DVCS collaboration meeting
January 26th 2018
Calorimeter analysis update
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$\pi^0$ calibration
**π⁰ calibration**

- Done for all kinematics (Fall 2014, Spring 2016, Fall 2016)

- Issue: loss of gain sometime too fast for π⁰ calibration (usually: after long down time, or at the start of a run period)
**π⁰ calibration**

- Linear interpolation/extrapolation: did not work
- Exponential fit: did not work (Later realized I made a mistake in my formula. Might have worked.)
- Empirical correction:
  - **Approximation**: loss of gain similar for all (most of) the blocks
  - → Variation of π⁰ invariant mass proportional to the variation of π⁰ calibration coefficients
  - → **Correction run by run of π⁰ calibration coefficients** by a factor \( \frac{0.134977 \text{ GeV}}{\text{reconstructed π⁰ mass}} \)

SQL DB updated (France & Jlab)
\( \pi^0 \) contamination subtraction
• DVMP event: $e p \rightarrow e p \pi^0$
• $\pi^0 \rightarrow \gamma \gamma$
• If 1 single $\gamma$ is detected in the calorimeter: looks like a DVCS event $e p \rightarrow e p \gamma$
• Missing mass can be compatible with DVCS if missed $\gamma$ had low energy
• Contamination must be removed
principle

- Real data: $ep \rightarrow ep\pi^0$ events identification: 2 $\gamma$ in the calorimeter & invariant mass compatible with $\pi^0$
- For each detected $\pi^0$: simulation of 5000 decays $\pi^0 \rightarrow \gamma\gamma$ (Monte-Carlo generates random $\gamma$ directions and energies, projections on calorimeter surface)
- Check if $\gamma$ are detected (Energy threshold, geometrical cuts) $\Rightarrow 0\gamma - 1\gamma - 2\gamma$ cases
- Estimation of the proportion of simulated decays where a single $\gamma$ is detected
- $\Rightarrow \pi^0$ contamination
Description of the subtraction process

• Code basis from Camille Desnault

• Step 1 : From real data, $\pi^0$ identification
  • Reads rootfiles after clustering (ana.C).
  • Look at ntuple ntu2 : 2 clusters in the calorimeter
  • Select $\pi^0$ with “Cut1” :
    • Energy threshold cuts on both clusters : run by run and block by block :
      \[ \text{TriggerSim} \ast \pi^0 \text{coefficients} \ast \alpha \]
      \[ \alpha = 1 \quad \alpha = \frac{\text{elas}\_\text{coe}_2\_\text{same}_\text{HV}}{\text{elas}\_\text{coe}_1} \quad \alpha = 1 \]
      \[
      \begin{array}{|c|c|c|}
        \hline
        \text{Elastic coefficients 1} & \text{Elastic coefficients 2}\_\text{same}_\text{HV} & \text{Elastic coefficients 2}\_\text{new}_\text{HV} \\
        \hline
      \end{array}
      \]
    • Geometrical cuts : removed edges of the calorimeter (3 cm (= 1 block)):
      - $-21 \text{cm} < x_c < 12 \text{cm}$
      - $-21 \text{cm} < y_c < 21 \text{cm}$
    • $\pi^0$ invariant mass cut : fitted $\pi^0$ invariant mass for a few runs of the kinematic, cut at $\pm 3\sigma$. 
Description of the subtraction process

• Step 2 : For each identified $\pi^0$ : Monte-Carlo simulation of 5000 decays $\pi^0 \rightarrow \gamma\gamma$
  • Decay in the $\pi^0$ center of mass frame : polar angles $\theta$ and $\phi$ generated uniformly : $\theta$ between 0 and $\pi$, $\phi$ between 0 and $2\pi$. Each $\gamma$ has the energy $E_{\pi}/2$.
  • Lorentz boost along the $\pi^0$ momentum
  • Projection on the calorimeter (+ shower depth correction)
    • Code basis from Malek Mazouz
  • Check if $\gamma$ detected : same as “Cut1”
    • Count the number of cases where $0 – 1 – 2 \gamma$ are detected : $N_{0\gamma}$, $N_{1\gamma}$, $N_{2\gamma}$ out of the 5000 decays
  • For each $\pi^0$, save $N_{0\gamma}$, $N_{1\gamma}$, $N_{2\gamma}$ and $1\gamma$ case as if real DVCS data (cf. ana.C)
Description of the subtraction process

• Step 3 : Subtraction.
  • Simulated data from the $\pi^0$ subtraction process must be normalized by $\frac{1}{5000} \cdot \frac{1}{N_{2\gamma}} = \frac{1}{N_{2\gamma}}$.
  • “Cut2” : same cuts must be applied to real data and simulated subtraction data.
    • Energy threshold (preliminary : clustering energy threshold)
    • Geometrical cuts : An “octagonal” cut must be applied to account for inefficiencies of the subtraction method in the corners (to be determined)
    • Other cuts can be added…
Method checking against Monte-Carlo

- **Goal**: reproduce the efficiency plot from Maxime Defurne’s thesis to check the subtraction results against simulation.
- **Used Maxime Defurne’s thesis Monte Carlo simulation**:
  - Generates $\pi^0$ uniformly (polar angles + energy) & simulates a decay & projection on the calorimeter
  - Ran $\pi^0$ subtraction on 2-$\gamma$ events & compared results to 1-$\gamma$ events

\[ \pi^0 \text{ subtraction efficiency, for kin48_2 (run 13000)} \]
\[ (\text{with cut } M_{x^2} < 1.35 \text{ GeV}) \]
Method checking against Geant4

- Used Geant4 simulation from Rafayel (pi0_2010/no_esmear)
  - Modification to save 1-cluster events too
  - Tested a 12 GeV kinematic (run 220 ~kin48_2)
  - Tested a 6 GeV kinematic (run 9124, kin3high)
- GOOD

\[ \pi^0 \text{ subtraction efficiency, for } \sim \text{kin48}_2 \text{ (run 220)} \]
\[ \text{(with cut } M_x^2 < 1.2 \text{ GeV)} \]

\[ \pi^0 \text{ subtraction efficiency, for kin3high (run 9124)} \]
• Discussion on Cut1 geometrical cut: Do we cut the edges of the calorimeter (3cm) or not?
  • Pros: $\gamma$ energy reconstruction on the edges of the calorimeter is biased by energy leaks.
  • Cons: In the simulation, 2-$\gamma$ events can be mistaken for 1-$\gamma$ events

Real data:
1. 2 clusters detected: 2-$\gamma$ event
2. During data analysis: 1 $\gamma$ is on the edge of the calorimeter: whole event discarded.
3. Final situation: no $\pi^0$ contamination, no event kept

Simulated subtraction data:
1. 2 clusters: should be a 2-$\gamma$ event
2. But 1 $\gamma$ is on the edge of the calorimeter: $\gamma$ discarded. But the other $\gamma$ is kept.
3. Final situation: 1-$\gamma$ event, counted as a contaminating $\pi^0$ event
4. Cannot discard both $\gamma$ and count a 0-$\gamma$ event: false
5. Cannot discard whole event as if did not exist either.

• Estimation from data: 1/3 of $\pi^0$ events are in this situation
• If cut $Mx^2 < 1.35$ GeV: 0.5% only. Error seems acceptable.
Octagonal cut

- Proposition for all kinematics:
  \[
  \begin{align*}
  y_c &\leq 20 \\
  y_c &\geq -20 \\
  x_c &\leq 11 \\
  x_c &\geq -20 \\
  y_c - x_c &\leq 33 \\
  y_c + x_c &\leq 24 \\
  y_c + x_c &\geq -33 \\
  y_c - x_c &\geq -24
  \end{align*}
  \]

\( \pi^0 \) subtraction efficiency, for run 12508 (kin48_1)

\( \pi^0 \) subtraction efficiency, for run 13000 (kin48_2)
Octagonal cut

$\pi^0$ subtraction efficiency, for run 12508 (kin48_1)

$\pi^0$ subtraction efficiency, for run 12838 (kin48_3)

$\pi^0$ subtraction efficiency, for run 13000 (kin48_2)

$\pi^0$ subtraction efficiency, for run 13100 (kin48_4)

Geant4 issue?
Octagonal cut

\[ \pi^0 \text{ subtraction efficiency, for run 14150 (kin36_2)} \]

\[ \pi^0 \text{ subtraction efficiency, for run 14476 (kin36_3)} \]

\[ \pi^0 \text{ subtraction efficiency, for run 14270 (kin60_1)} \]

\[ \pi^0 \text{ subtraction efficiency, for run 14528 (kin60_3)} \]
Octagonal cut

\[ \pi^0 \]

subtraction efficiency, for run 10553 (kin36_1)

Geant4 issue?
Geant4 issue with kin36_1, kin36_3 and kin48_4

Geant4 simulation (1 single photon detected case) for kin36_1 (top left) kin48_4 (top right) and kin36_3 (bottom left) :
Photons position yc:xc in the calorimeter

Coverage issue ?

Calorimeter angle / distance :
kin36_1 : 11.3 deg / 164 cm : small angle & distance combo ?
kin48_4 : 9.87 deg / 250 cm : smallest angle ?
kin36_3 : 10.46 deg / 250 cm : small angle ?
Conclusion : status and outlook

• $\pi^0$ calibration complete + SQL DB updated (France & Jlab)
• $\pi^0$ subtraction method validated with Maxime Defurne’s Monte-Carlo simulation and Geant4 simulation
• $\pi^0$ subtraction done for all 12 GeV data (Fall 2014, Spring 2016, Fall 2016).
  • Subtraction rootfiles are available in France and can be copied at Jlab.

• TODO list (in progress) :
  • Define/choose octagonal cuts for every kinematics
  • Identify & Fix Geant4 calorimeter coverage issue for kin36_1 and kin48_4
    • hypothesis : generation phase space too small

• NEXT :
  • Accidentals subtraction (fast)
  • Geant4 & Monte Carlo simulation (acceptance): missing mass calibration + smearing
  • Cross-sections extraction