\frac{1}{\sqrt{Se_{ff}}} = \frac{\sqrt{\sigma_{stat}{}^2 + \sigma_{sys}{}^2}}{S}$$

Equivalent sample size if there were no background

$$S_{eff} = \frac{S^2}{S + BG + c^2 BG^2} = \frac{S}{1 + \frac{BG}{S}(1 + c^2 BG)}$$

This is the quantity of merit for us.

HBD Effect

HBD will introduce:

$$R = f \cdot \varepsilon \cdot \frac{BG}{BG^{HBD}}$$

With f the increase in stats, ε the electron pair efficiency, and R the reduction of the background.

$$BG^{HBD} = \frac{f\varepsilon}{R} BG$$

$$c^{HBD} = \sqrt{\frac{R}{f\varepsilon} 0.0144\% + 0.04\%}$$

$$S^{HBD} = FG^{HBD} - BG^{HBD} = f\varepsilon S$$

$$\Rightarrow \quad S_{eff}^{HBD} = \frac{S^{HBD^2}}{S^{HBD} + BG^{HBD} + c^{HBD^2} BG^{HBD^2}} = \frac{Sf\varepsilon}{1 + \frac{1}{R}\frac{BG}{S}(1 + c^{HBD^2}\frac{f\varepsilon}{R} BG)}$$

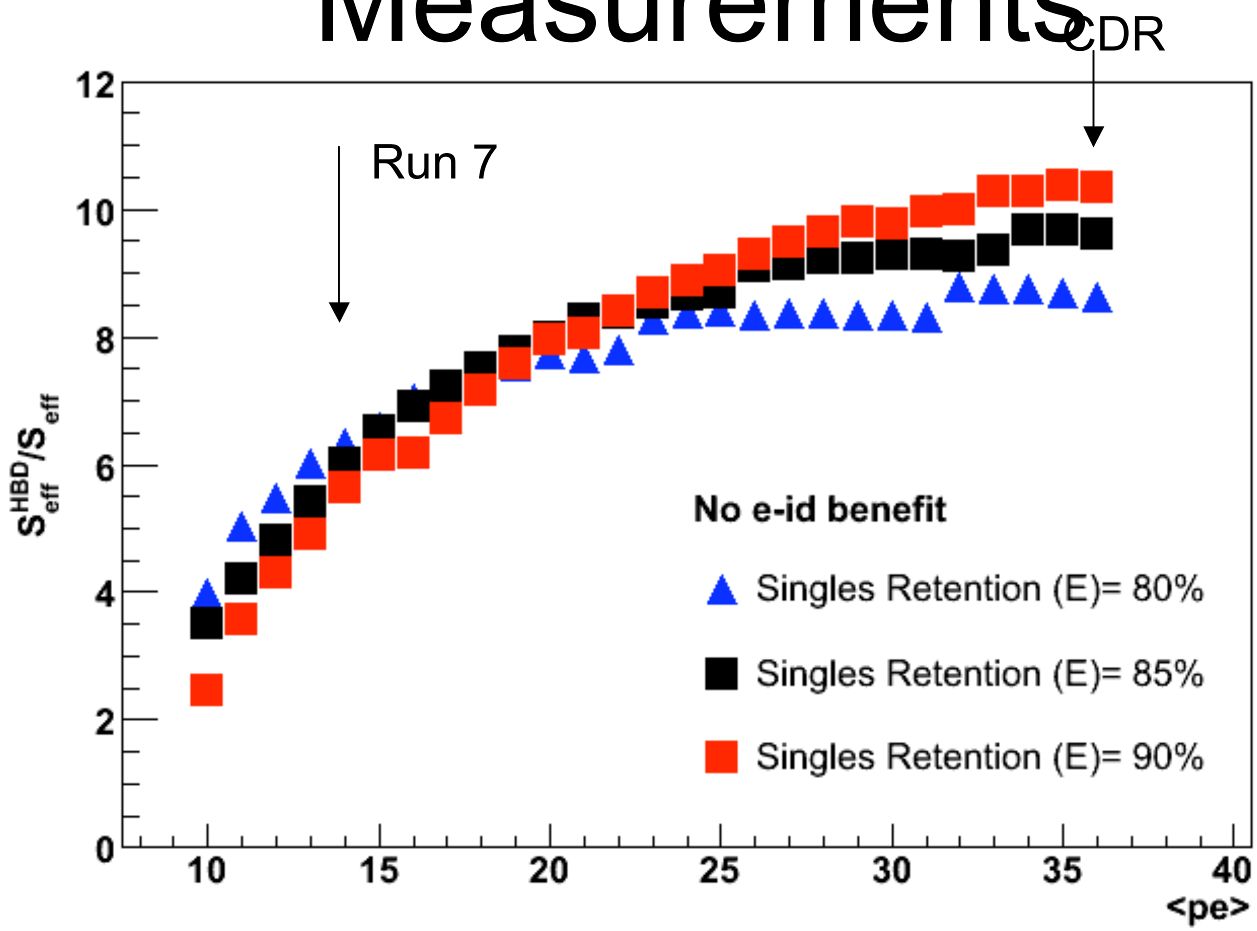
Measure of Improvement

$$\frac{S_{eff}^{HBD}}{S_{eff}} = \frac{1+\frac{BG}{S}(1+c^2 BG)}{1+\frac{1}{R}\frac{BG}{S}(1+c^{HBD^2}\frac{f\varepsilon}{R}BG)} \times f\varepsilon$$

The measure of improvement

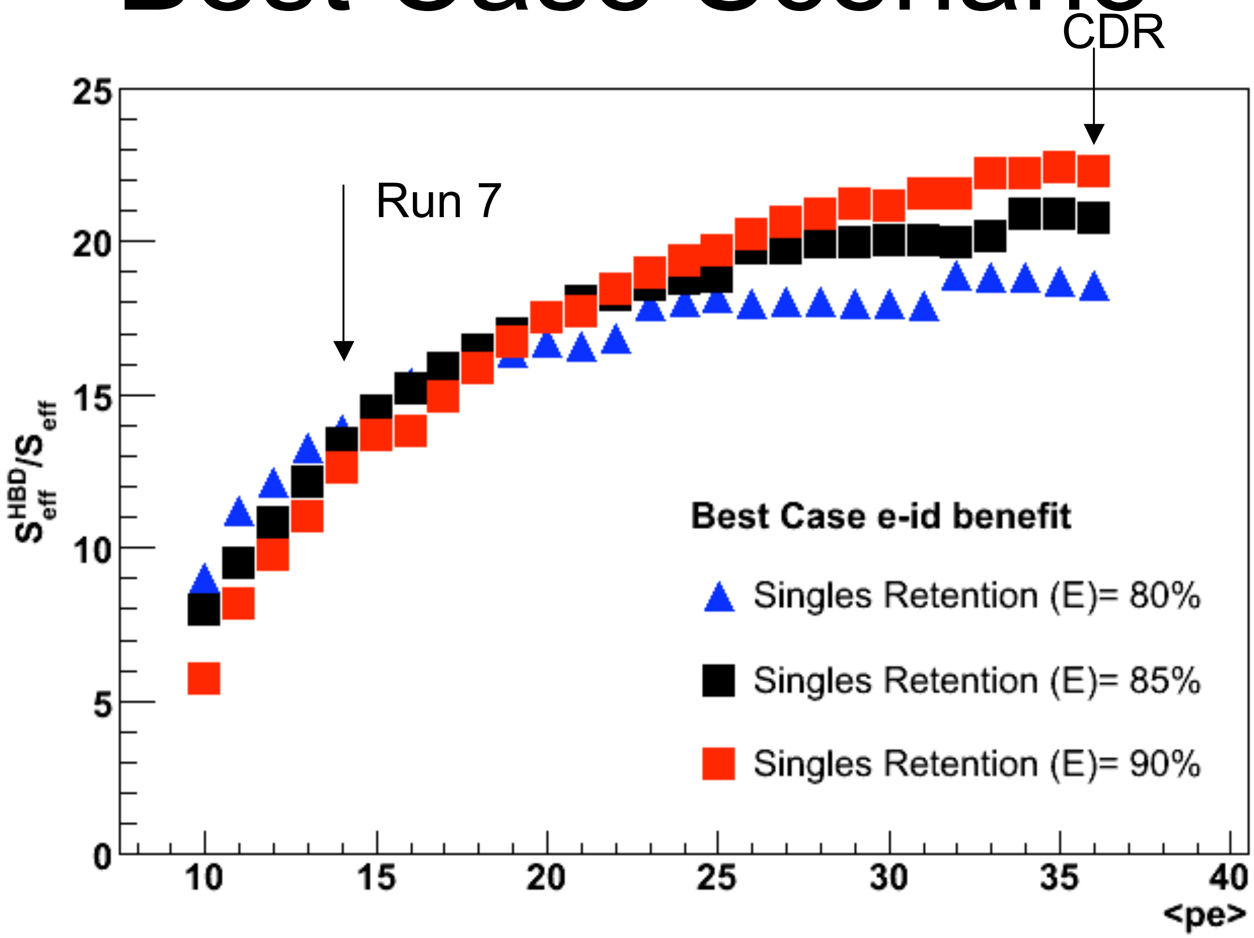
In Run 4, in the bin between 430 and 550 MeV there were 311 signal counts with a signal to background ratio of 1:175.

Improvement of Measurements



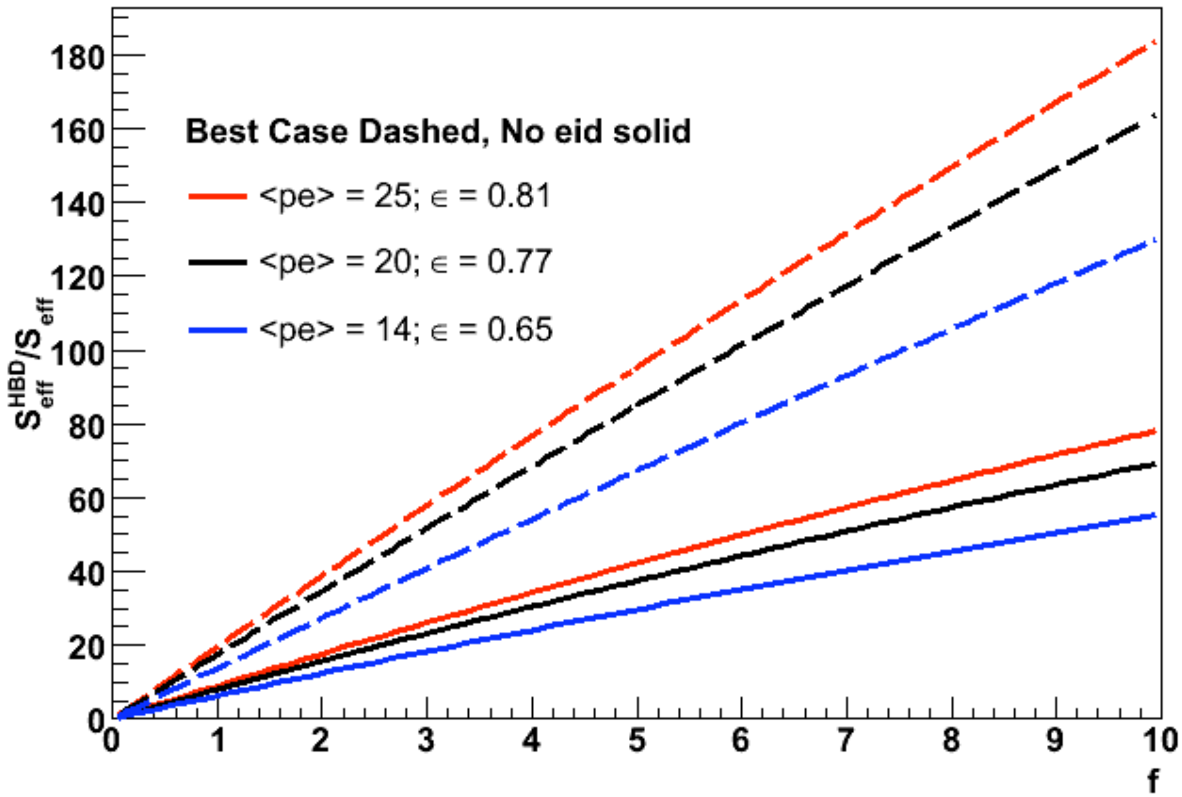
With a Run 4 sized data set (f=1)

Best Case Scenario



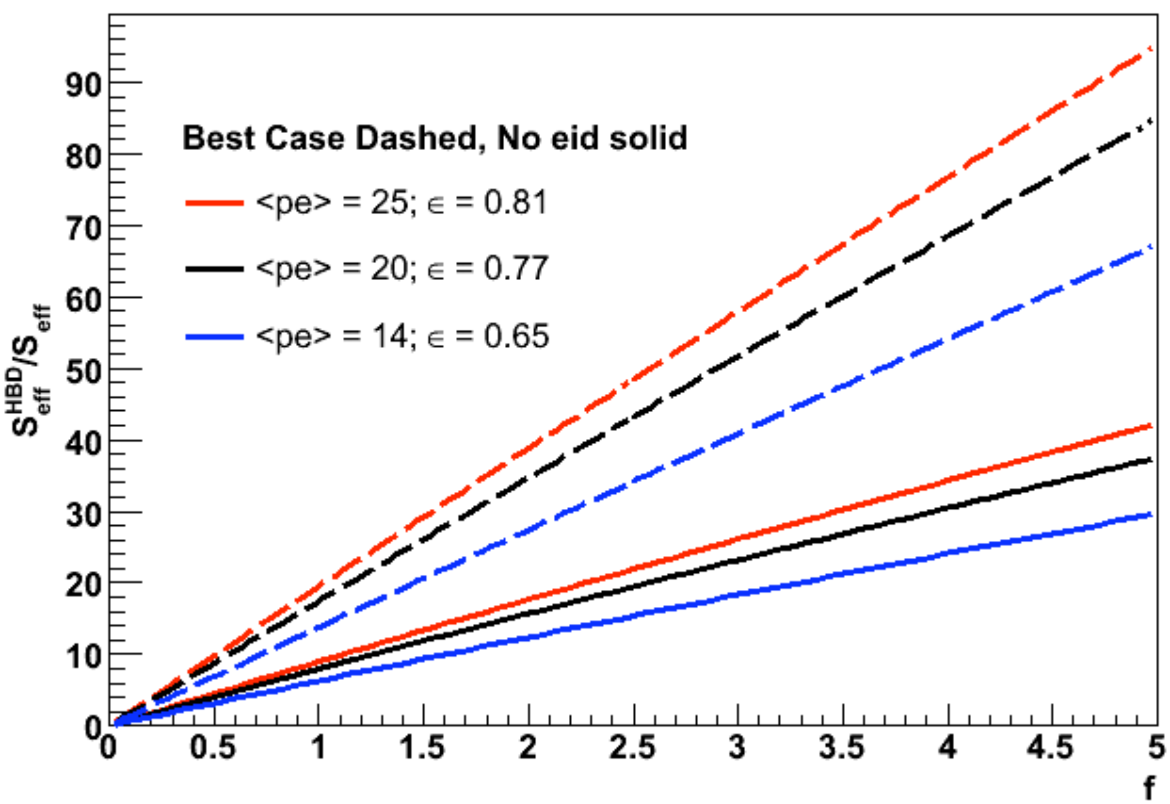
Best case: there was hadron contamination in Run 4 and the HBD gets rid of almost all of it. (Run 4 sized data set f=1)

Improvement with a larger data set



f is the increase in statistics compared to Run 4

Zoomed view of f dependence



Singles vs Doubles in MC with Scintillation

- Calculates an actual number of pe via a random number from a Poisson distribution with a mean = <pe>
- For each pe calculates an avalanched signal size via a random number from an exponential distribution (centered around 1 to stay in units of pe)
- This values are summed to form the single signal and the same thing is done using a Poisson with mean = 2<pe> for the doubles.
- Do the same thing for scintillation using a Poisson with mean <scint>= 1,1.5,2. Repeat 3 or 7 times for assumed clustering algorithim.
- Add the scintillation sum to the signals (solos and doubles).
- Subtract <scint> x 3 or 7 from the signals.

Improvement with scintillation