Electromagnetic processes and trigger system (Collider mode)

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Electromagnetic dissociation

EMD

- EMD: Electromagnetic dissociation of nuclei in the beam:
  - ✓ absorption of photons with emission of several neutrons, protons (mostly one) and other particles
  - ✓ new nucleus is produced after emission which gets lost from the beam (wrong A/Z ratio)

- Main consequences of EMD:
  - ✓ MPD: emitted particles may fire the MPD trigger system and contaminate hadronic events
  - ✓ NICA: reduced beam lifetime
  - ✓ General: contamination/heating of construction materials and magnets

- How relevant/often? :
  - ✓ Collider mode, BiBi@7 GeV:
    σ_{had} ~ 7 b, σ_{EMD}^{single} ~ 24 b (<n> ~ 1.382, <p> ~ 0.046), σ_{EMD}^{mutual} ~ 2 b
  - ✓ Fix-target mode, Xe+W (T = 2.5 A·GeV):
    σ_{had} ~ 5.7 b, σ_{EMD}^{single} ~ 2.58 b (<n> ~ 1.038, <p> ~ 0.0269)

- Cross sections are large:
  - ✓ EMD is a way more important for beam losses than hadronic interactions
  - ✓ EMD events may fire the trigger:
    <u>collider mode</u>: two simultaneous single EMD events or mutual EMD event for forward detectors or any EMD event for the TOF
    <u>fixed-target</u>: any EMD event

Simulation of EMD events

- RELDIS event generator (cross sections and emitted particle energy/spatial distributions)
- Works well at SPS/RHIC/LHC energies

И. А. Пшеничнов, У. А. Дмитриева, А. О. Светличный, Известия РАН. Серия физическая, 2020, Т. 84, № 8, стр. 1215-1220
ALICE, Phys.Rev.C 107 (2023) 6, 064902 • e-Print: 2209.04250 [nucl-ex]
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E.V. Karpechev et al., Nucl.Phys.A 921 (2014) 60-84 • e-Print: 1307.5548 [nucl-ex]

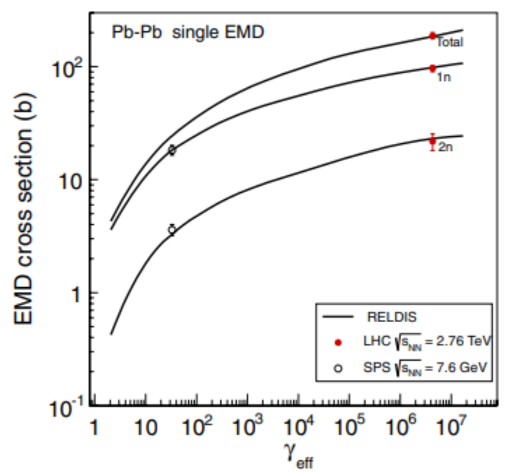
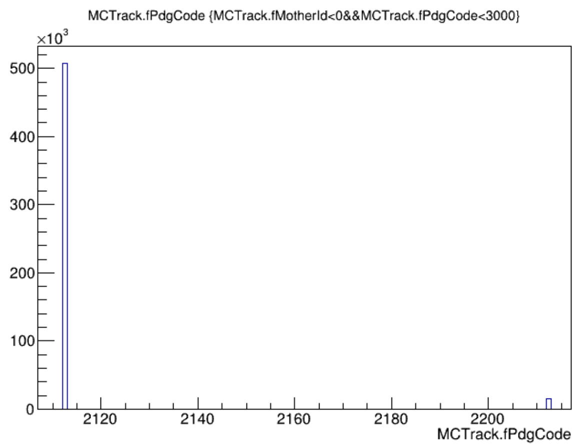


FIG. 5 (color online). Total single EMD cross sections and partial EMD cross sections for emission of one and two neutrons as a function of the effective Lorentz factor γ_{eff}. The closed symbols are our data, while the open symbols represent the results obtained at CERN SPS [10] at 30 GeV. The RELDIS predictions [10] for total, $1n$, and $2n$ EMD cross sections are shown as solid lines.

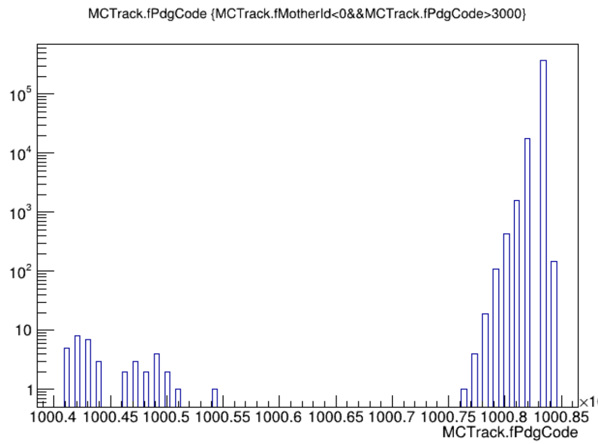
- Results for NICA are kindly provided by the team of I. Pshenichnov and A. Svetlichny – THANKS !!!
- Simulated events are filtered through the full MpdRoot simulation of the MPD
- Standard algorithms for the trigger system are used (see previous presentations)

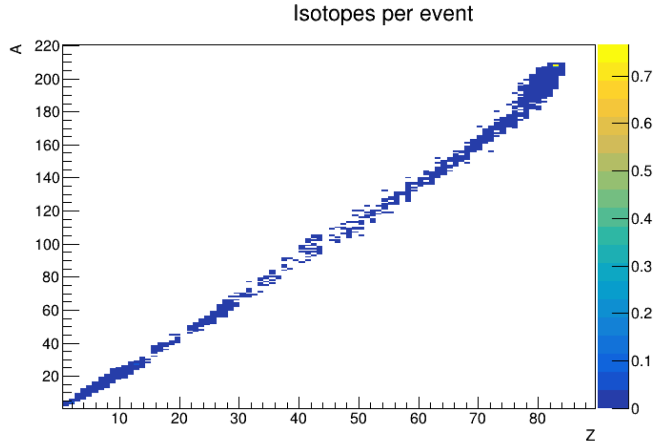
EMD events by RELDIS

produced hadrons by PDG

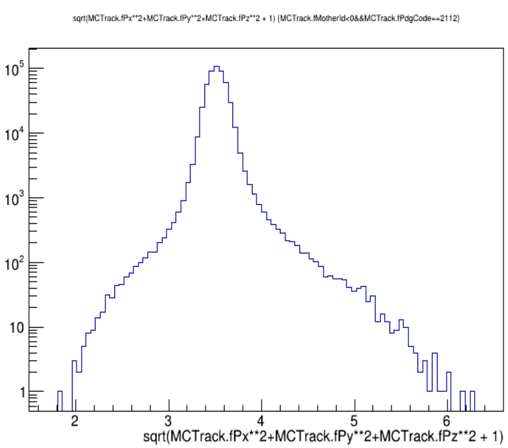


produced isotopes by PDG

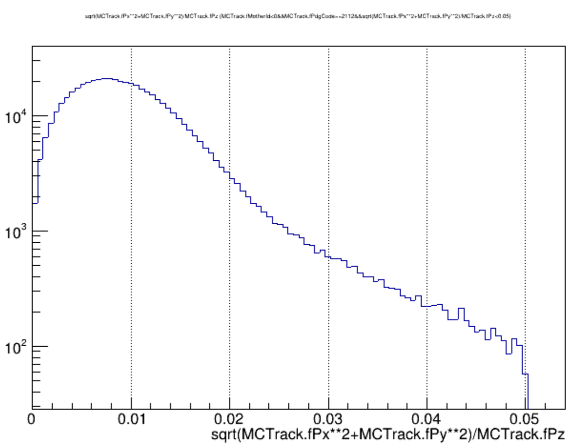


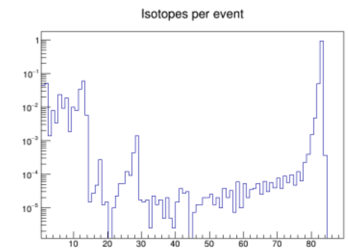


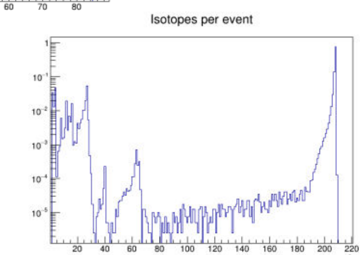
energy of produced neutrons



p_T/p_Z for neutrons



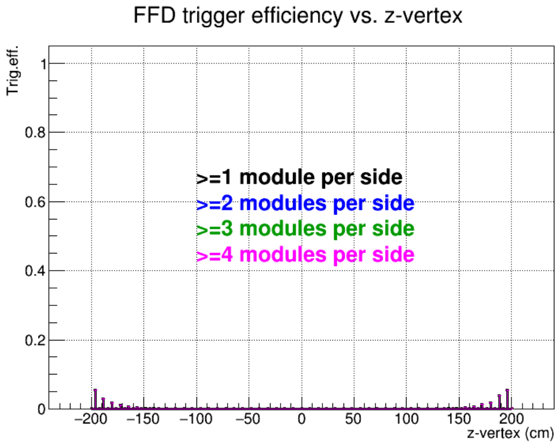


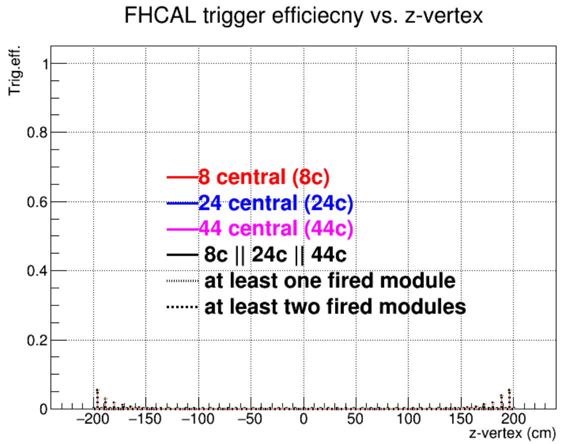


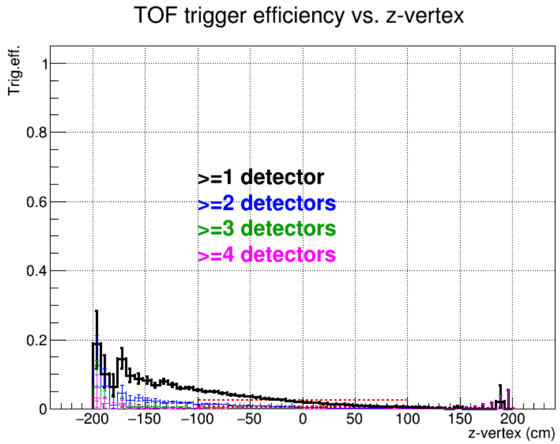
- Quite monochromatic neutron beam is produced with E ~ 3.5 MeV
- At a distance L neutron beam shifts from the central line by ~ L * p_T/p_z → scrapes inner part of FHCAL
- FFD and TOF can be fired by secondary particles mostly

Single EMD events: E+W

- 1 M events processed with standard MpdRoot selections (σ_{vertex} = 50 cm) and trigger tunes
- Standard collider mode trigger configuration: E+W detectors must fire simultaneously





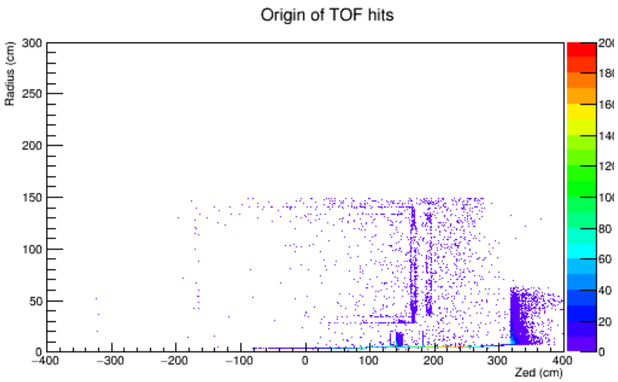


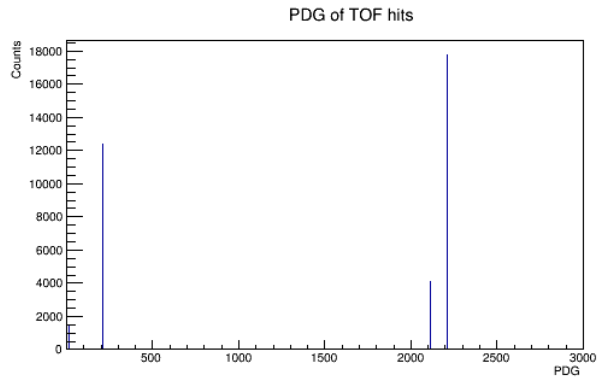
FFD: 5.16329e-006 0 0 0
FHCAL: 7.81913e-007
TOF: 0.0242503 0.00632889 0.00163338 0.000420083

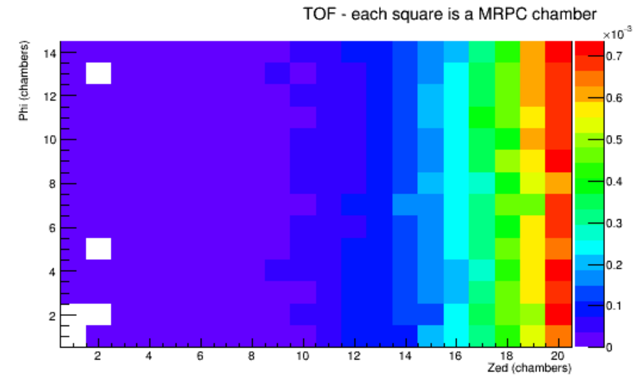
- Efficiency of forward trigger detectors in collider configuration (E+W) is negligible for single EMD events
- Efficiency of TOF is rather high (~ 2% for $\boldsymbol{\sigma_{ED}^{single}}$ ~ 24 b) meaning that peripheral hadronic events will have a significant admixture of EMD events

Single EMD events: TOF

- Closer look at TOF:







- What if we mask MRPC chambers at large |zed| for trigger decision:
  - ✓ 1-20 MRPC: 0.0242503 0.00632889 0.00163338 0.000420083
  - ✓ 3-18 MRPC: 0.0152812 0.00272003 0.000492441 0.000121024
  - ✓ 4-17 MRPC: 0.0113869 0.0017832 0.000303305 7.79818e-005

- TOF trigger efficiency for EMD events is reduced by a factor of ~ 2, but still remains quite noticeable
- With a minimum requirement of one fired MRPC chamber, TOF trigger will collect hadronic events with admixture of ~3% of EMD events → no acceptable
- Minimum requirement for the TOF trigger: 2-3 fired MRPC chambers with masked side chambers

Pile-up of single EMD events

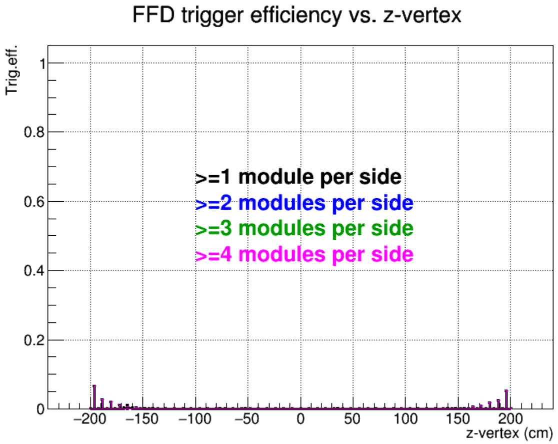
- Two single EMD events may happen simultaneously (EMD pile-up) by emitting n/p/h in the opposite directions thus emulating a standard hadronic collision
- Probability of EMD pile-up at one bunch crossing (two independent EMD events with emission of ~ one neutron each → fake the hadronic collision) is estimated to be 1.4e-6 at full NICA luminosity (10^{27} $cm^{-2}s^{-1}$).
- With probability of hadronic interactions at full luminosity ~ 5e-4 per bunch crossing → 0.3% of hadronic interactions will be contaminated by EDM pile-up events
- What is probability to detect such events in the trigger detectors?
- Probability for E || W trigger detectors to be fired by single EMD event:

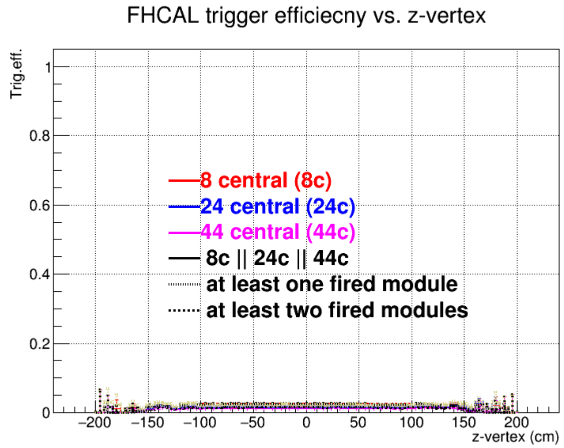
FFD: 0.0168744 0.00381387 0.00143174 0.000547158
FHCAL: 0.121954

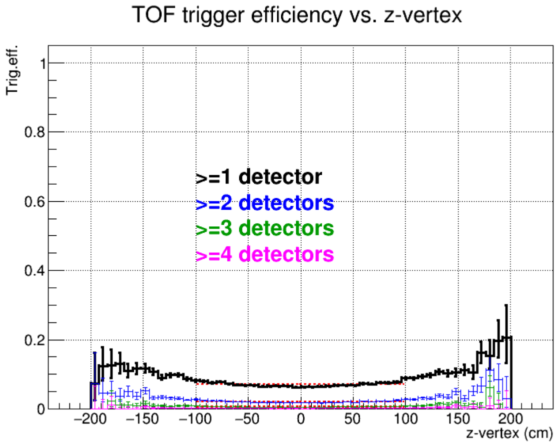
- Hence probability for pile-up EMD event to be recorded 0.3% * 0.1 * 0.1 ~ 0.005%
- A fraction of recorded pile-up EMD events is negligible
- However, this estimations show that if we decide to study very peripheral events with emission of ~ 1 neutron per forward detector (0.1-0.3 b or 4% from σ_{had} ~ 7 b) we will face a significant admixture of pile-up EMD events

Mutual EMD events: E+W

- 1 M events processed with standard MpdRoot selections (σ_{vertex} = 50 cm) and trigger tunes
- Standard collider mode trigger configuration: E+W detectors must fire simultaneously







FFD: 0.00090286 4.95225e-005 6.76418e-006 0
FHCAL: 0.0246564
TOF: 0.071105 0.021117 0.00623211 0.00188643

- Contamination of recorded data sample by mutual EMD events will be ~ 0.03% (FFD), 0.7% (FHCAL) and 2% (TOF). TOF contamination can be reduced to 1% by masking three side layers of MRPC chambers (large |zed|) in trigger decision
- Peripheral events will be significantly contaminated !!!

Conclusions for EMD

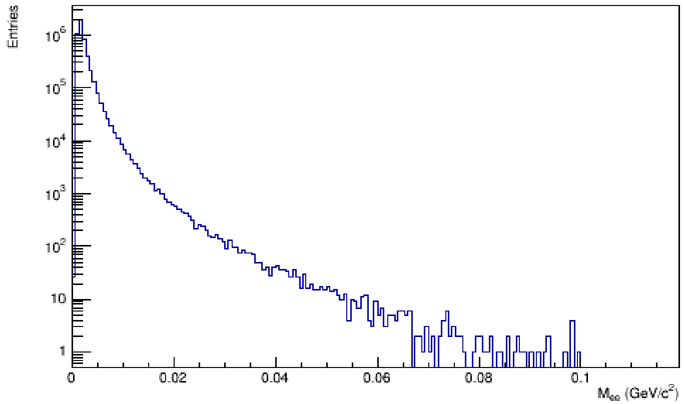
- EMD processes play a noticeable role for the NICA and MPD
- EMD processes are three times more important for beam losses than hadronic interactions
- EMD processes (pile-up single EMD and mutual EMD) will contaminate very peripheral events (events with ~ 1 neutron per side and minimum activity at central rapidity)
- EMD processes will not drive logic of online trigger, EMC events will constitute ~ percent of recorded events → not a big loss for DAQ bandwidth
- However, analysis of peripheral hadronic events will require extra efforts to make sure that selected events are not contaminated by EMD processes

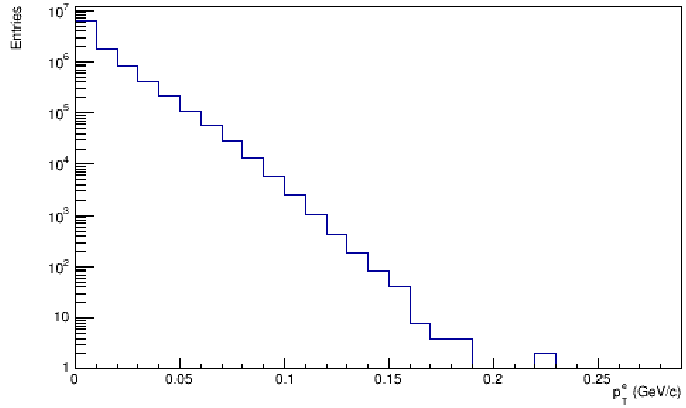
- Studies for the fixed-target mode are ongoing → situation will be worse ???

$\gamma\gamma \rightarrow e^{+}e^{-}$

Photoproduction

- Photoproduction of dielectron pairs
- Widely studied in Ultra-Peripheral Collisions (UPC) at RHIC and LHC:
  - ✓ cross section – hundreds of kilobarns
  - ✓ requires dedicated trigger (low multiplicity at central rapidity, zero forward activity)
- Photoproduction will happen in A+A at NICA energies as well → produced leptons may fire the trigger system
- Order-of-magnitude estimations for photoproduction of e^+e^- pairs were obtained using Starlight event generator, results kindly provided by E. Kryshen and N. Burmasov – THANKS!!!
- BiBi@7 GeV, 5M events, σ ~ 40000 b, M_{ee} of produced pairs and electron momentum:

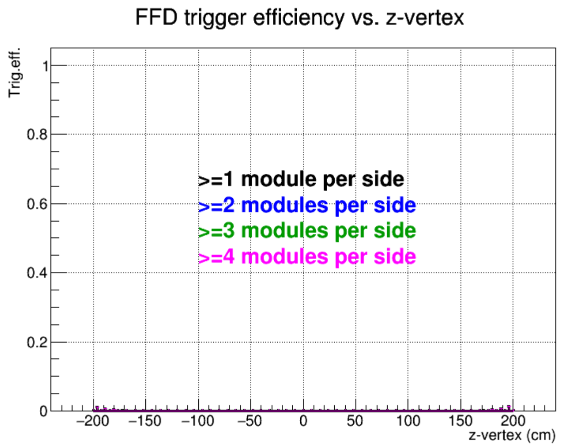


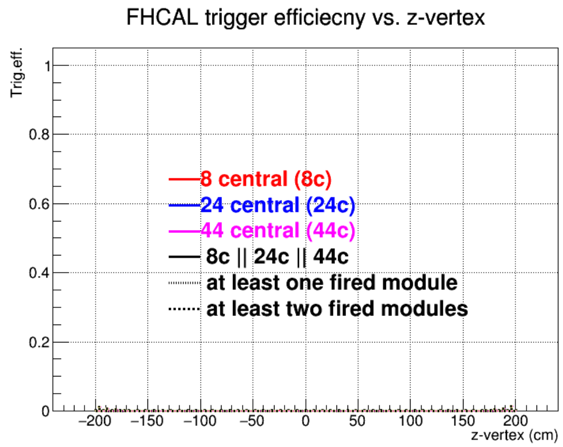


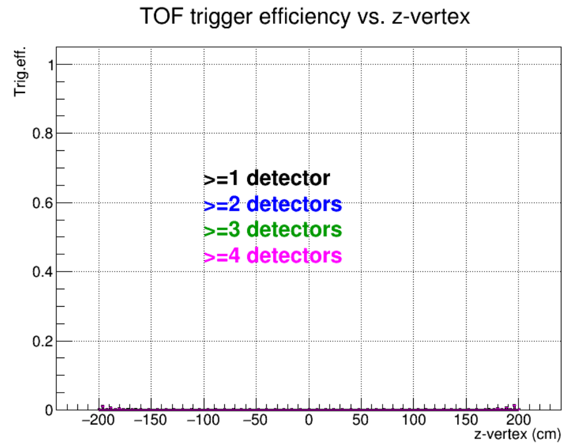
- Pushed 5M events of γγ→ee through MpdRoot with standard settings for the trigger system

Single EMD events: E+W

- 5 M events processed with standard MpdRoot selections (σ_{vertex} = 50 cm) and trigger tunes
- Standard collider mode trigger configuration: E+W detectors must fire simultaneously







FFD: < 2e-7
FHCAL: <2e-7
TOF: 5.68869e-005 <2e-7 <2e-7 <2e-7

- Forward trigger detectors are mostly blind to photoproduction
- With a minimum requirement of 1 fired MRPC chamber for TOF trigger, it will fire with an effective cross section of 40,000b · 5.7e-5 ~ 2.3 b → HUGE background → minimum requirement of two fired MRPC chambers for physics analyses
- TOF occupancy is uniform, no way to reduce efficiency by acceptance cuts, only by increasing number of fired MRPC chambers

Conclusions

- Photoproduction processes have huge cross sections but characterized by very low multiplicity (~ 2 tracks)
- Forward FFD and FHCAL detectors are mostly blind to dileptons from photoproduction
- TOF in minimum trigger configuration may effectively trigger on photoproduction processes → not a big effect for the DAQ bandwidth but extra studies will be needed and tighter selection criteria to clean up the collected data sample for physics analyses

- Studies for the fixed-target mode are ongoing → situation will be worse ???

BACKUP