Gamma-Hadron Separation Update

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Outline

Four New Gamma-Hadron Separation Variables

1. $CX_2 = \frac{nb2}{cxPE}$
2. $AX_3 = \frac{nTop \times nFit}{cxPE}$
3. $AX_4 = \frac{nOut \times nTop \times nFit}{cxPE}$
4. $AX_4P = \frac{nOut + nTop \times nFit}{cxPE}$

➢ Study MC, Proton MC, and Data distributions
➢ Study Efficiency and Q-Factor Distributions for the best cuts to be applied
➢ Study Energy Dependence on the Cuts
➢ Test Cuts on 416 Days of Crab Data (97 Days of Total Integration Time)
➢ Test New Cuts on the New Crab Data (tPed Adjusted)
➢ Conclusions
Cuts for $AX_4$ & $CX_2$

- $AX_4 \geq 10^5$ & $CX_2 \geq 4.28$ & nFit $\geq 80$:
  
  Reject 99.73% of Proton MC, 99.79% of Data, keep 13.88% MC

  $\Rightarrow Q = 2.65 \Rightarrow 2.65/1.62 = 1.64$ Improvement in Q-Factor

- Energy Dependence on the Cuts:
  
  - Efficiency of Gamma MC is dependent on the energy of the primary particle ($E_P$)
  
  - For Proton MC the Efficiency is nearly independent on $E_P$
  
  - Gamma-Ray showers with $E_P < \sim 1$ TeV will not be observed with these cuts
  
  - Mean for Gamma-Ray showers is $\sim 17$ TeV
Test of AX4 & CX2 Cuts on the Crab

416 Solar Days of Crab Data
(97 Days of Total Integration time)

4.0 square bin

Fractional Excess increased from 0.6% to 7.0%

We need $1.4^{0.5} = 0.5$ the time required by the $X_2$ cut to observe the same source with the same significance.

Significance increased from 3.64 to 5.05, a factor of 1.4.

Compare to $X_2 \geq 2.5$ & $p_{fit} \geq 20$:

$\chi^2_{red} = 10.8$ & $p_{fit} = 0.008$ for AX4

$\chi^2_{red} = 2.8$ & $p_{fit} = 0.008$ for CX2

Fractional Excess increased from 0.6% to 7.0%
$AX_4P = (nOut + nTop) \times (nFit/cxPE)$
Cuts for $AX_4P$

- $AX_4P \geq 3000 \& nFit \geq 80$:
  
  Reject 99.35% of Proton MC, 99.68% of Data, keep 19.61% MC

  $\rightarrow Q = 2.44 \rightarrow 2.44/1.62 = 1.51$ Improvement in Q-Factor

- Energy Dependence on the Cuts:
  
  - Efficiency of Gamma MC is dependent on the energy of the primary particle ($E_P$)
  
  - For Proton MC the Efficiency is nearly independent on $E_P$
  
  - Gamma-Ray showres with $E_P \sim 100$ GeV can still be detected but with very low efficiency $\sim 0.1\%$
  
  - Mean for Gamma-Ray showers is $\sim 19$ TeV
Test of AX₄P Cut on the Crab

- 416 Solar Days of Crab Data (97 Days of Total Integration time)
- 1.3° square bin
- Compare to $X_2 \geq 2.5$ & $n\text{Fit} \geq 20$
  - Significance increased from 3.64 to 4.74, a factor of 1.3
  - We need $1.3^{-0.5} = 0.6$ the time required by the $X_2$ cut to observe the same source with the same significance
  - Fractional Excess increased from 0.6% to 5.0%
\[ AX_3 = \frac{(n\text{Top} \times n\text{Fit})}{cx\text{PE}} \]
Cuts for $AX_3$

- $AX_4P \geq 3000$ & nFit $\geq 80$:
  
  Reject 99.7% of Proton MC, 99.86% of Data, keep 14.9% MC
  
  $\rightarrow Q = 2.72 \rightarrow 2.72/1.62 = 1.68$ Improvement in Q-Factor

Energy Dependence on the Cuts:

- Efficiency of Gamma MC is dependent on the energy of the primary particle ($E_P$)
- For Proton MC the Efficiency is nearly independent on $E_P$
- Gamma-Ray showers with $E_P \sim 100$ GeV can still be detected but with very low efficiency $\sim 0.1$
- Mean for Gamma-Ray showers is $\sim 21$TeV
Test of AX₃ Cut on the Crab

- 416 Solar Days of Crab Data (97 Days of Total Integration time)
- 1.3° square bin

- Compare to $X_2 \geq 2.5$ & nFit $\geq 20$:
  - Significance increased form 3.64 to 4.58, a factor of 1.26
  - We need $1.26^{0.5} = 0.63$ the time required by the $X_2$ cut to observe the same source with the same significance
  - Fractional Excess increased from 0.6% to 7.1%
Test of Cuts on the New Crab Data (tPed Adjusted)

- Used same Bin Size of 1.3° Square Bin

- For AX_4:
  - Significance Decreased from 5.05 to 4.82
  - Fractional Excess increased from 7.0% to 13.6%

- For AX_4P:
  - Significance Decreased from 4.74 to 3.92
  - Fractional Excess increased from 5.0% to 19.6%

- For AX_3:
  - Significance Decreased from 4.58 to 4.29
  - Fractional Excess increased from 7.1% to 42.5%

- The Decrease in the Significance is due to the different Fitter used.
  - These cuts were optimized for a three layer fitter, the Crab data with the tPed shift were reconstructed with a two layer fitter (Airshower and Outrigger)
  - May have to reoptimize my cuts with the two layer fitter
Conclusions

- We have four new variables that give us the following advantages over $X_2$:

  1. Increase in **Q-Factor** by a factor of 1.5 - 1.7
  2. Increase in **Significance** on the Crab by a factor of 1.3 - 1.4
  3. Increase in **Fractional Excess** on the Crab by a factor of 8 – 12 !!
  4. We can see a Crab-Like source with ~ 0.5 the time required by $X_2$

- **Disadvantage of the new variables:**
  - Have low detection efficiency for low energy gamma ($E_p < 1$TeV)

- **Actions to be taken by the collaboration:**
  - At least one of these variables should go online
  - Read my memo and comment on it :)
