Non-Flammable RICH Radiator Gas for Engineering Run

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Criteria for gas choices

(1) Appropriate index of refraction

- light yield
- ring size
- pion threshold

  $n - 1 \sim 8\ 10^{-4}$ is desirable

if $n-1 > 10^{-3}$, too many pions

if $n-1 < 3 \times 10^{-4}$ photon yield is too small

(2) Radiation length

- gamma conversion in gas

  --> backgrond Cerenkov photon
- multiple scattering

  --> angular resolution of ring

(3) Scintillation emission rate

--> background photon

PISA simulation shows that if emission rate is 1/cm per MIP, number of PMT hits due to the scintillation is about 100 PMT per event for Au+Au central collisions (HIJING)

(4) UV cut off

- photo-electron yield
- PMT UV cut off is ~200nm

Our Choice in CDR

* C_2H_6
* CH_4 for low multiplicity run or higher pt run
* C_2H_6 is factor ~2 better in e/π than CH_4 for Au+Au run

Search for non-flammable RICH radiator gase for ER

T.Frawley set up Web page for this effort.

http://fsuhip.physics.fsu.edu/~frawley/rich/gas_choice/rich_gas_choice.html

Many radiator gas are considered

Gas	Formula	(n-1)*10K	Pi-thr	dN/dl	UV-cut.	Thickn. Comm.	(% RL)	Flammable
Argon	Ar	2.84	5.85	.87		1	1.3	No
Nitrogen	N2	2.97	5.73	.91	140 nm	2	0.46	No
Methane	CH4	4.41	4.70	1.34	147 nm	3	0.22	5-15%
Carbon Dioxide	CO2	4.50	4.65	1.42	185 nm	4	0.77	No
Vinylidene Fl.	C2H2F2	6.9(c)	3.75	2.10		5	1.1	5.5-21.3%
Ethylene	C2H4	6.96	3.74	2.12		6	0.39	2.7-36%
Ethane	C2H6	7.06	3.71	2.15	160 nm	7	0.41	3-12.4%
Freon 22	CHClF2	7.7(c)	3.56	2.35		8	2.1	No
Freon 13	CClF3	7.82	3.53	2.38		9	2.4	No
Sulfur Hex	SF6	7.83	3.52	2.39		10	3.2	No
Propane	C3H8	10.05	3.11	3.06		11	0.61	2.1-9.5%
Chloroethene	CH2:CHCl	10.6(c)	3.03	3.22		12	1.7	4-22%
Freon 12	CCl2F2	11.27	2.94	3.43		13	3.2	No
Freon 114	C2Cl2F4	14	2.64	4.26	225 nm	14	4.1	No
Pentane	C5H12	17.1	2.38	5.21		15	1.0	1.4-7.5%
Freon 14	CF4	4.88(a)	4.5	1.49	131 nm	16	1.6	No
Freon 116	C2F6					17	2.5	No
	C4F10	15.5(a)	2.52	4.72	165 nm	18	4.3	No
	C5F12	19.4(b)	2.24	5.90	170 nm	19	5.2	No

many of them are rejected because

- it is flammable
- index is too small (small photon yield)
- index is too high (low pion threshold)
- too much scintillation
- UV cut off is at > 200 nm

We come to the following candidates that can be used unmixed

CO_2:

- Scintillation rate: 0.021 photons/cm of MIP
- Rad. Length: 0.77%
- n-1: 4.5×10^{-4}
- UV cut off: 185 nm

Freon 22

- Rad. Length: 2.1%
- n-1: 7.7×10^{-4}

Freon 13

- Rad. Length: 2.4%
- n-1: 7.8×10^{-4}

SF_6

- Rad. Length: 3.2%
- n-1: 7.8×10^{-4}

NOTE:

CO_2 can be a good replacement for CH_4

- refactive index value is similar to CH_4
- more radiation thickness than CH_4 or C_2H_6
- Scinitllation rate should be OK (a few PMT hits per events)
- gas handling system can be compatible with that for ethane

Freon 22, Freon 13, SF_6

- refractive index is similar to C_2H_6
- All of them are very thick in rad. length
- requires a different gas handling system

Simulation of RICH performance with CO2 and Freon 13

* PISA (all detectors inside of RICH)
* PISA RICH code updated to handle CO2 and Freon13
* HIJING central Au+Au events
  - 600 events for each of CO2, Freon13, C2H6 radiator (1800 events total)
  - primary emmision angle is limited to 60 degree < θ < 120 degree to save CPU time
  - Event vertex is fixed to Z=0
  - 150 events in $10<\theta<60$ and $120<\theta<170$ degrees are also generated for each radiator gas. Those events are merged with the 60 to 120 degree events to simulates events with angle cuts 10 to 170 dgrees.
  - single e tracks are merged to measure electron efficiency of pion rejection cuts

* Analyzed by STAF (RICH module only) with new MERGE facility of DIO

* "tracks" are reconstructed by fictitious perfect track reconstruction (i.e. use GEANT track ID) in RICH module
* For those "reconstructed" tracks, RICH PID cuts are applied. Cuts parameters were
  - NPMT....# of PMT hits in RICH
  - chi2....chi-squares value
  - timing..timing of the hit cluster
  - rdisp...displacement of RICH cluster center relative to the track projection

  NPMT and chi2 are the two main cut parameters.

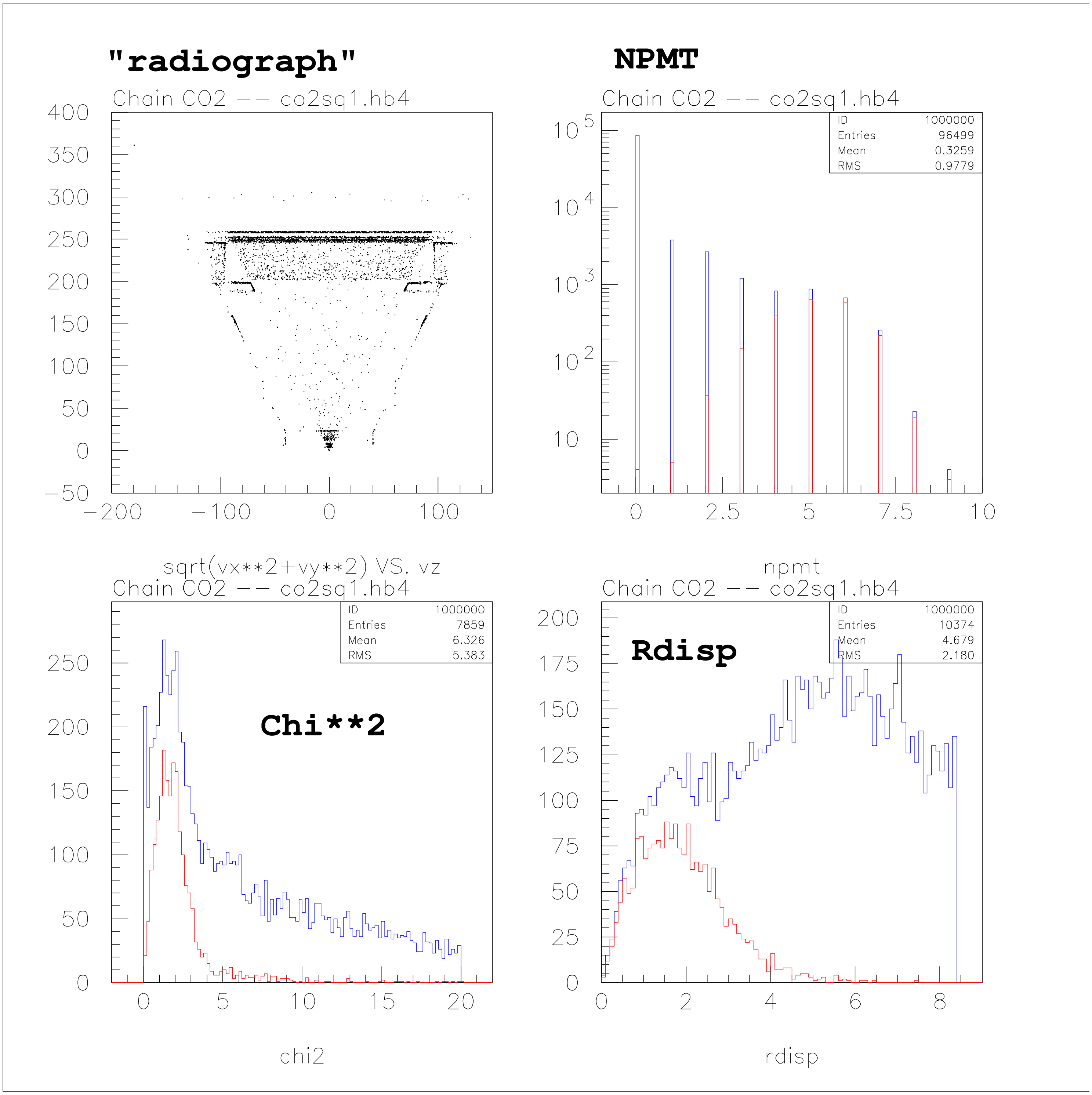
  For many sets of (NPMT, chi2, timing, rdisp), pion rejection factor and electron efficiency are obtained.

  --> pion rejection factor is obtained as a function of electron efficiency

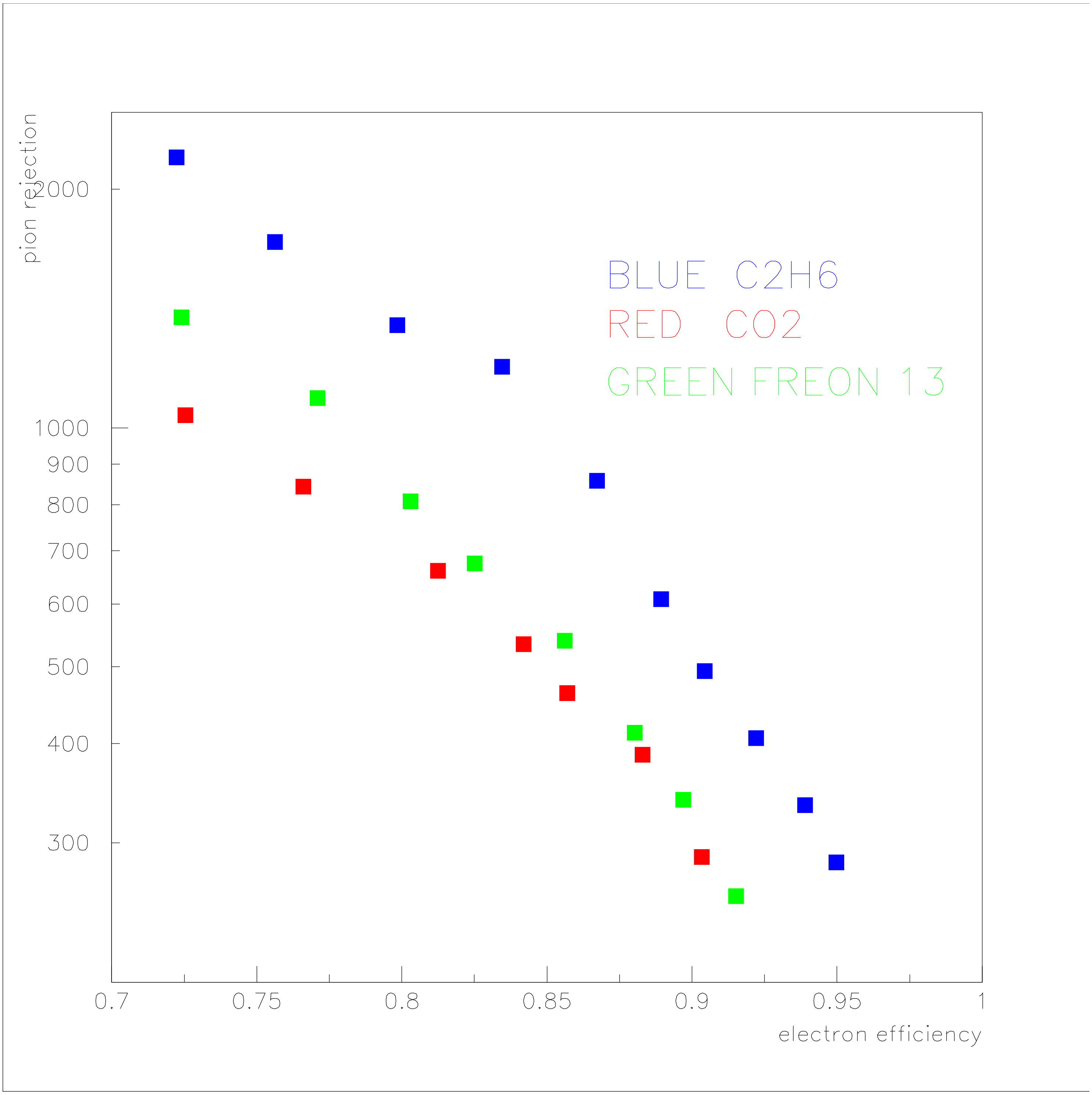
Distributions for CO2 radiator file

Blue: all charged tracks (pt>0.2 GeV)
Red: electron/positron tracks

(3/4 of electron tracks were merged tracks)



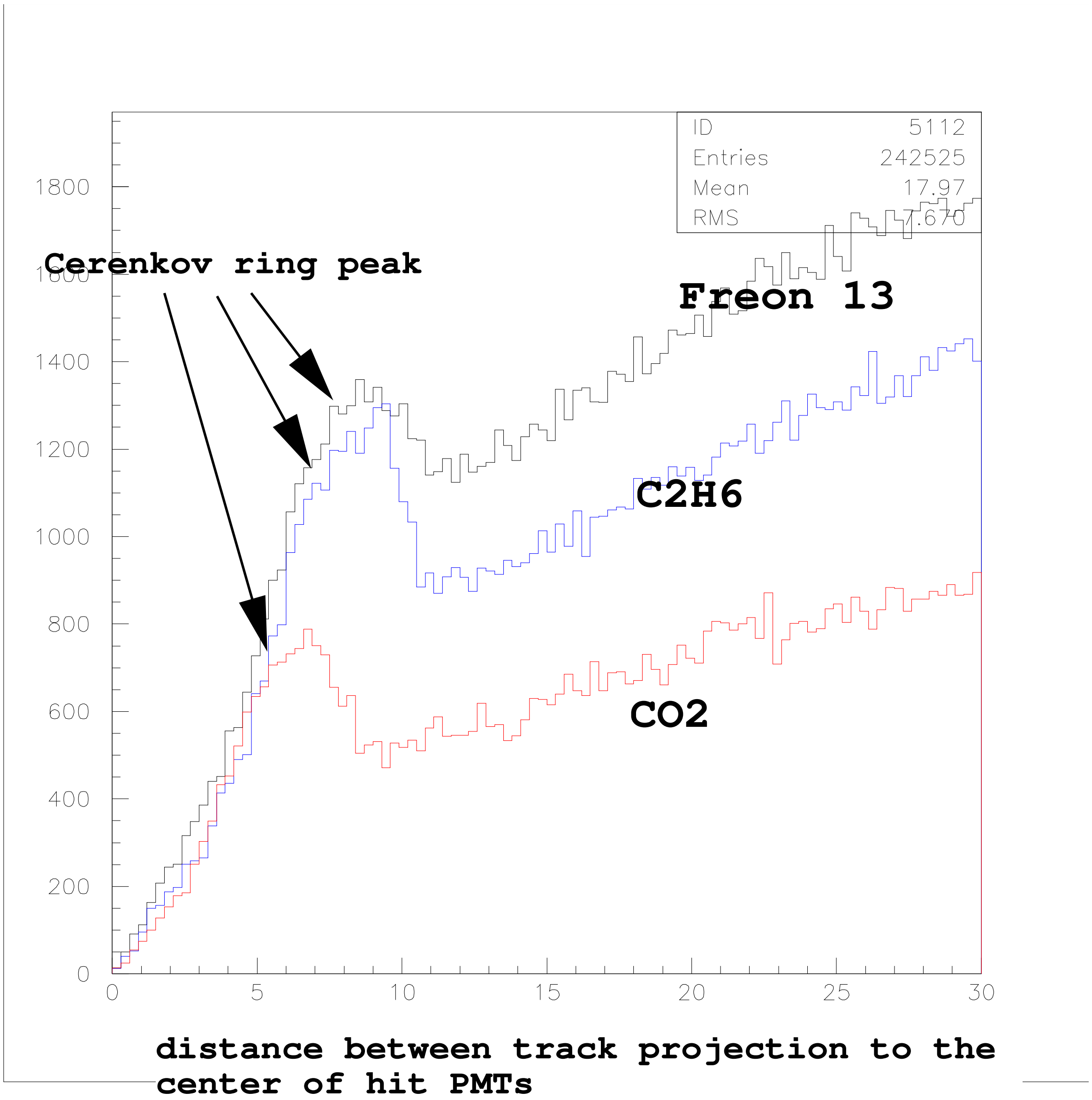
Result



C2H6 is factor 2 better than CO2 or Freon

e/p separation of CO2 and Freon is almost identical except for low electron efficiency region (ε~70%), where Freon 13's pion rejection factor appears to be better by ~30 %

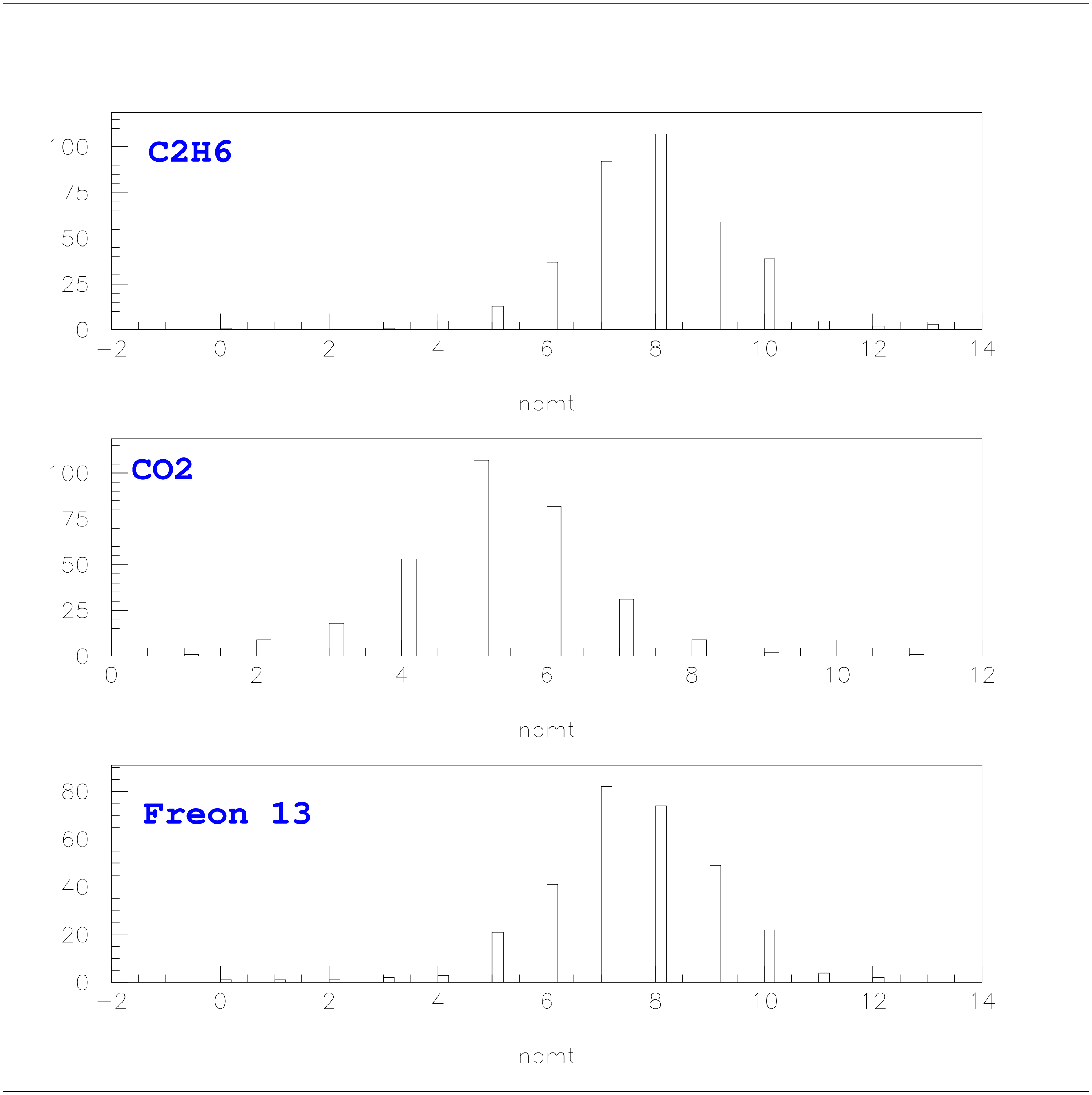
Why Freon 13 has poorer e/p rejection?



The peaks in the distribution are due to the Cerenkov ring. The continuum is from background hits. S/B ratio at the peak is a measure of RICH performance.

Freon 13 has higher background level because of gamma conversion in the gas. The width of the peak of Freon 13 is wider, probably due to multiple scattering. This results in poorer S/B ratio than C2H6.

Why CO_2 is worse than C_2H_6?
--- Photon statistics ---



# of PMT hits in CO_2 is at the edge to see a "ring" with good efficiency

N0 = 100 /cm is assumed in the simulation (Test beam value: 120 /cm)

Conclusion:

We have a good replacement for CH4...CO2

* small scintillation
* good UV cut off
* Radiation thickness(0.77%) is thicker than CH4 (0.22%), but is acceptable

CO2 is not a satisfactory replacement of C2H6.

* e/p separation is a factor 2 poorer

Freon 13 is not a satisfactor replacement for C2H6.
(The same thing is applied to Freon 22 and SF6)

* e/π separation power is degraded by factor 2. I think this is due to an increased level of background from gamma conversion in the gas.
* requires a quite different gas handling system
* environmental concern

We prefer CO2 as non-flammable radiator gas in Engineering Run.

* similar e/π separation as freon 13
* less effect to downstream detectors
* Gas handling system can be compatible with that of ethane.

C2H6 is better choice when safety issue is cleared.

- lower radiaiton thickness
- higher photon yield
- -> 2 times better e/π separation than CO2