CLAS Collaboration Meeting

18-21 June, 2019

A Charged Particle Veto in the Central Detector Using Only CND and CTOF

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for the CLAS Collaboration

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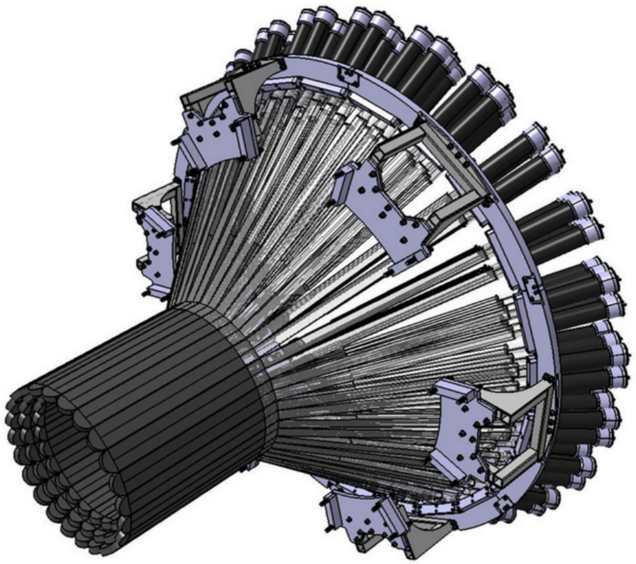
Overview

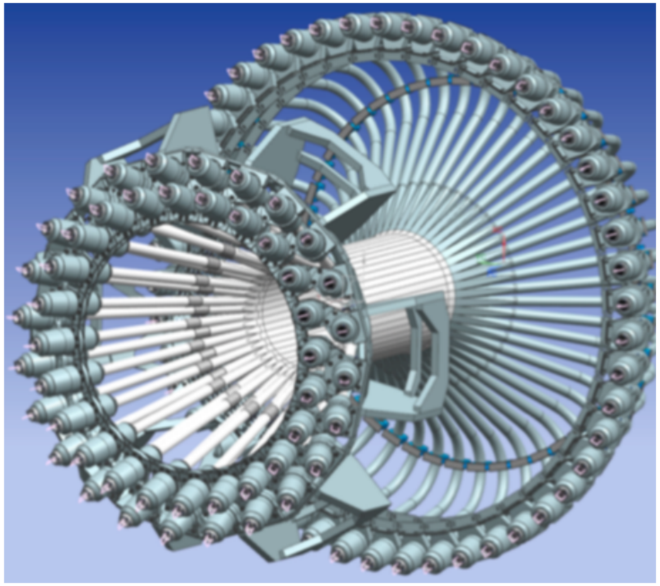
- Background and Motivation
- Development and Evolution
- Results
- Implementation
- Further Ideas and Considerations

Background



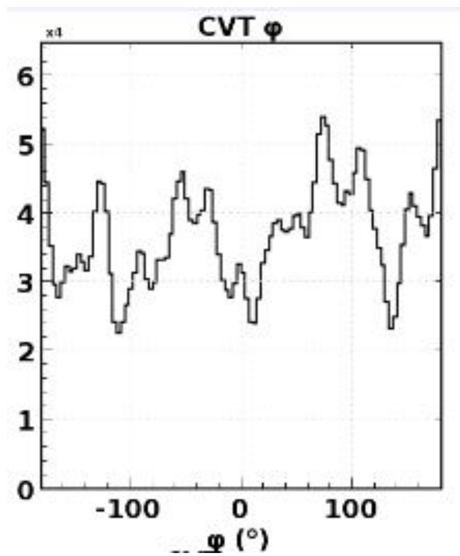
Central Neutron Detector
Plastic scintillator
3 radial layers, total ~10 cm
Angular coverage 40° < θ <120°
Azimuthal coverage 2π
Neutron detection efficiency ~10%

Central Time-of-Flight Detector
Plastic scintillator
~3 cm thick
Angular coverage 35° < θ <125°
Azimuthal coverage 2π
Potential neutron detection efficiency ~3%



Motivation

- Tracking in the CVT is neither 100% efficient nor uniform
  - → CND sees charged particle contamination



- Can an effective charged particle veto be constructed using only CTOF and CND? *(spoiler: yes!)*

Development and Evolution

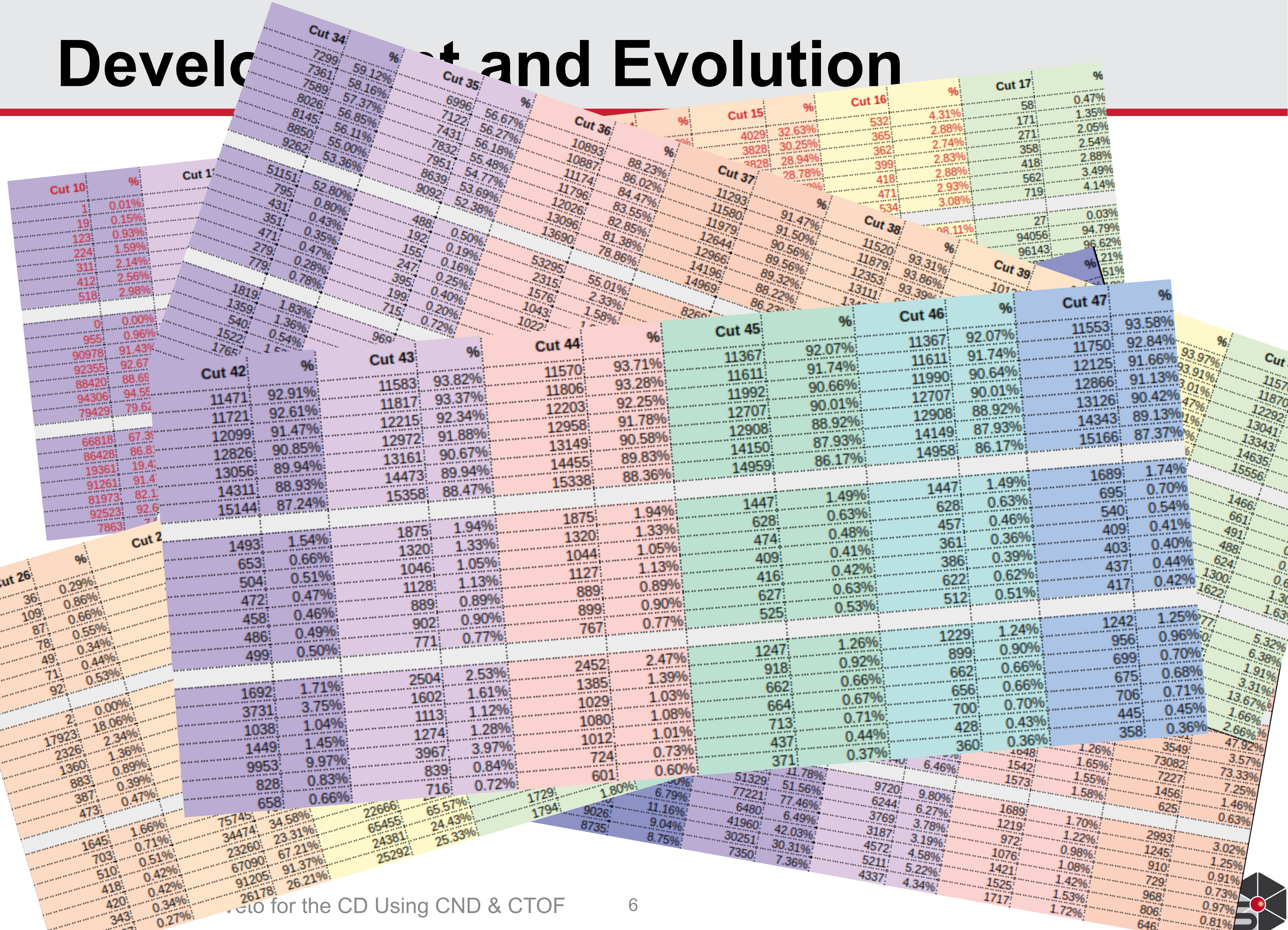
- Requirements:
  - Veto charged particles without losing neutrons
  - May only use position and energy deposition information from CTOF and CND
  - Cannot rely on vertex tracking

- ROOT macro → TSelector → CND clustering → COATJAVA (EventBuilder)

- Start with what we observed in single-particle, single-momentum simulations
  - Neutrons at 400-1000 MeV
  - Protons from 400-1000 MeV*
  - π+ from 400-1000 MeV*

*RG-A shows we won't see many above 800 MeV

Develo… …t and Evolution



Development and Evolution

- **Interesting trials**
  - Sector/φ
    - Criteria: Charged particles have curved tracks – if φ changes more than (5, 10, &c.) degrees or (1, 2) sectors, apply veto
    - Problem: Particles frequently "graze" multiple sectors, making this a fuzzy and unreliable cut
  - Layer ordering
    - Criteria: If hits within an event trigger layers in order radially, apply veto
    - Problem: In real life, we won't know which hit was first

Development and Evolution

- **Milestone trials**
  - Hit and layer multiplicities defined
    - Allow for a cut to be made based on how many hits within an event, or how many layers were triggered (regardless of number of hits)
  - Total event energy deposition defined
    - Allow for a cut to be made based on the total energy deposition of an event
    - Also defined total event energy per detector (very useful in conjunction with hit/layer multiplicity cuts)

Development and Evolution

- **The veto today**
  - Two main sections
    - Section 1 defines useful quantities (total event energy, hit and layer multiplicity…)

```
for(int i=0; i<size; i++)
      {
        if(CND_hits_energy[i]>1)
            {
              counts++;
              if(CND_hits_layer[i]==1)
                  {
                    counts_l1++;
                  }

              [...]

            }
      }
 for(int i=0; i<ctof_size; i++)
      {
        if(CTOF_hits_energy[i]>1)
            {
              ctof_counts++;
            }
      }
```

```
if(counts>0 && ctof_counts==0)
      {
        for(int i=0; i<size; i++)
            {
              if(CND_hits_energy[i]>1)
                  {
                    total_event_energy += CND_hits_energy[i];
                    total_cnd_energy += CND_hits_energy[i];
                    cnd_only_counts++;
                  }
            }
      }
```

Development and Evolution

- **The veto today**
  - Section 2 applies the veto using the quantities defined in section 1 – an example:

```
else if(cnd_only_counts>0)
     {
       if(total_cnd_energy>10 && counts<3)
          {
            neutron++;
            cnd_only_neutron_counts++;
          }
       if(total_cnd_energy<=10 && counts<4)
          {
            neutron++;
            cnd_only_neutron_counts++;
          }
     }
```

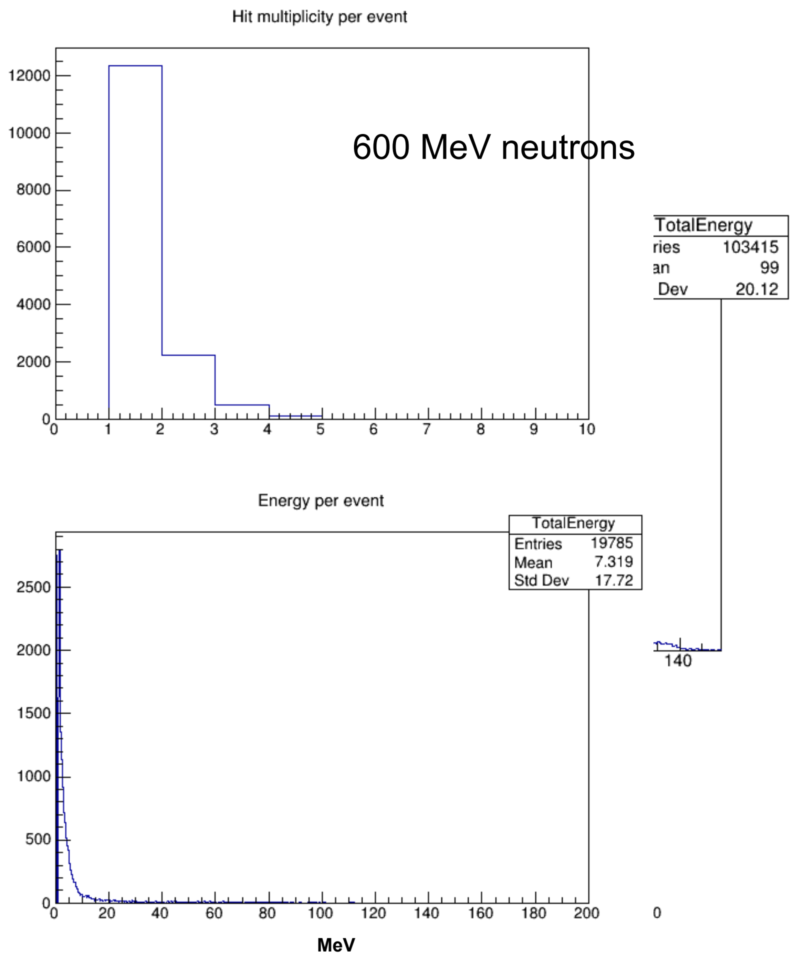
Events only in CND

CND total event energy > 10 MeV, and hit multiplicity less than 3

Increment two counters – neutrons and CND only neutrons

Development and Evolution

- **The veto today**



- If an event was in CTOF only:
  - total energy for the event is < 13 MeV and hit multiplicity is < 3
- If an event was in CND and CTOF:
  - CND event energy is < 30 MeV, and CTOF event energy is < 13 MeV, and layer multiplicity is exactly 1
  - total event energy is < 10 MeV, and CTOF event energy is < 10 MeV, and layer multiplicity is exactly 2
- If an event was in CND only:
  - total event energy > 10 MeV and hit multiplicity is < 3
  - Total event energy ≤ 10 MeV and hit multiplicity is < 4

Results

Baseline

Very few pions of all momenta were detected in only CND…

…or only in CTOF…

… almost all were detected in both CND and CTOF

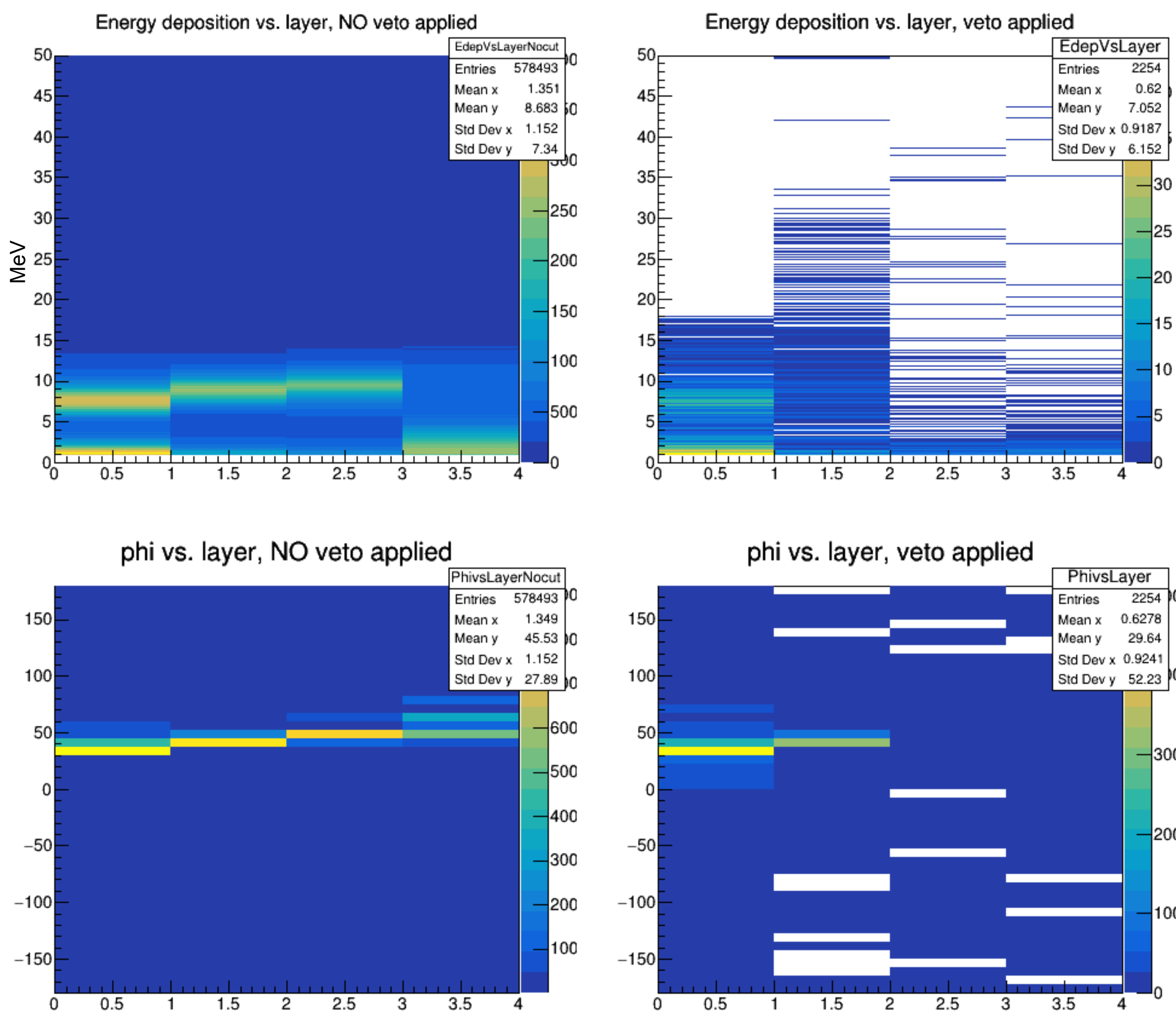
CND + CTOF + CND&CTOF

Particle	Energy	CND baseline	CND only	% of CND baseline	CND-only % of total	CTOF baseline	CTOF only	% of CTOF baseline	CTOF-only % of total	CND & CTOF	detected in both % of total	total detected
neutron	400	8318	6996	84.11%	56.67%	5350	4028	75.29%	32.63%	1322	10.71%	12346
neutron	500	8836	7122	80.60%	56.27%	5534	3820	69.03%	30.18%	1714	13.54%	12656
neutron	600	9439	7431	78.73%	56.18%	5797	3789	65.36%	28.64%	2008	15.18%	13228
neutron	700	10110	7832	77.47%	55.48%	6286	4008	63.76%	28.39%	2278	16.14%	14118
neutron	800	10404	7951	76.42%	54.77%	6565	4112	62.64%	28.33%	2453	16.90%	14516
neutron	900	11599	8639	74.48%	53.69%	7453	4493	60.28%	27.92%	2960	18.39%	16092
neutron	1000	12717	9092	71.49%	52.38%	8267	4642	56.15%	26.74%	3625	20.88%	17359
proton	400	1105	488	44.16%	0.50%	96388	95771	99.36%	98.86%	617	0.64%	96876
proton	500	95925	192	0.20%	0.19%	99065	3297	3.33%	3.32%	95733	96.48%	99222
proton	600	97788	155	0.16%	0.16%	99355	1722	1.73%	1.73%	97633	98.11%	99510
proton	700	98567	247	0.25%	0.25%	99409	1089	1.10%	1.09%	98320	98.66%	99656
proton	800	98884	395	0.40%	0.40%	99302	813	0.82%	0.82%	98489	98.79%	99697
proton	900	98958	199	0.20%	0.20%	99542	783	0.79%	0.79%	98759	99.02%	99741
proton	1000	99084	715	0.72%	0.72%	99039	670	0.68%	0.67%	98369	98.61%	99754
pi+	400	96651	969	1.00%	0.98%	98186	2504	2.55%	2.53%	95682	96.50%	99155
pi+	500	98367	1114	1.13%	1.12%	98447	1194	1.21%	1.20%	97253	97.68%	99561
pi+	600	98856	415	0.42%	0.42%	99276	835	0.84%	0.84%	98441	98.75%	99691
pi+	700	99070	1443	1.46%	1.45%	98327	700	0.71%	0.70%	97627	97.85%	99770
pi+	800	99238	1718	1.73%	1.72%	98106	586	0.60%	0.59%	97520	97.69%	99824
pi+	900	99318	549	0.55%	0.55%	99267	498	0.50%	0.50%	98769	98.95%	99816
pi+	1000	99437	1794	1.80%	1.80%	98071	428	0.44%	0.43%	97643	97.77%	99865

All files:
100,000 particles
$\varphi = 0$
$\theta = 60$

Results

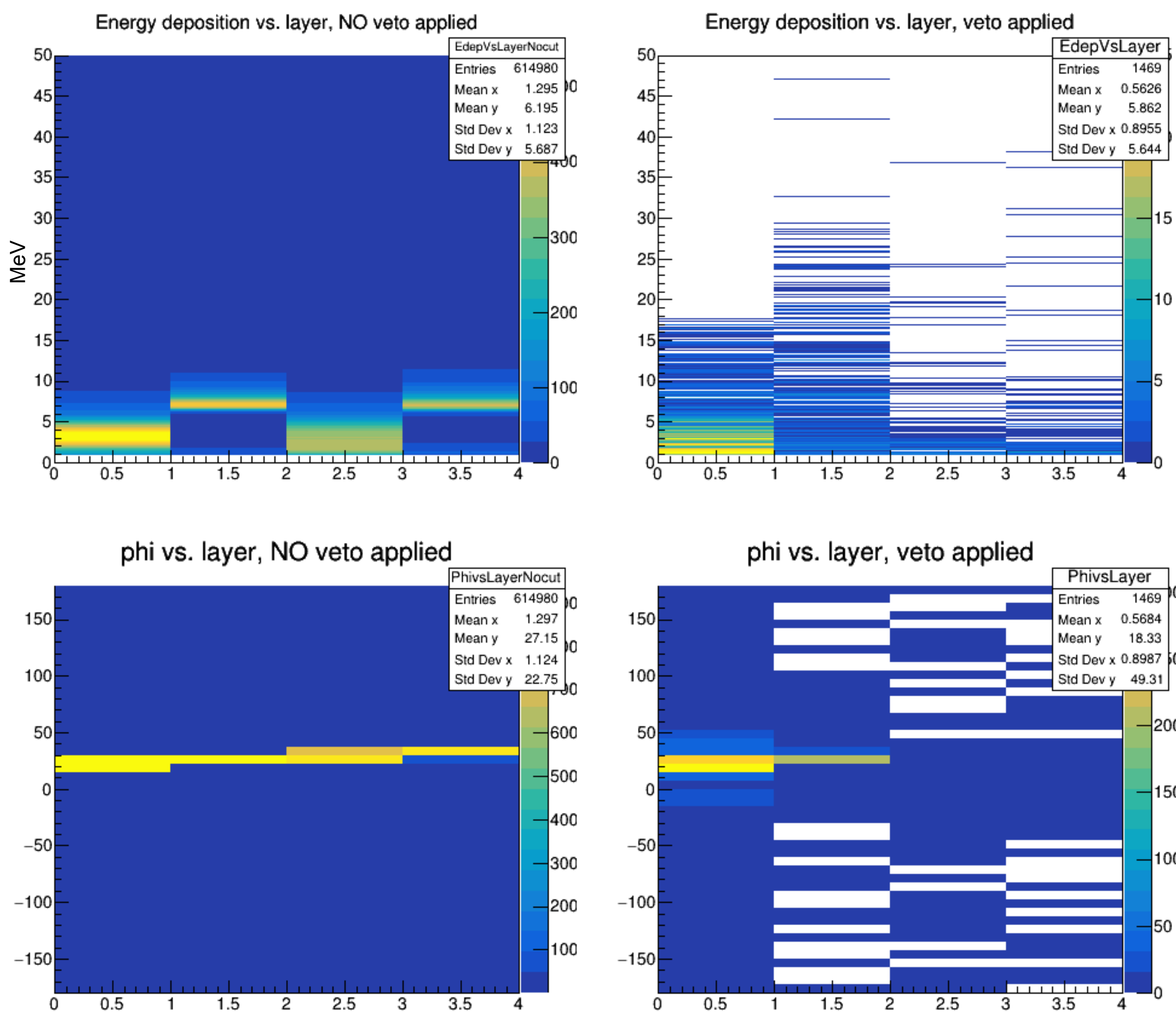
400 MeV neutrons protons



total detected	Cut 47	%	
12346	11553	93.58%	←n
12656	11750	92.84%	
13228	12125	91.66%	
14118	12866	91.13%	
14516	13126	90.42%	
16092	14343	89.13%	
17359	15166	87.37%	
96876	1689	1.74%	←p
99222	695	0.70%	
99510	540	0.54%	
99656	409	0.41%	
99697	403	0.40%	
99741	437	0.44%	
99754	417	0.42%	
99155	1242	1.25%	←π+
99561	956	0.96%	
99691	699	0.70%	
99770	675	0.68%	
99824	706	0.71%	
99816	445	0.45%	
99865	358	0.36%	

Results

600 MeV neutrons protons



total detected	Cut 47	%	
12346	11553	93.58%	
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13228	12125	91.66%	←n
14118	12866	91.13%	
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16092	14343	89.13%	
17359	15166	87.37%	
96876	1689	1.74%	
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99770	675	0.68%	
99824	706	0.71%	
99816	445	0.45%	
99865	358	0.36%	

Further Testing

- Further testing is underway to ensure that the veto is suitable for use in reconstruction of real data:
  - Testing on Monte Carlo simulations of particles at all appropriate angles and momenta
  - Inclusion of kaons
  - Tests on already-reconstructed RG-B data

Implementation

- Implementation will go in parallel with optimization and testing – we don't anticipate any changes to the structure of the veto, likely just energy and multiplicity refinements to the already-defined criteria!

Implementation

Tentative plan (as of yesterday):

At the beginning of the **CLUSTERING** for CND and CTOF, the following quantities must be defined, if not present already, for hits that qualify to be in the **same cluster**:

- Total energy
- Hit multiplicity, including the proper edep threshold
- Layer multiplicity, including the proper edep threshold

Then the clustering should be done (needs to be checked and maybe optimized), and the above quantities, on which the veto is based upon, should be **passed to EventBuilder**.

In **EventBuilder**: for CD neutral candidates, i.e. hits in CND and/or CTOF, which are NOT matched to CVT tracks (but it can be done also for those that are):

- Distinguish between the three cases: CTOF only, CND only, CTOF+CND
- For each case, create a « neutral » flag, based upon the veto criteria
- For events for which the neutral flag is on, proceed to neutron PID check: low and high b AND edep cut (right now only high b cut is present for CND)
- Include also PID for neutrons in CTOF (not present yet)

Other ideas/plans:

- Study additional veto criteria for **photons**, on top of beta/edep cut
- Include PID for photons in EB, not present yet (just reverse neutron cut)
- ID of pions and protons (with rough momentum/angle reconstruction)

Summary

- Refining and testing of a CTOF/CND-only charged particle veto is underway
- At present, the veto has been tested on single-particle, single momentum simulations*
- Implementation into the CND clustering algorithm will go in parallel with further testing