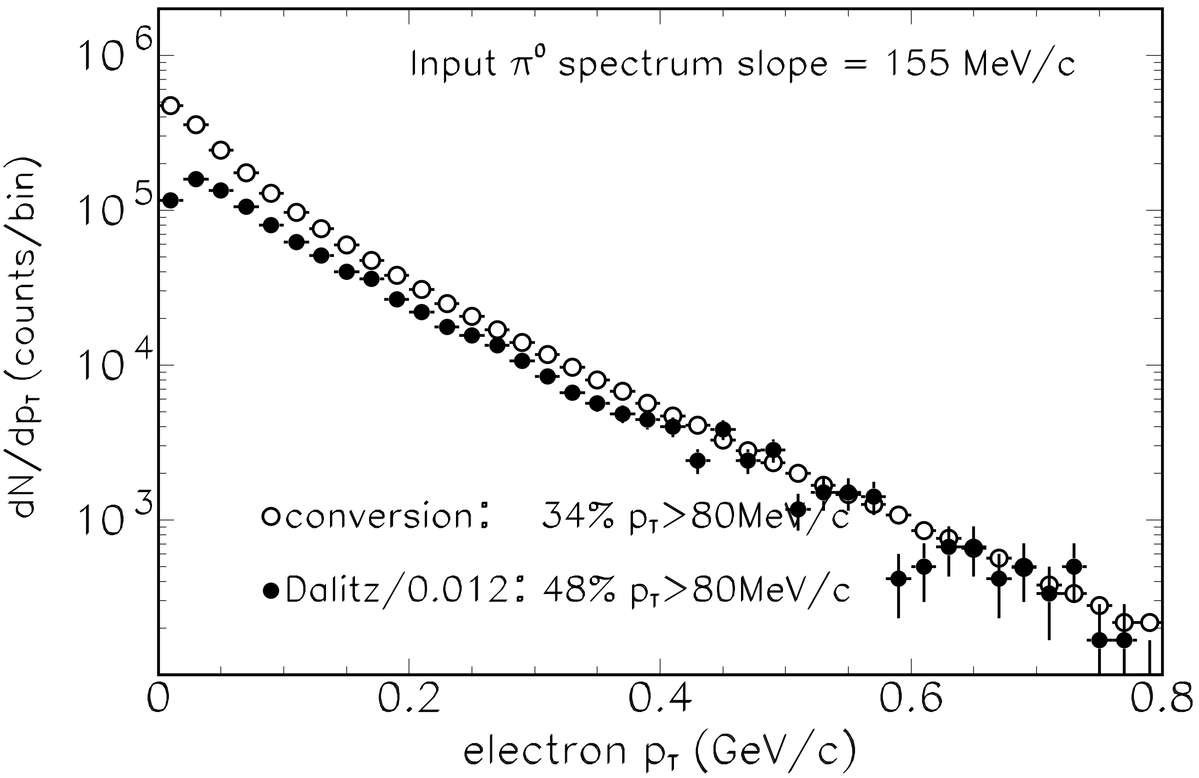
(Front and) "Back of the Envelope" Calculation of $e^{\pm}$ background Dalitz decays and pair production

It should be possible to do a "back of the envelope" calculation of the background in the electron arms of Phenix due to Dalitz decays of π^0's and pair production from the π^0 decay photons in the materials in the inner region — in particular the Be in the beam pipe and the Si in the MVD.



For central Au+Au collisions, dN/dy for π^0's at y=0 is about 450 (based on Hijet). Most π^0's (98.8%) decay into a pair of photons. Therefore, assume 2×450 photons per unit rapidity around y=0. From the number of radiation lengths of material in the path of these photons and the geometry of the detector arms, the number of conversion electrons (where "electrons" = electrons and positrons) headed towards the electron arms can be estimated.

Each electron arm covers $\Delta\eta \approx 0.7$ and $\Delta\phi \approx 90°$. From this, the approximate number of π^0 decay photons headed towards the electron arms is:

$$\frac{N(\gamma)}{event} \approx 2 \times \frac{dN}{dy}(\pi^0) \times \Delta\eta \times \frac{90°}{360°} \times 2arms = 2 \times 450 \times 0.70 \times 0.25 \times 2 = 315 \qquad (1)$$

The number of electrons produced by any material in the path of these photons is

$$\frac{N(e^{\pm})}{event} \approx \frac{N(\gamma)}{event} \times 2 \times \frac{dx}{X_0} \times \frac{7}{9} \times f_{pair}(p_{Tcut}) \qquad (2)$$

where dx is the thickness of the material, X_0 is the radiation length of the material, $f_{pair}(p_{Tcut})$ is the fraction of the produced particles above the p_T cutoff imposed by the magnetic field, and the factor of two is because each conversion produces both and electron and a positron. The factor of 7/9 connects the number of radiation lengths with the conversion probability. Electrons produced via pair production travel approximately in the direction of the photon which converted, so this expression gives the number of electrons headed in the direction of the electron arms. However, in Phenix, there is a magnetic field which prevents electrons with p_T less than $\approx$80 MeV/c from reaching the electrons arm.

Calculating the fraction of electrons above the 80 MeV/c cutoff is not a simple problem, so this portion of the problem has been done via Monte Carlo. Figure 1 shows the p_T distribution of electrons produced via pair production (open circles) from a Monte Carlo calculation. This calculation allowed 10^6 π^0's to decay. When the decay was into the dominant $\gamma\gamma$ channel, both photons were forced to produce an $e^{\pm}$ pair via pair production. The initial π^0 spectrum assumed $\frac{1}{p_T}\frac{dN}{dp_t} \propto \exp(\frac{-p_t}{155MeV/c})$ with a flat rapidity distribution. The 155MeV/c slope parameter was chosen to match the mean p_T (310MeV/c) of π^0's produced in a Hijet calculation for central Au+Au collisions. All of the initial π^0's were in the range $y = \pm 0.5$. Figure 1 also shows the p_T spectrum of electrons produced in Dalitz decay of the π^0. This will be discussed below.

In figure 1 shows that 27% of the electrons from pair production are above the 80 MeV/c p_T cutoff imposed by the spectrometer's magnetic field. Combining all of these numbers gives a prediction of the mean number of background electrons produced in the beam pipe ($dx/X_0 = 0.0028$) and in the inner Si layer of the MVD ($dx/X_0 = 0.0032$):
$N(e^{\pm})$/event from beam pipe $\approx 315 \times 2 \times 0.0028 \times (7/9) \times 0.34 = 0.34$,
$N(e^{\pm})$/event from inner Si layer $\approx 315 \times 2 \times 0.0032 \times (7/9) \times 0.34 = 0.47$
Because the MVD Si does not contribute when the vertex is outside of the MVD the expected background from the MVD Si should be reduced by an additional factor of ≈ 0.86 (from 0.53/event to 0.46/event). Full PISA calculations of these background rates gave $0.49 \pm .06$ electrons/event from the beam pipe and $0.56 \pm .06$ electrons/event from the inner Si layer of the MVD — higher by factors of 1.05$\pm$.13 and 1.22$\pm$.13, respectively, than the estimates. In the tables of background shown in the CDR update, the background rates from the beam pipe and MVD are slightly higher than the numbers quoted here because those calculations included additional background from sources other than π^0's.

The same "back of the envelope" calculation can be applied to Dalitz decay. The branching ratio for the decay $\pi^0 \rightarrow e^+e^-\gamma$ is 1.2%. The number of these Dalitz electrons headed towards the electron arms is approximately:

$$\begin{aligned} \frac{N(Dalitz)}{event} &\approx 2 \times \frac{dN}{dy}(\pi^0) \times 0.0012 \times \Delta\eta \times \frac{90^\circ}{360^\circ} \times 2arms \times f_{Dalitz}(p_{Tcut}) \\ &\approx 2 \times 450 \times 0.012 \times 0.70 \times 0.25 \times 2 \times 0.48 = 1.81 \end{aligned}$$

where $f_{Dalitz}(p_{Tcut}) = 0.48$ is the fraction of Dalitz decay electrons in fig. 1 (solid circles) which are above the 80 MeV/c p_T cutoff. The result of a full PISA calculation was 2.33$\pm$.12/event, a factor of 1.28$\pm$.07 larger.

All three estimates are slightly smaller than the results of the full PISA calculations.

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