

Rates of hits in dRICH from DIS and machine backgrounds

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Task description

1. determine complete data throughput of dRICH produced by DIS and machine backgrounds, separating in Synchrotron Radiation and others;
2. study DIS tracks that are excluded by the current reconstruction algorithms;

We use recent campaign:

`epic:/RECO/26.07.1/epic_craterlake/Bkg_Exact1S_2us/GoldCt/10um/`

with Status Code Shift from [TWiki](#)

After determining dRICH hit rates we will compute the number of hits/PDU/10 ns frame.

DCR of 300 kHz/ch (maximum allowed) will be added analytically.

Sources of hits

- Not possible to use RECO data only (**missing link from DRICHRawHits to MCParticle**);
- Simulation (FULL) data have link to MCParticle - from branch "_DRICHHits_particle.index" with index of "DRICHHits";
- in MCParticles loop from "MCParticles.parents_begin" to "MCParticles.parents_and" separating photons and non photon (PDG!=22);
- selected by "MCParticles.generatorStatus": $\text{ABS}(\text{stat}-2000) < 100 \Rightarrow \text{source}=2$ etc. for other sources (typically stat=2004 - initial Synch.Rad. photon, or 2001 - gen. final state photon);

Interaction rate

Symbol	Process	Description	Sampling Frequency (kHz)	Status Code Shift
	signal	DIS NC 18x275 $Q^2 > 1$ (Deep inelastic scattering neutral current)	500	0
	synrad	Synchrotron Radiation	14000	2000
	ebrems	Electron bremsstrahlung radiation	316.94	3000
	etouschek	Electron Touschek scattering (intrabeam scattering)	1.3	4000
	ecoulomb	Electron Coulomb scattering processes	0.72	5000
	p.b.gas	Proton beam gas interactions	22.5	6000

Source ID:

1

2

3

4

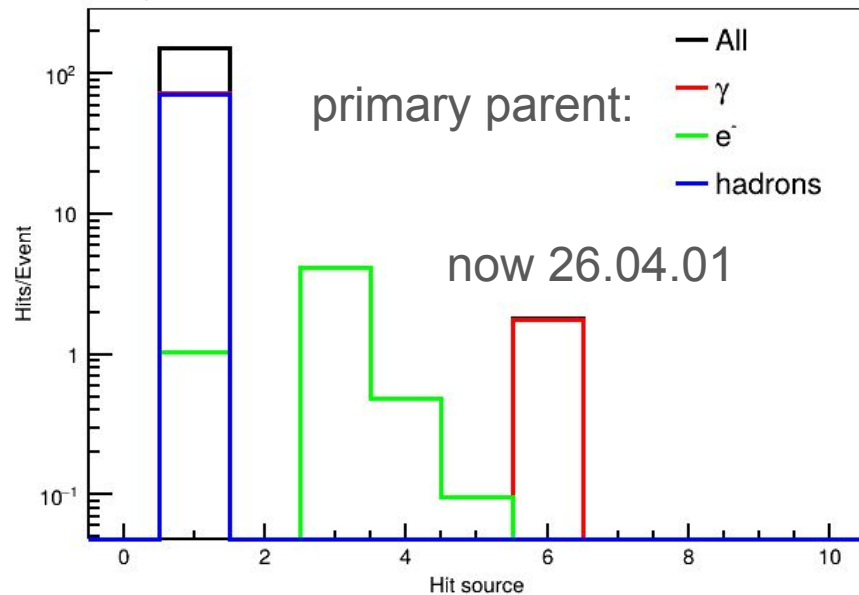
5

6

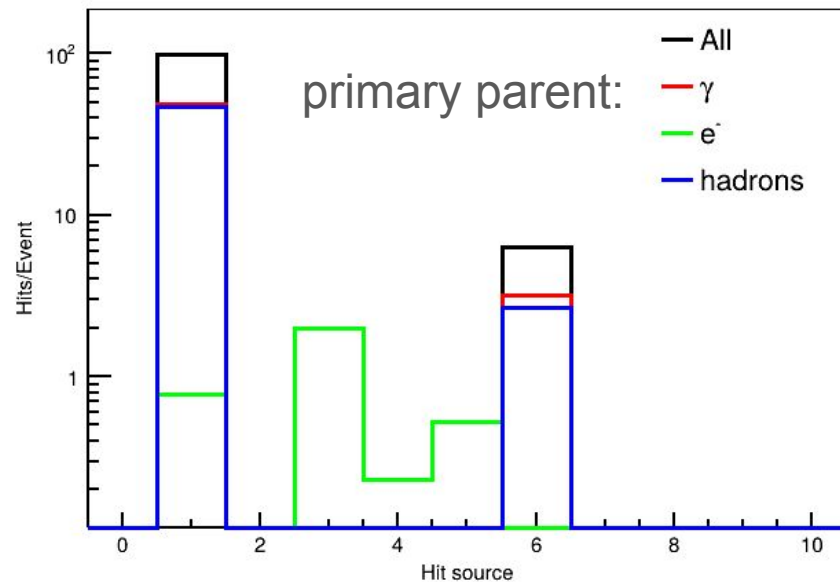
Results for 10x100 GeV in 2 us data frame

- total dRICH hit rate from DIS($Q^2 > 1 \text{ GeV}^2$) = 161 hits/event: (DIS=96%, Synchrotron Radiation γ =0%, bremsstrahlung e^- =2.6%, p -gas=1.1%, other=0.4%);
- total dRICH hit rate from SIDIS($Q^2 < 1 \text{ GeV}^2$) = 108 hits/event: (DIS=91.6%, Synchrotron Radiation γ =0%, bremsstrahlung e^- =1.9%, p -gas=5.8%, other=0.7%).

26.07.1,Bkg_Exact1S_2us/GoldCt/10um/10x100/mi
nQ2=1/pythia8NCDIS (100 file=9999 events)



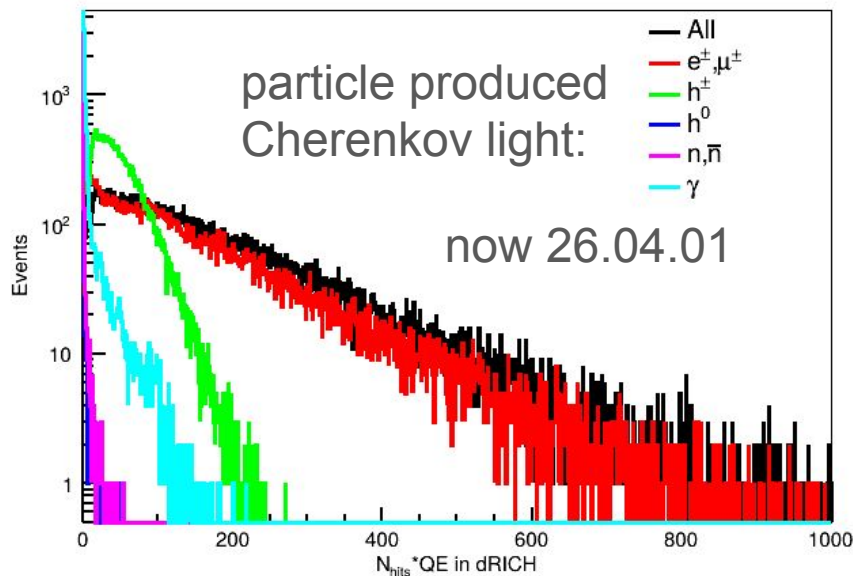
26.07.1,Bkg_Exact1S_2us/GoldCt/10um/SIDIS/
pythia6/10x100/q2_0to1 (320 files=32k events)



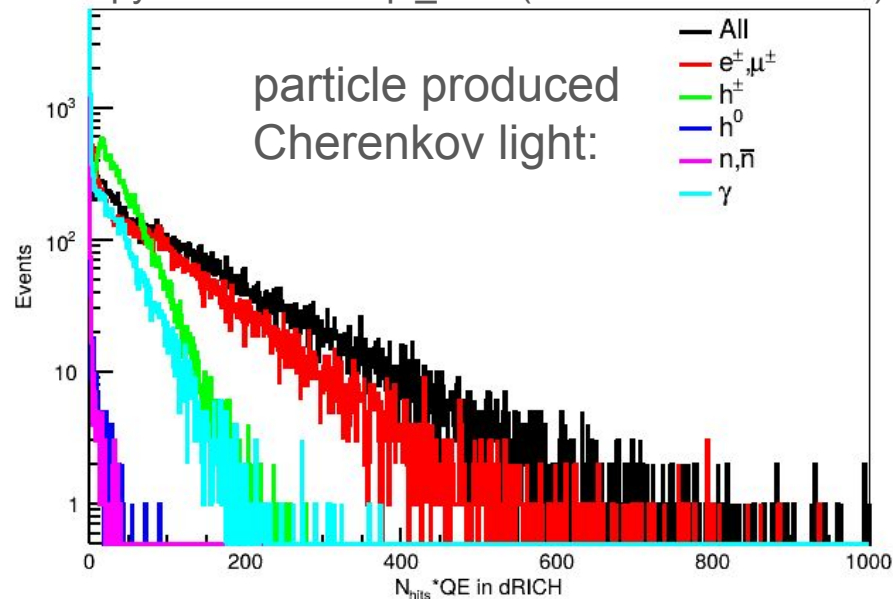
Results for 10x100 GeV in 2 us data frame cont.

- mean number of dRICH hits/event from DIS($Q^2 > 1 \text{ GeV}^2$) = 161: $e/\mu^\pm = 120$, $h^\pm = 38$, $h^0/n = 0.02/0.03$, $\gamma = 3$;
- mean number of dRICH hits/event from SIDIS($Q^2 < 1 \text{ GeV}^2$) = 108: $e/\mu^\pm = 65$, $h^\pm = 30$, $h^0/n = 0.07/0.04$, $\gamma = 13$.

26.07.1,Bkg_Exact1S_2us/GoldCt/10um/10x100/mi
nQ2=1/pythia8NCDIS (100 file=9999 events)

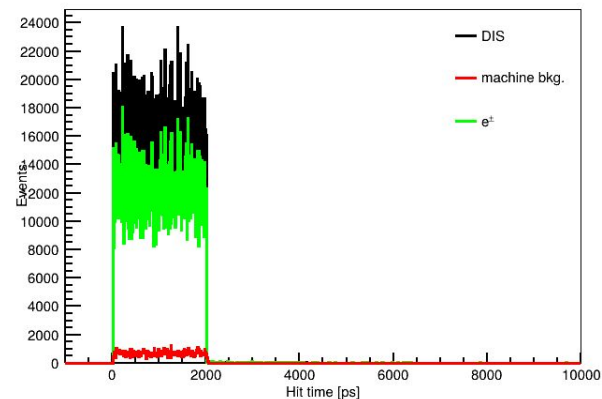
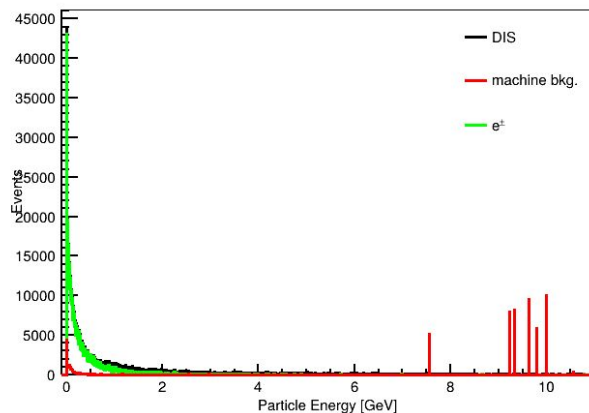
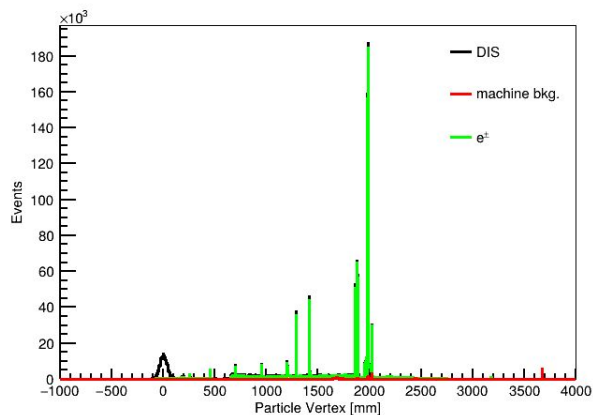
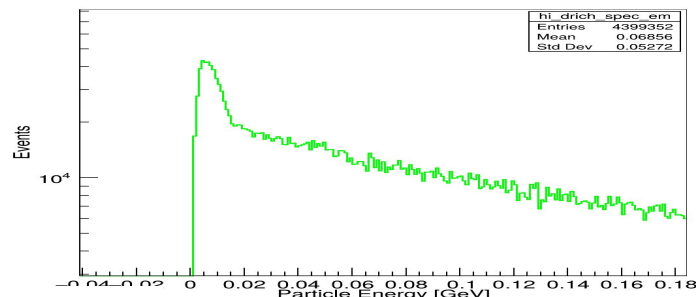


26.07.1,Bkg_Exact1S_2us/GoldCt/10um/SIDIS/
pythia6/10x100/q2_0to1 (320 files=32k events)



Separation in time, energy and vertex

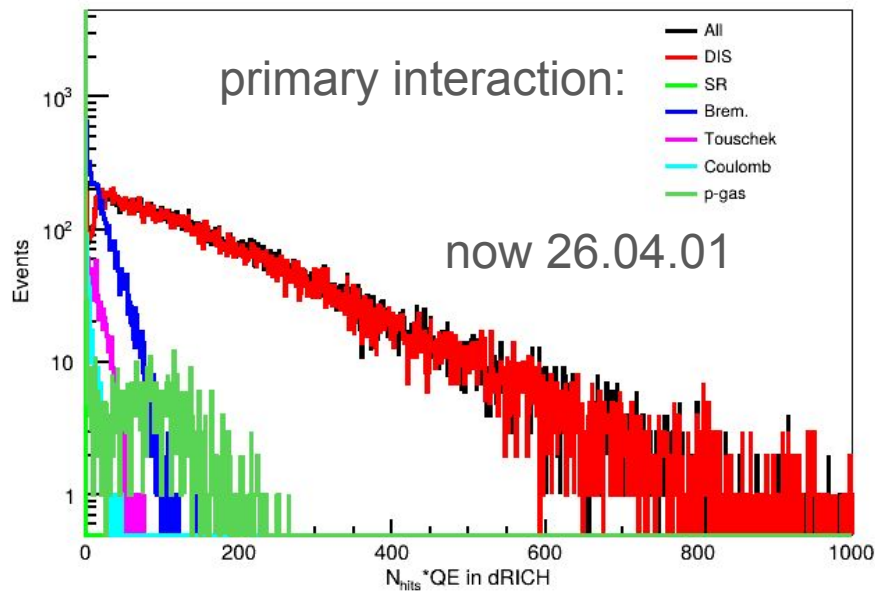
- Z-vertex distribution shows that $e/\mu^\pm$ and background events are generated mostly at beam pipe flanges ($R \sim 31$ mm) just before dRICH (or ToF?) $1980 \text{ mm} < Z < 1983 \text{ mm}$;
- the energy of $e/\mu^\pm$ and background tracks producing Cherenkov light is low < 1 GeV - mean $= 0.4$ GeV, with second peak < 15 MeV;
- $> 50\%$ of $e/\mu^\pm$ have < 200 MeV;
- 12% of $e/\mu^\pm$ have < 15 MeV;
- how do they make through magnetic field?
- time distributions of all hits are similar.



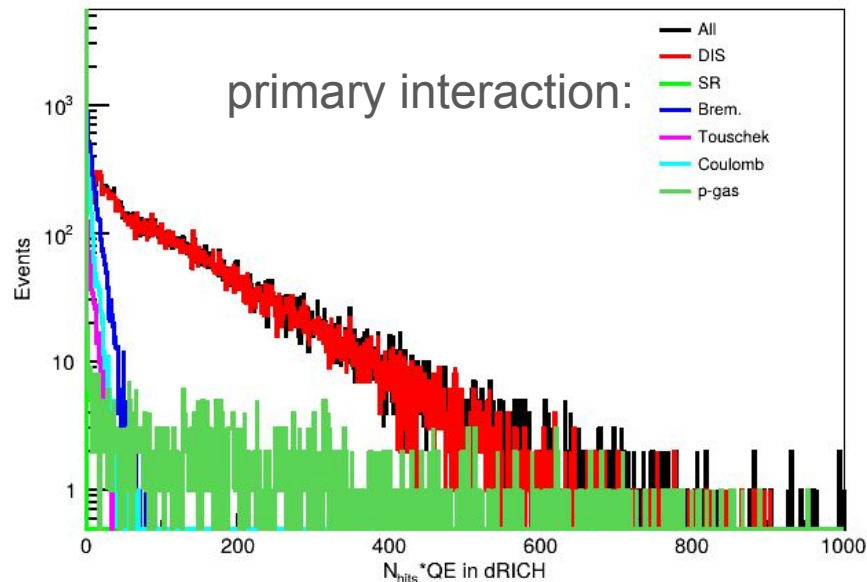
Results for 10x100 GeV in 2 us data frame cont.

- mean number of dRICH hits/event from DIS($Q^2 > 1 \text{ GeV}^2$)=161: DIS=154, Synchrotron Radiation $\gamma=0$, e^- bremsstrahlung=4, e^- Touschek=0.5, e^- Coulomb=0.1, p -gas=1.8;
- mean number of dRICH hits/event from SIDIS($Q^2 < 1 \text{ GeV}^2$)=108: DIS=99, Synchrotron Radiation $\gamma=0$, e^- bremsstrahlung=2, e^- Touschek=0.2, e^- Coulomb=0.5, p -gas=6.3.

26.07.1,Bkg_Exact1S_2us/GoldCt/10um/10x100/mi
nQ2=1/pythia8NCDIS (100 file=9999 events)



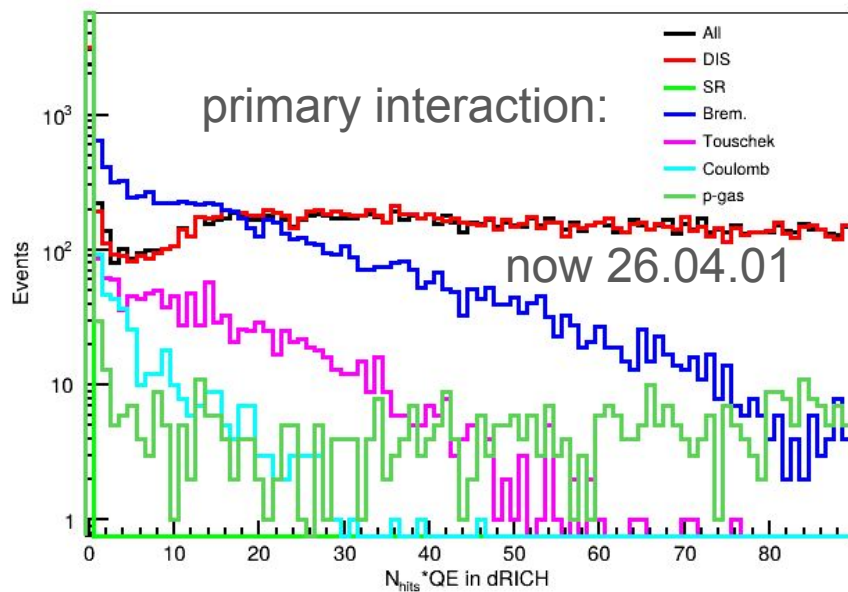
26.07.1,Bkg_Exact1S_2us/GoldCt/10um/SIDIS/
pythia6/10x100/q2_0to1 (320 files=32k events)



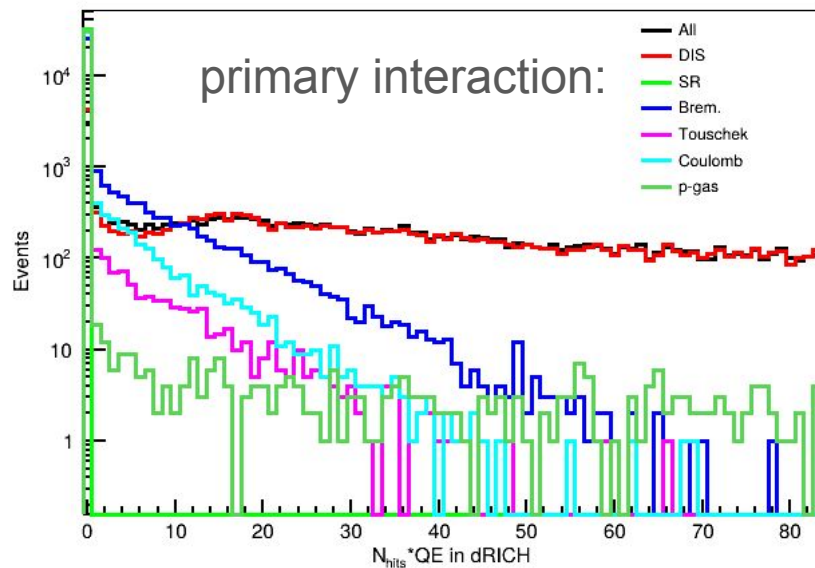
Results for 10x100 GeV in 2 us data frame zoom

- mean number of dRICH hits/event from DIS($Q^2 > 1 \text{ GeV}^2$)=161: DIS=154, Synchrotron Radiation $\gamma=0$, e^- bremsstrahlung=4, e^- Touschek=0.5, e^- Coulomb=0.1, p -gas=1.8;
- mean number of dRICH hits/event from SIDIS($Q^2 < 1 \text{ GeV}^2$)=108: DIS=99, Synchrotron Radiation $\gamma=0$, e^- bremsstrahlung=2, e^- Touschek=0.2, e^- Coulomb=0.5, p -gas=6.3.

26.07.1,Bkg_Exact1S_2us/GoldCt/10um/10x100/mi
nQ2=1/pythia8NCDIS (100 file=9999 events)



26.07.1,Bkg_Exact1S_2us/GoldCt/10um/SIDIS/
pythia6/10x100/q2_0to1 (320 files=32k events)



Normalization of signal/background

- name of campaign: “Bkg_1SignalPer2usFrame” suggests that we have 1 DIS signal every $2 \mu\text{s}$ + Background integrated in these $2 \mu\text{s}$ (100 events/file);
- $\text{DIS}(Q^2 > 1 \text{ GeV}^2) = 0.6 \mu\text{b}$, thus $L = R/s = 1/(1 \mu\text{s} * 0.6 \mu\text{b}) = 24637 \text{ 1}/(\text{fb} * \text{y})$;
- Concluding, there is no normalization of the signal, only Background is added in time frame of $2 \mu\text{s}$ to every event (at what luminosity?/beam current?);
- However, there is no Background alone simulation in this campaign: how do we calculate the total background rate?
- Probably the recipe could be the following:

$$\text{SignalRate} = \frac{N_{sig.hits}}{N_{gen.events}} L \times \sigma_{tot} \quad \text{where} \quad R_{int} = L \times \sigma_{tot}$$

$$\text{BackgroundRate} = \frac{N_{bkg.hits}}{N_{gen.events}} \frac{1}{2\mu\text{s}}$$

Absolute signal/background rates

- configuration 10x100 GeV, timeframe of each event $2\ \mu\text{s}$;
- nominal luminosity $100\ \text{fb}^{-1}$ [DIS($Q^2 > 1\text{GeV}^2$)= $0.6\ \mu\text{b}$ =1.9 kHz, SIDIS($Q^2 < 1\text{GeV}^2$)= $40\ \mu\text{b}$ =127 kHz]:

	$Q^2 < 1\text{GeV}^2$	$Q^2 > 1\text{GeV}^2$	All Q^2 -range
DIS/SIDIS	13.75 MHz	0.35 MHz	14.1 MHz
Synchrotron Radiation	0 (0/10 ⁶ standalone)		
e ⁻ bremsstrahlung	1 MHz (0.82 MHz standalone)		
e ⁻ Touschek	0.12 MHz (0.36 MHz standalone)		
e ⁻ Coulomb	0.26 MHz (0.102 MHz standalone)		
p-gas	3.15 MHz (3.04 MHz standalone)		
e-p elastic	?	?	?
Total	18.3 MHz	4.9 MHz	18.6 MHz

Absolute dRICH PDU rates in 10 ns frames

- each individual PDU containing 256 SiPM sensors;
- dRICH contains 1248 PDUs.

DCR	$256 \times 300 \text{ kHz/ch} = 76.8 \text{ MHz} = 0.768 \text{ hits/PDU/10 ns}$ (99.9%)
DIS/SIDIS	$14.1 \text{ MHz}/1248 \text{ PDUs} = 1.13 \times 10^{-4} \text{ hits/PDU/10 ns}$
Synchrotron Radiation	0
e^- bremsstrahlung	$1 \text{ MHz}/1248 \text{ PDUs} = 8 \times 10^{-6} \text{ hits/PDU/10 ns}$
e^- Touschek	$0.12 \text{ MHz}/1248 \text{ PDUs} = 9.6 \times 10^{-7} \text{ hits/PDU/10 ns}$
e^- Coulomb	$0.26 \text{ MHz}/1248 \text{ PDUs} = 2.1 \times 10^{-6} \text{ hits/PDU/10 ns}$
p-gas	$3.15 \text{ MHz}/1248 \text{ PDUs} = 2.5 \times 10^{-5} \text{ hits/PDU/10 ns}$
e-p elastic	?
Total	0.76815 hits/PDU/10 ns

p-gas cross-check at 100 GeV

- in 25/12/00 campaign we have standalone p-gas background simulation;
- using [background wiki](#) parameters:

$$R_{int} = \frac{I_p}{e} \times \rho_{H2} \times L \times 2\sigma_{pp}$$

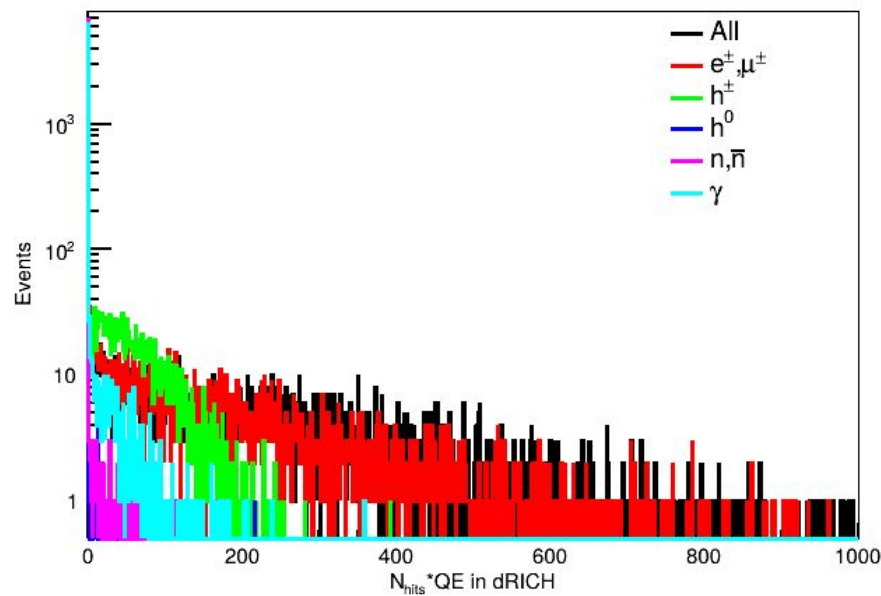
$$R_{int} = \frac{1A}{e} * 6.326 \times 10^7 \frac{molecules}{cm^3} * 1050cm * 2 * 38.5mb = 32kHz$$

- dRICH receives 95 hits/event;
- Using this value we can estimate the absolute dRICH hit rate:

$$R_{hits} = 95 \frac{hits}{event} \times 32kHz = 3.04MHz$$

compare to 3.15 MHz found from mixed events simulations.

- depends on proton beam current (here 1 A), and energy ($\sigma_{pp}(E_p)$)



Coulomb cross-check at 10 GeV

- in 25/12/00 campaign we have standalone Coulomb background simulation;
- using [background wiki](#) parameters (only total interaction rate is provided in the last bottom Table):

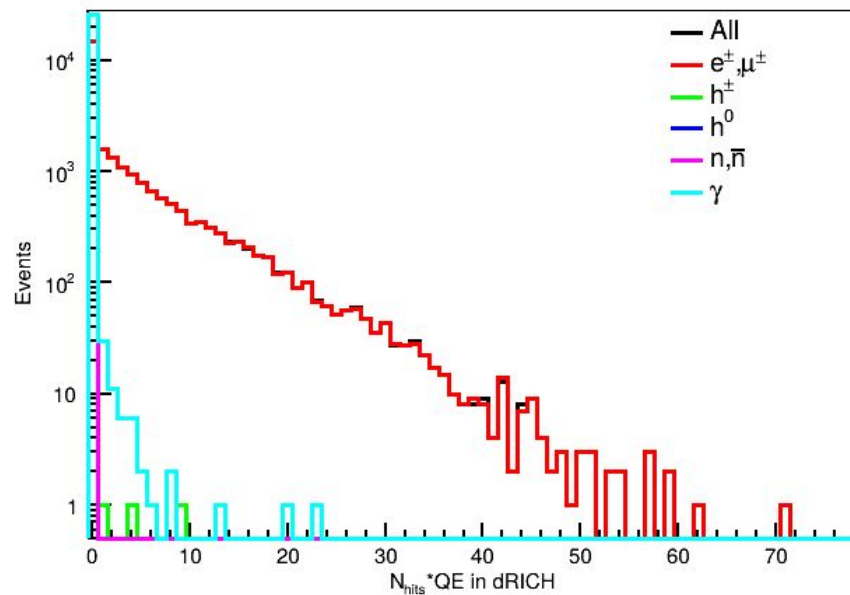
$$R_{int} = 29.56 kHz$$

- dRICH receives 3.48 hits/event;
- Using this value we can estimate the absolute dRICH hit rate:

$$R_{hits} = 3.48 \frac{hits}{event} \times 29.56 kHz = 0.1 MHz$$

compare to 0.26 MHz found from mixed events simulations.

- depends on electron beam current (here ?), and energy ($\sigma_e(E_e)$)



Touschek cross-check at 10 GeV

- in 25/12/00 campaign we have standalone Touschek background simulation;
- using [background wiki](#) parameters (only total interaction rate is provided in the last bottom Table):

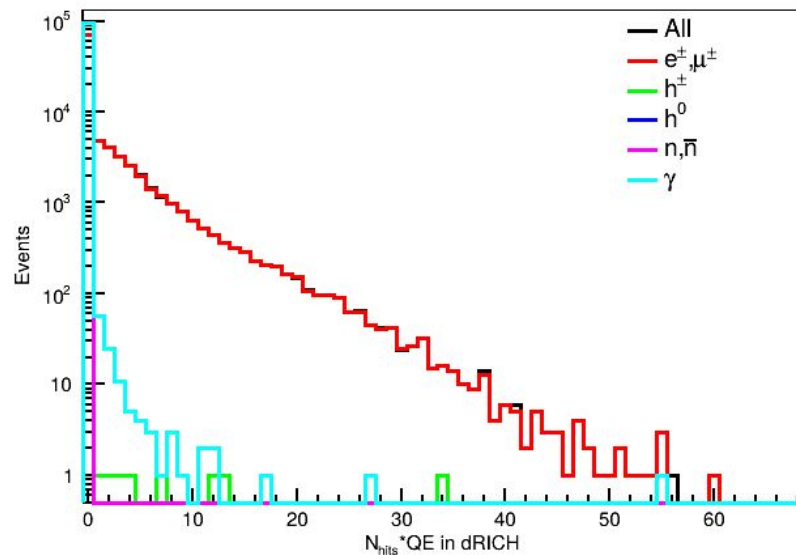
$$R_{int} = 233.5 kHz$$

- dRICH receives 1.54 hits/event;
- Using this value we can estimate the absolute dRICH hit rate:

$$R_{hits} = 1.54 \frac{hits}{event} \times 233.5 kHz = 0.36 MHz$$

compare to 0.12 MHz found from mixed events simulations.

- depends on electron beam current (here ?), and energy ($\sigma_e(E_e)$)



Bremsstrahlung cross-check at 10 GeV

- in 25/12/00 campaign we have standalone Bremsstrahlung background simulation;
- using [background wiki](#) parameters (only total interaction rate is provided in the last bottom Table):

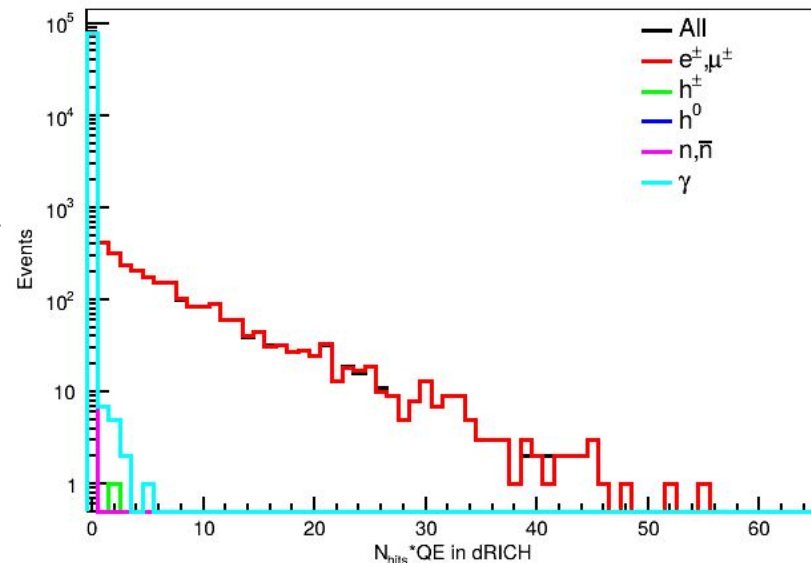
$$R_{int} = 3177.25 kHz$$

- dRICH receives 0.256 hits/event;
- Using this value we can estimate the absolute dRICH hit rate:

$$R_{hits} = 0.256 \frac{hits}{event} \times 3177.25 kHz = 0.82 MHz$$

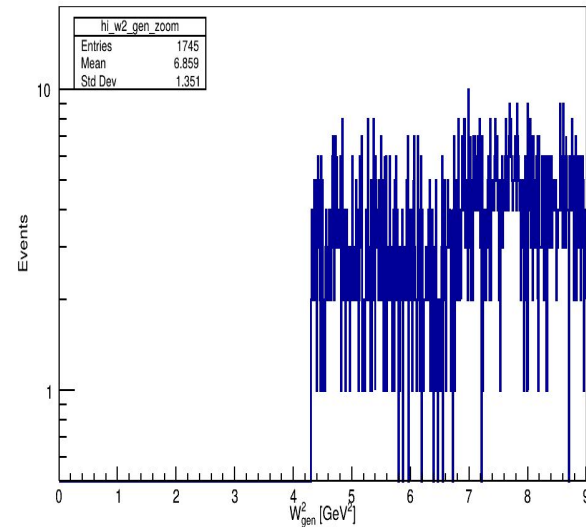
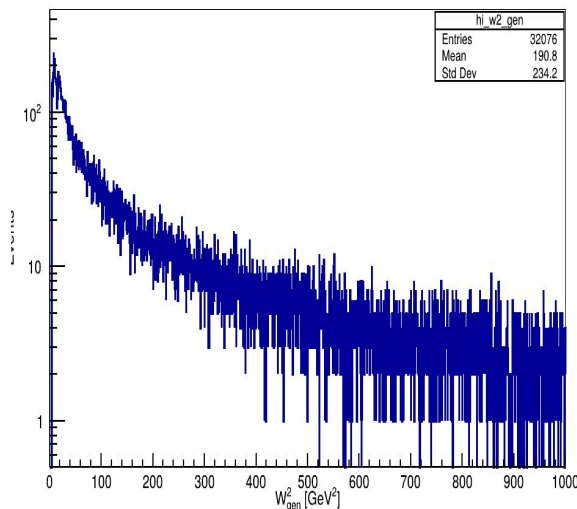
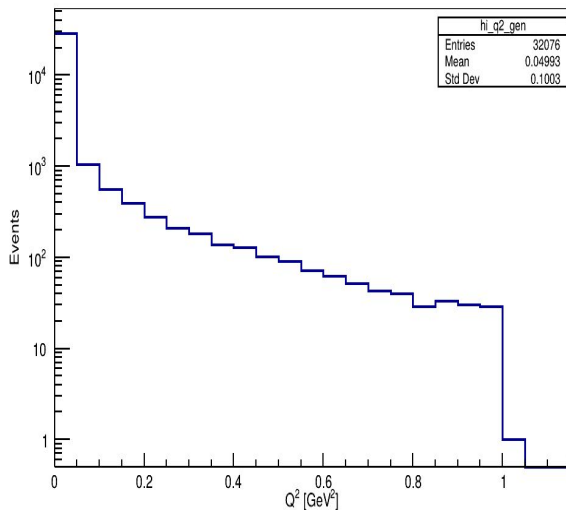
compare to 1 MHz found from mixed events simulations.

- depends on electron beam current (here ?), and energy ($\sigma_e(E_e)$)



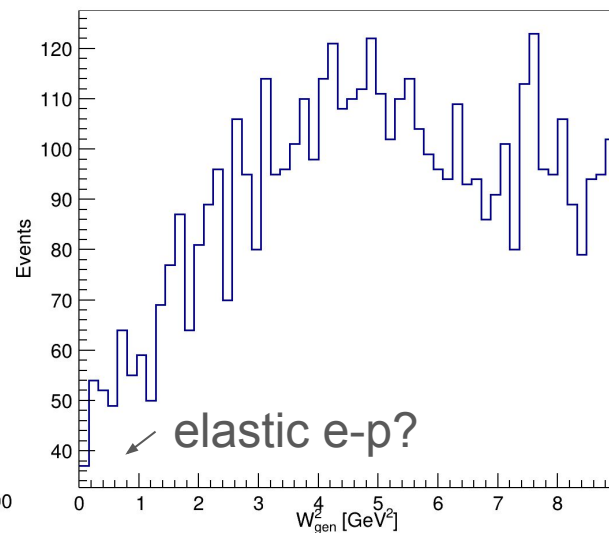
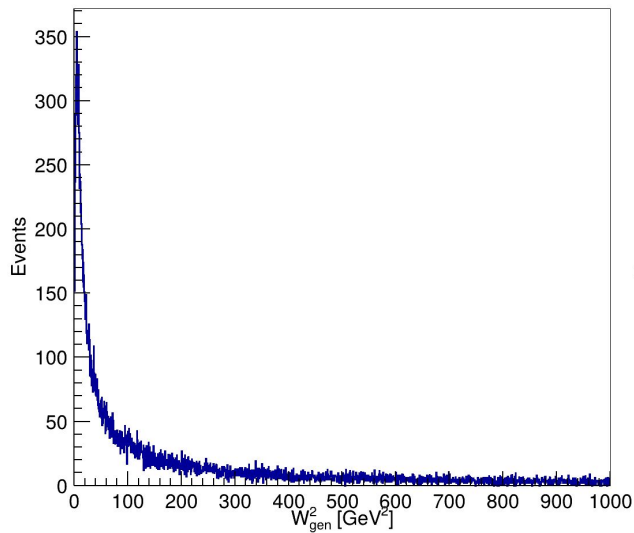
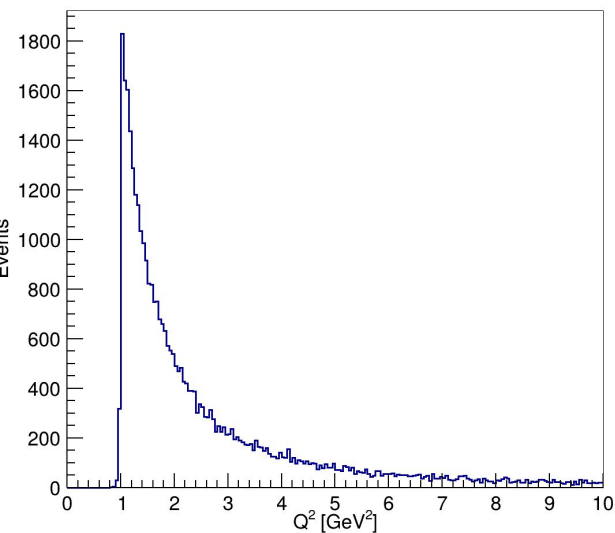
SIDIS Pythia6 $Q^2 < 1 \text{ GeV}^2$

- Q^2 distribution exhibits slow growth towards $Q^2=0$, with rapid jump at $Q^2 < 0.05 \text{ GeV}^2$;
- W^2 -distribution is decreasing with W , extending to very large values;
- minimal $W^2=4 \text{ GeV}^2$, excluding the elastic peak and the resonance region;
- for a complete rate estimates the elastic scattering, resonances (and possibly exclusive channels e.g. π^+n , π^0p etc.) must be simulated separately.



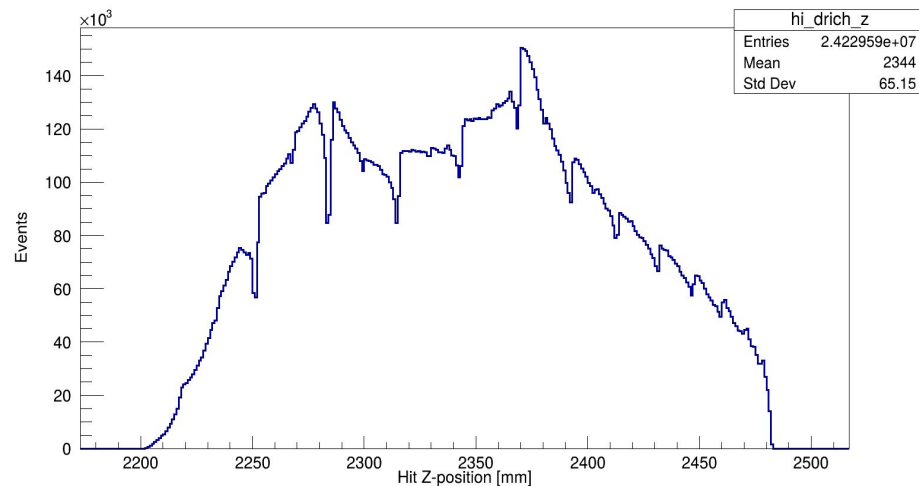
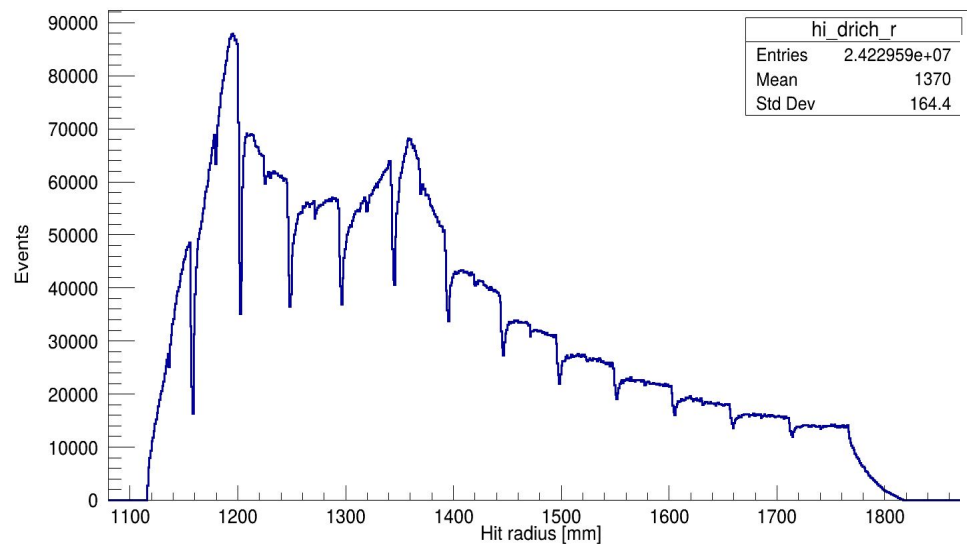
DIS Pythia8 $Q^2 > 1 \text{ GeV}^2$

- Q^2 distribution exhibits the expected $1/Q^2$ growth towards $Q^2=1$;
- W^2 -distribution is decreasing with W , extending to very large values;
- minimal $W^2=0$, the elastic peak and the resonances are not seen;
- for a complete rate estimates the elastic scattering, resonances (and possibly exclusive channels e.g. π^+n , π^0p etc.), but could be still OK due to duality.



Spacial Hit distributions

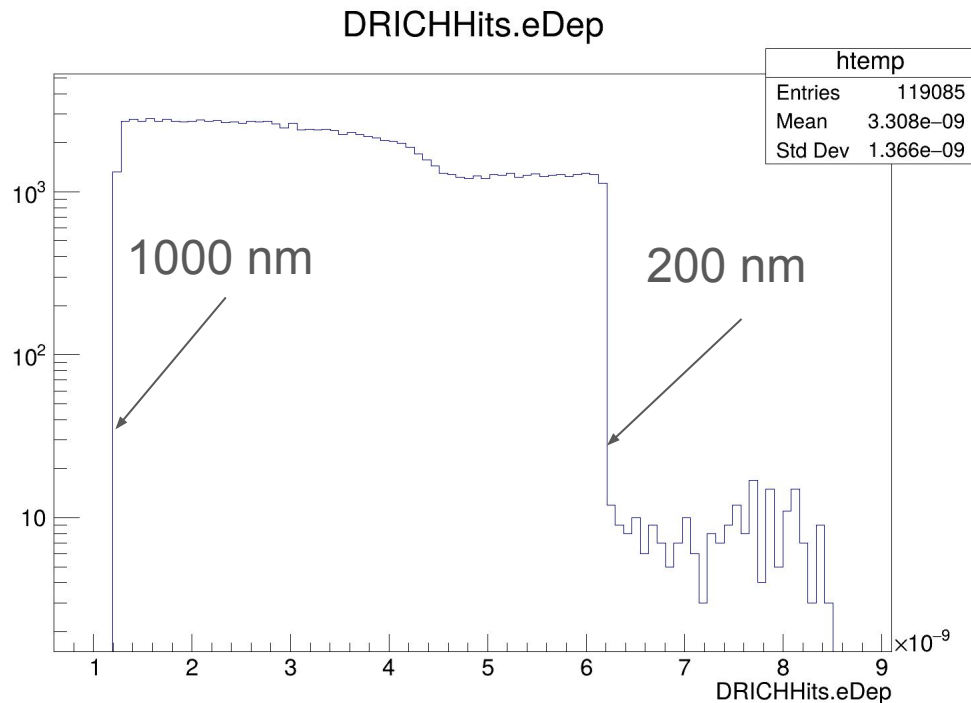
- hit rate depends on the radius from the beamline, but the dependence is not very strong - the difference in rate between closest PDUs and most distant could be >4 (depending on PDU density vs radius);
- dependence on Z is weak.



Hits accounted in DRICHHits

- even in the SIMulation file (FULL) “DRICHHits” branch contains only optical photon interactions;
- all direct ionization hits by charged particles (100% efficiency) and neutrals are missing;

1. ionizing hits must be added into DRICHHits branch;
2. these have to be treated separately from optical photons;
3. for neutrals the special avalanche layer ($\sim 2.4 \mu\text{m}$) must be defined.

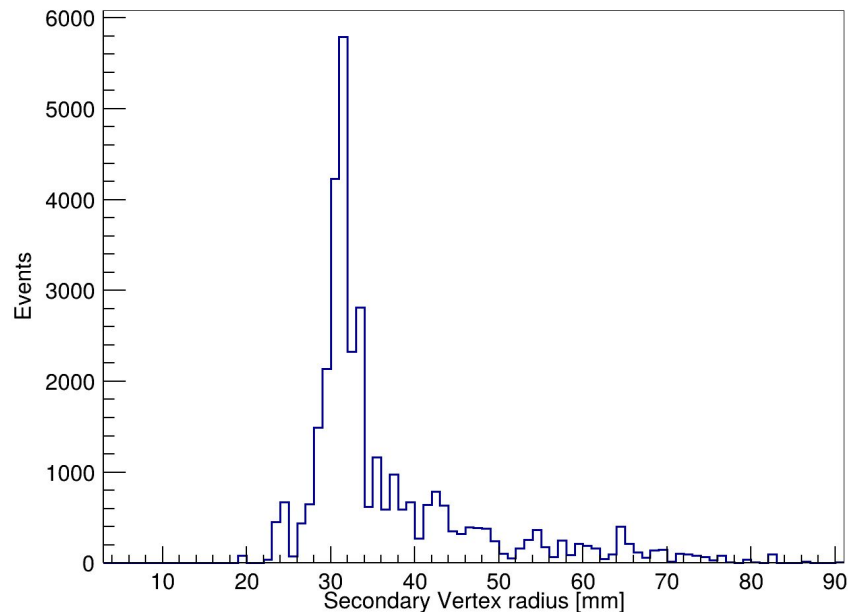
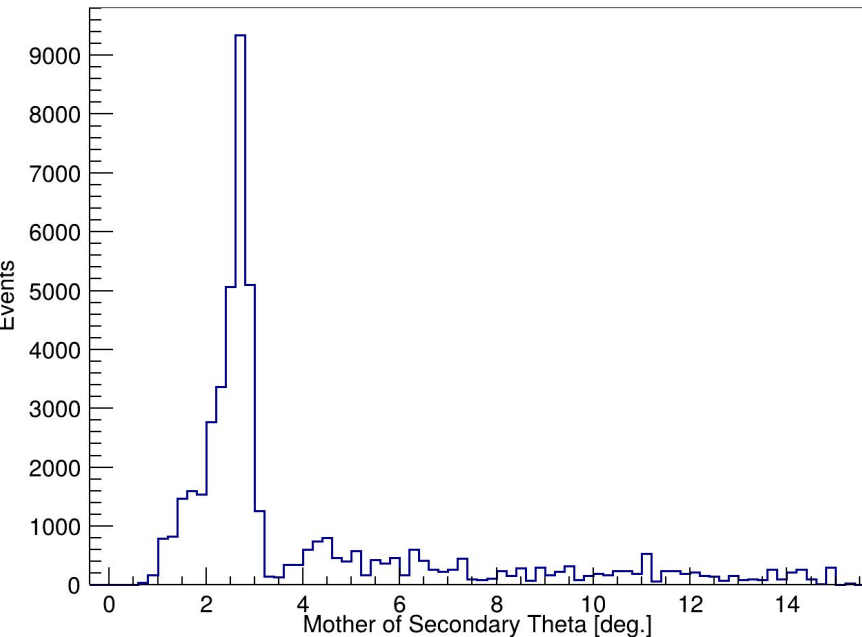


Summary

1. 99.9% of dRICH hit rate is due to DCR (at maximum damage);
2. excluding DCR, machine backgrounds account for 24% of dRICH hits;
3. 60% of (non DCR) dRICH hits is produced by secondary $e/\mu^\pm$, while the contribution of SIDIS $h^\pm$ is just 28% - **Are these electrons real?**
4. the contributions of elastic e-p scattering and resonance region (and probably exclusive channels) are missing at low Q^2 ;
5. dRICH (non DCR) hit rate increases at smaller radii by a factor >4 ;
6. Ionizing particles are indeed missing in simulated hits branch - need to check what happens shooting electrons against dRICH sensors.

Secondaries going in dRICH

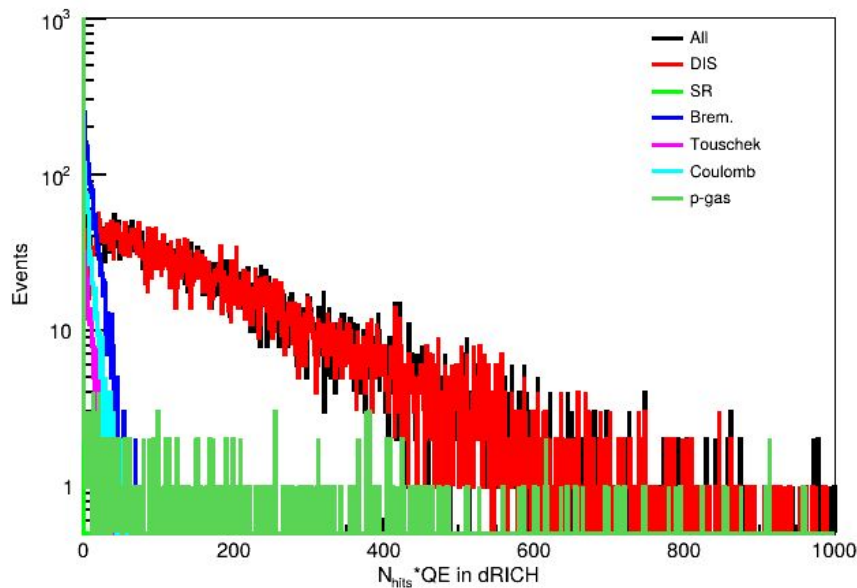
- particles (hadrons, gamma) producing most of secondaries at $1980 \text{ mm} < Z < 1983 \text{ mm}$ are produced at $\theta = 2.7^\circ$.
- the secondary vertex radius of 31 mm corresponds to a flange location.



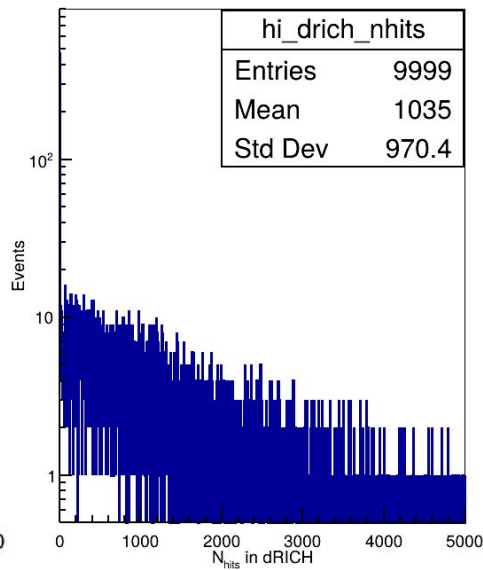
Number of dRICH hits per event

- observed number of hits/event~180 using "DRICHHits" branch and QE from <src/detectors/DRICH/DRICH.cc>;
- DIS and p-gas have similar mean value, while all electron beam backgrounds give small values <3;

QE-applied: sorted in sources



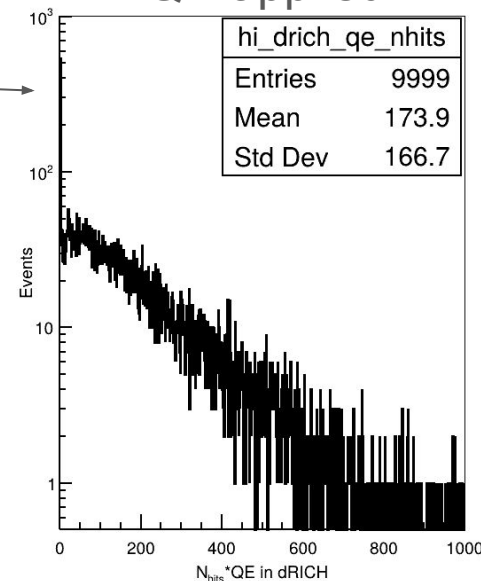
All SIM hits



mean

QE~21%

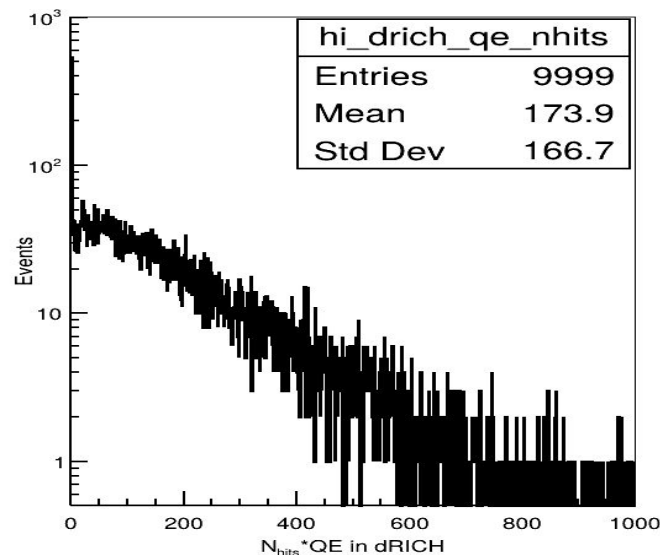
QE-applied



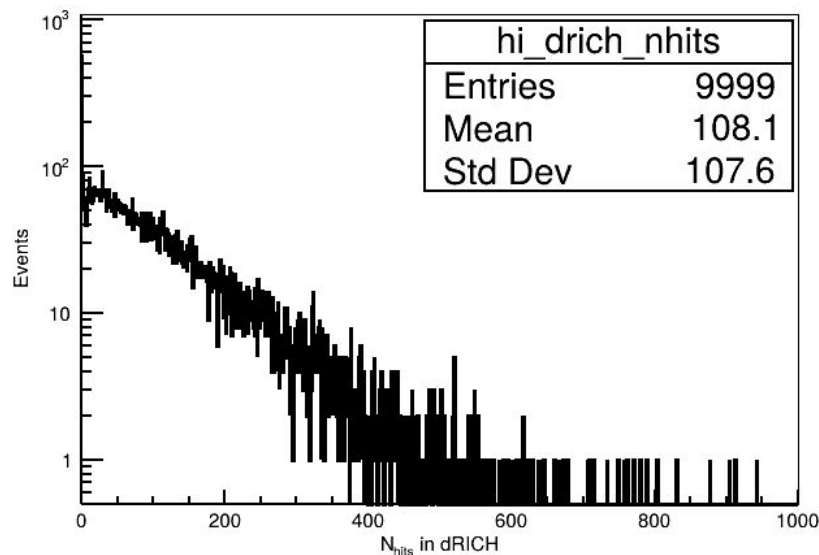
Number of dRICH raw hits per event

- using “DRICHRawHits” however gives 1.6 times less hits/event;
- why digitized hits are reduced? What is the base for hit removal?

DRICHHits: simulated hits * QE

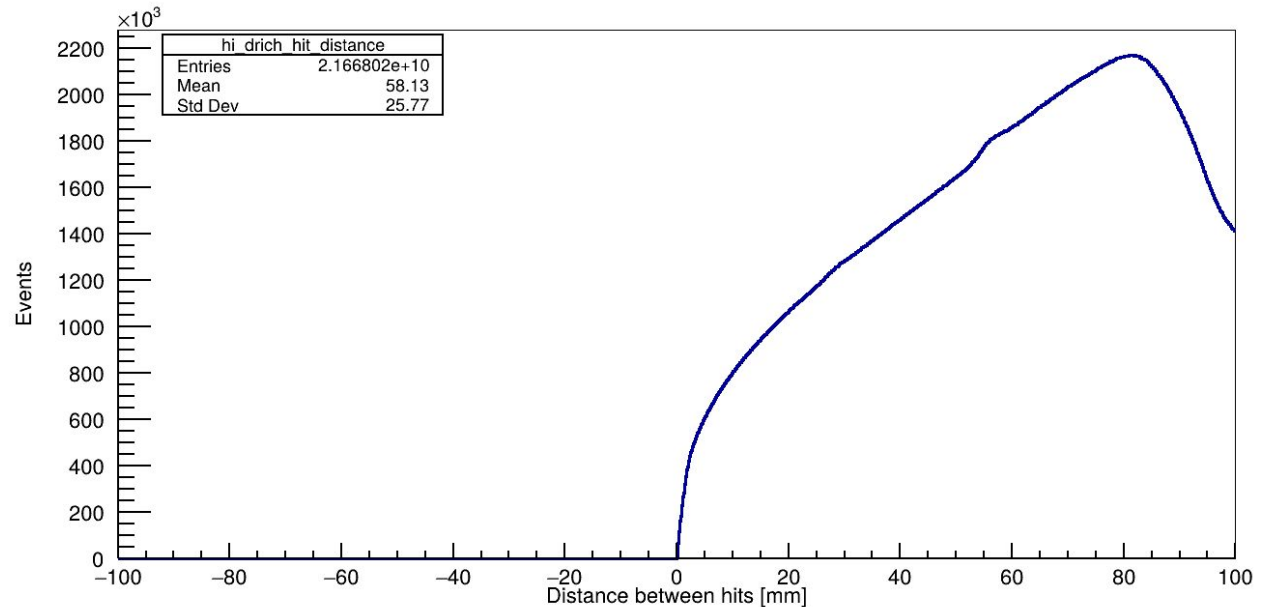


DRICHRawHits: digitized hits



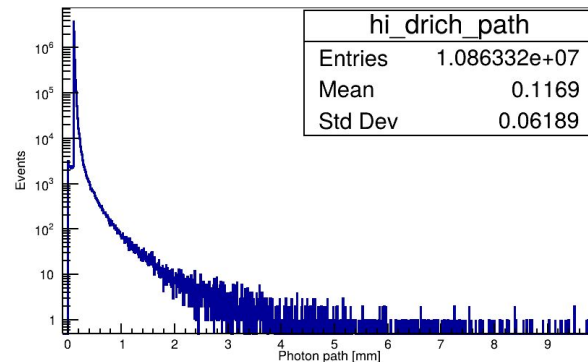
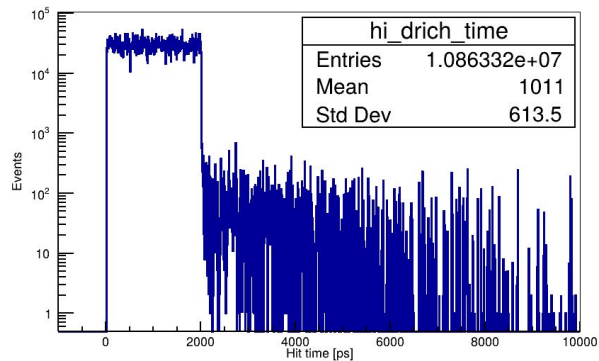
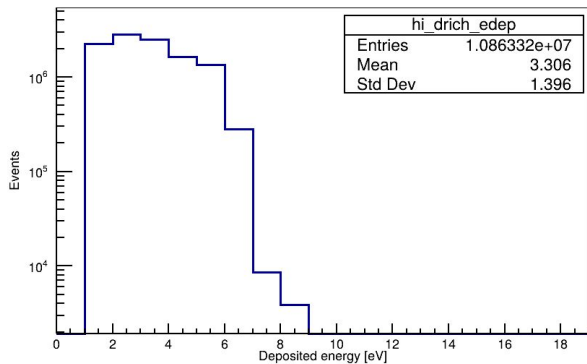
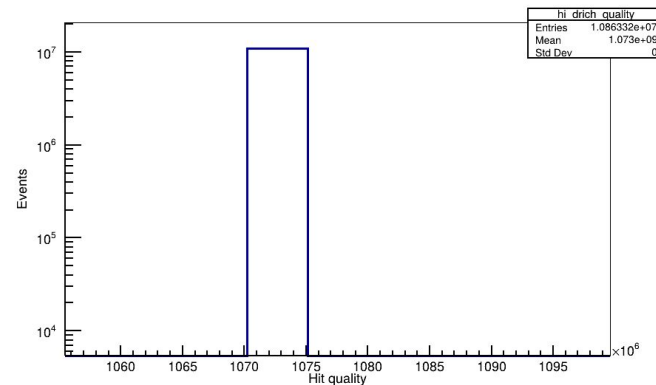
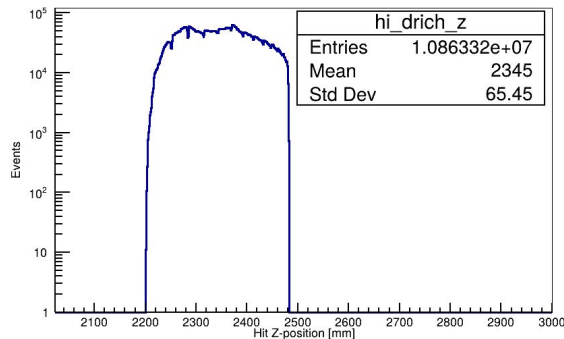
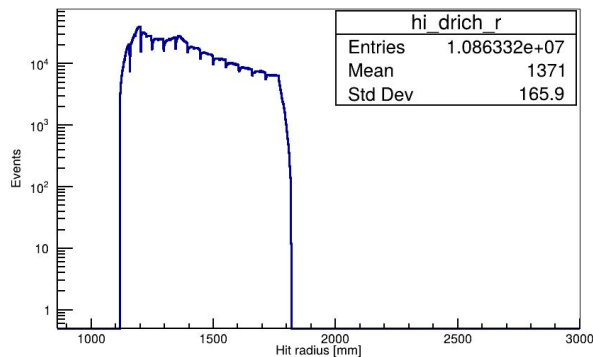
Distance between hits

- there no hits appearing in the same point;
- the density of hits does not seem to be high: >1 hit/SPAD is unlikely.



Can a part of hits be invalidated?

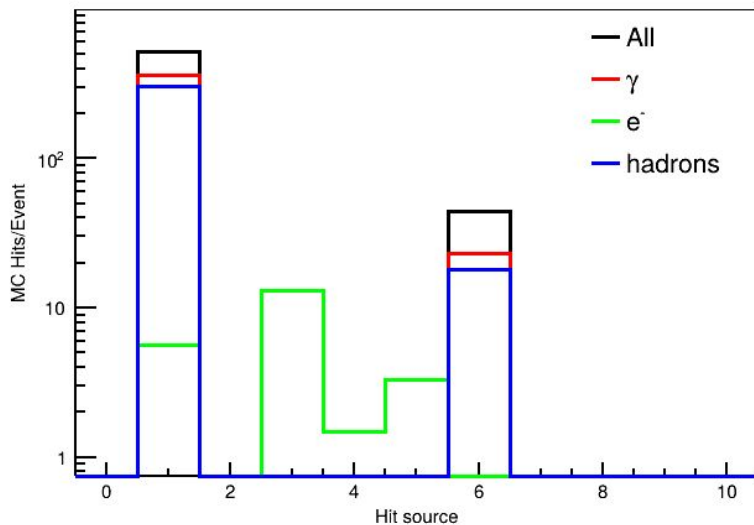
- all parameters of simulated hits seem to be reasonable, not clear why 60% of them is removed? Hit the same SPAD?



Results for 10x100 GeV in 2 us data frame

- total dRICH hit rate from $\text{SIDIS}(Q^2 < 1 \text{ GeV}^2) = 585 \text{ MC hits} = 108 \text{ hits/event}$:
(DIS=89.3%, Synchrotron Radiation $\gamma=0\%$, bremsstrahlung $e^- = 2.2\%$, p-gas=7.6%, other=0.8%);
- applied QE~21% and gaps between SiPMs in arrays.

26.07.1,Bkg_Exact1S_2us/GoldCt/10um/SIDIS/pythia6/10x100/q2_0to1 (320 files=32k events)



QE~21%,
gaps=13.5%

