Rad Hard Active Media for Calorimeters

E. Norbeck, J.E. Olson, A. Moeller, and Y. Onel
University of Iowa

- PPAC
- Čerenkov Liquid with Tungsten metal

Motivation

Radiation damage is a serious consideration for some of the LHC calorimeters even at the design luminosity.

The proposed factor of 10 increase in luminosity will require replacement of some detectors with rad-hard designs.

The research needed for the new designs must be underway now for the detectors to be ready for installation when they are needed.

What is a PPAC?

(Parallel Plate Avalanche Counter)

- Two flat plates
- Separated by 0.5 to 4 mm
- Filled with 5 torr to 1 atm of suitable gas
- 500 V to 3500 V between plates
- Excellent timing resolution.
- Excellent energy resolution for large showers.
- Signals large, can go directly into 50 Ω cable.

PPACs at one atmosphere

For PPACs in vacuum, for low energy heavy ions, plates must be as thin as possible—must use low pressure.

For large calorimeters, must operate at 1 atm

Small gas leaks are unimportant if gas is non-toxic and nonflammable.

Get useful signals from MIPs, ~a dozen primary electrons

Gas gain ~10^4

To keep voltage under 4 kV, use plate spacing ~0.5 mm.

To fine tune gain, HV may need to be adjusted for temperature and barometric pressure.

Best gas we have found so far is R134A
(after testing dozens of gasses and gas mixtures)

Tetra-fluoro-ethane

Used in automobile air conditioners

We found automobile grade as good as CP grade

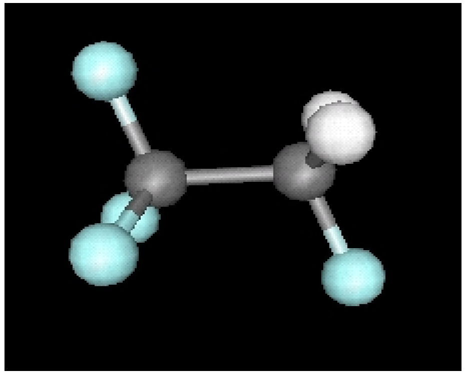
Excellent for anti-aging (use gold plated electrodes)

Little hydrogen (big signals from n-p)

Large stopping power (MW = 102)

Self quenching

No gas mixing required



F_3CCH_2F

Double PPAC for testing energy resolution

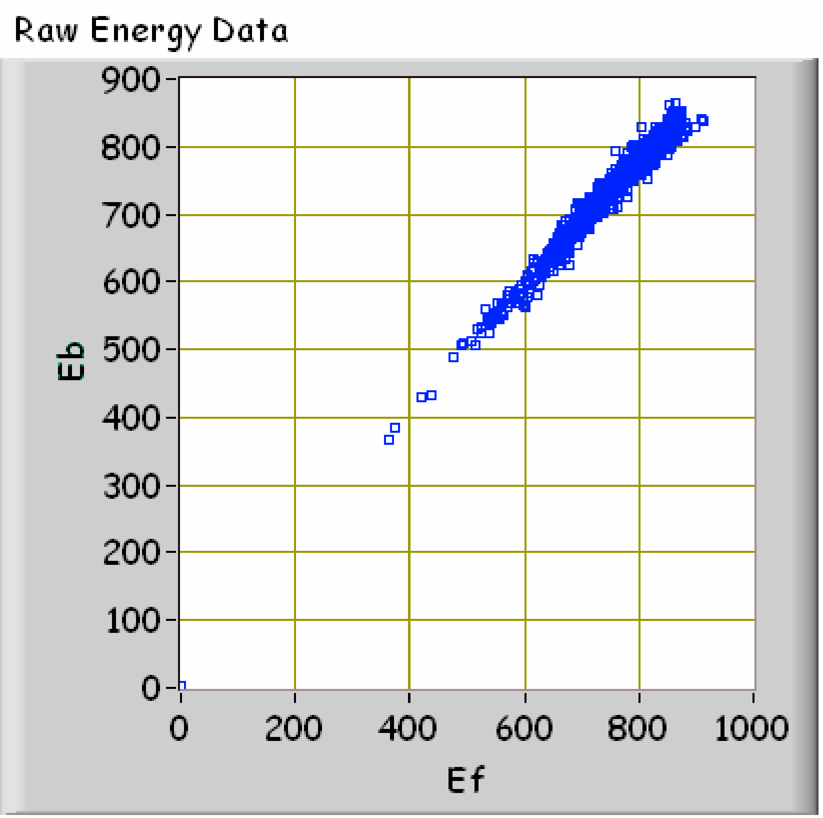
Diameter 10 cm

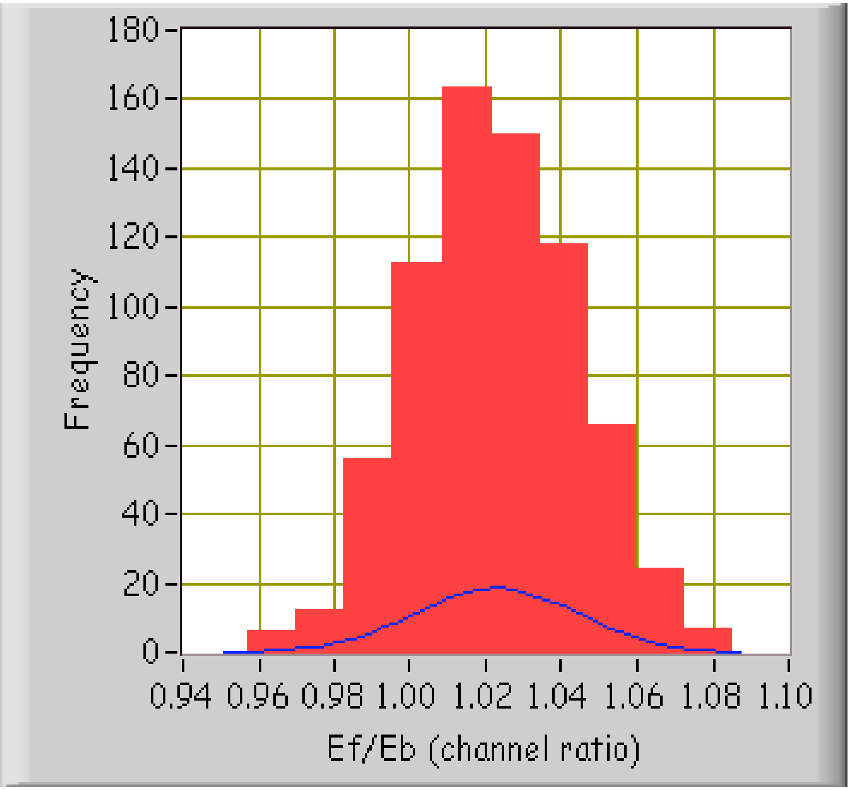
Operated with 30 torr of isobutane

Test with double PPAC

- Used EM showers from beam halo of 80 ps bunches (10^{10} positrons per bunch) of 7 GeV positrons from the Advanced Photon Source, at Argonne National Laboratory

Energy Resolution Data of PPAC Test at ANL





Ratio E_{front} to E_{back} is constant to within ± 2%

Signal Shape

Signal consists of a large, fast electron signal followed by a small, slow ion signal.

Speed of electron signal limited by RC time constant

R = 50 Ω (coax cable).
C is capacity between the plates
For a small area PPAC, <u>FWHM = 1.3 ns</u>

For large area double PPAC electron signal gone in 10 ns
Still fast enough for beam crossing time of 25 ns.

PPAC ion signal

- For most gasses the fast electron signal is followed by a small, slow (500 ns) signal from ions moving between the plates.
- With the highly polar R134A the ion signal is very small but lasts for 2500 ns.

PPACS can be made to have

- Excellent energy resolution
- Excellent timing resolution
- Radiation hardness

Desirable features for ZDC*

Radiation hard, useful even with luminosity upgrade

Signal output independent of position

Simple and low cost

*Zero Degree Calorimeter

Basic idea

Tungsten adsorber

Liquid for:

- Čerenkov radiator
- light pipe
- radiation shield for PMTs

Contained in polished aluminum tank, open at top

Liquid fills tank up to PMTs (65 cm deep)

Transverse leakage

Tests and simulations only for E far below 2.76 TeV

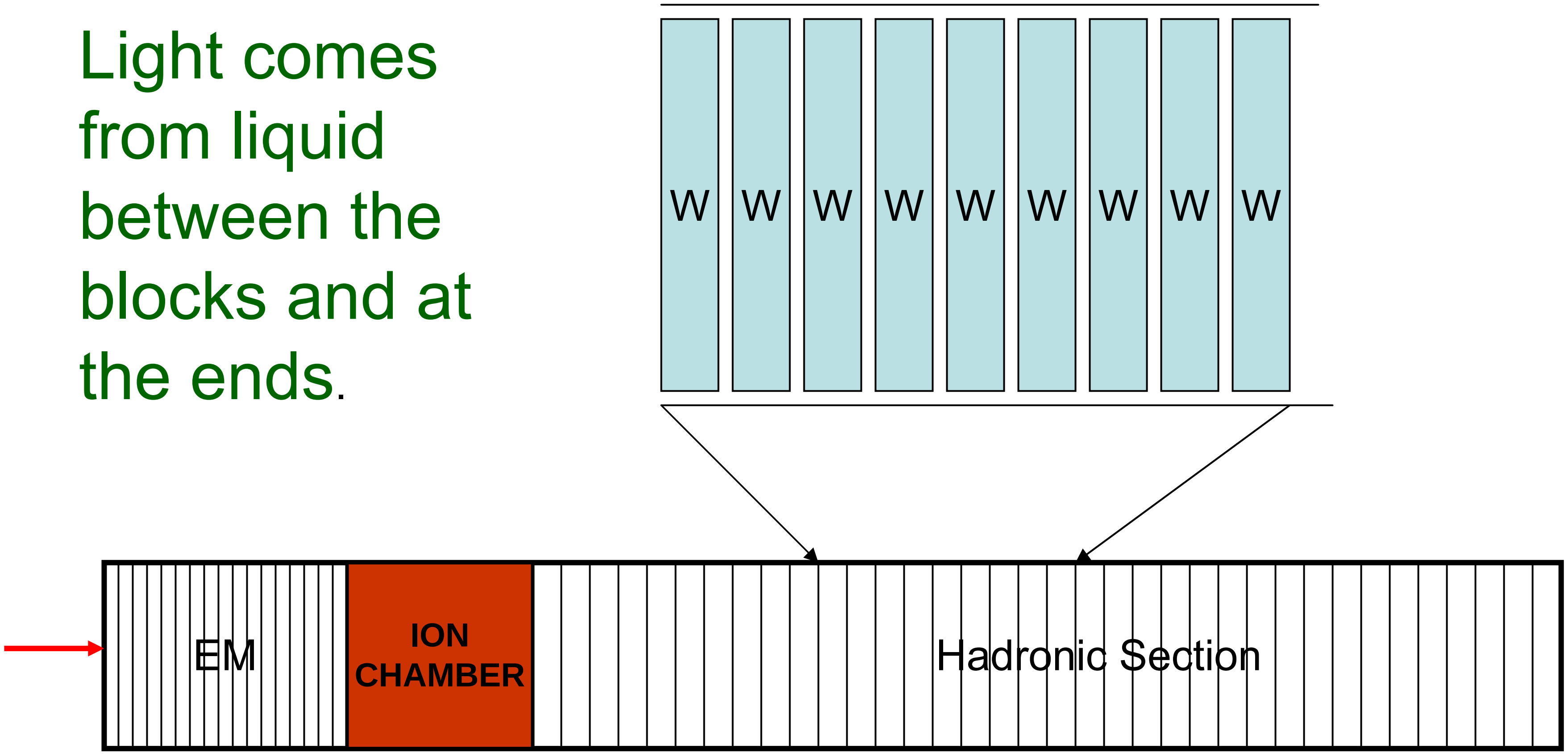
Leakage out side compensated by

light from Cerenkov fluid on outside edges.

Leakage out top and bottom compensated by

extra centimeter of tungsten at top and bottom.

Light comes from liquid between the blocks and at the ends.



View from the top showing the location of the W absorbers

Absorber

Tungsten blocks:

Polished and flashed with aluminum
for better light reflection

Hooks on top for easy removal

Horizontal subdivision

Use thin, polished aluminum sheets that go from the bottom of the tank up the level of the PMTs

Can subdivide in both X and Y directions

Fluid candidates

Requirements:

For maximum Čerenkov light

- High refractive index to generate more light
- Refractive index to match PMTs
- Transparent over wave lengths accepted by PMTs
- Low density (so shower particles have greater range)

Fluid candidates

For convenience:

- Not corrosive
- Not a health hazard
- Not too volatile or fire hazard
- Inexpensive in adequate purity
- Reasonable viscosity

Fluid candidates

Water n = 1.33 (low) ρ = 1.00

Advantages: availability, small spills evaporate

Disadvantages: Small n, corrosive, things grow in it

Mineral oil n = 1.46 ρ = 0.78

Advantages Can use MiniBooNE Mineral Oil (10^6 ℓ at FNAL)

Disadvantages: Cleanup messy

Ethylene glycol n = 1.43 ρ = 1.12 Antifreeze without additives

Advantages: Cleanup easy with water (not volatile)

Conclusions

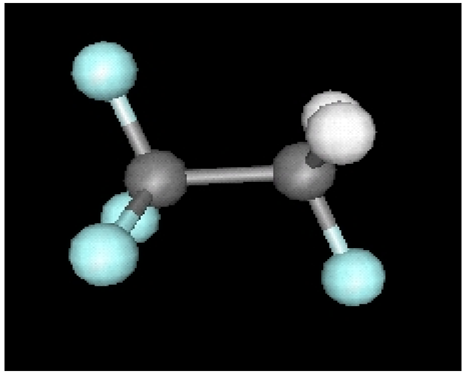
Need additional simulations to determine optimum size and spacing of tungsten blocks

A ZDC of this design

- Gives large signals
- Is inexpensive
- Can be constructed in a short amount of time
- Can be easily subdivided in horizontal directions

Tetra-fluoro-ethane

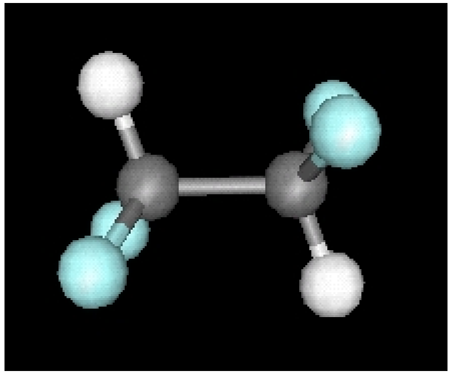
R134a



F_3CCH_2F

Large electric dipole moment
(about the same as for water)

Less stable form

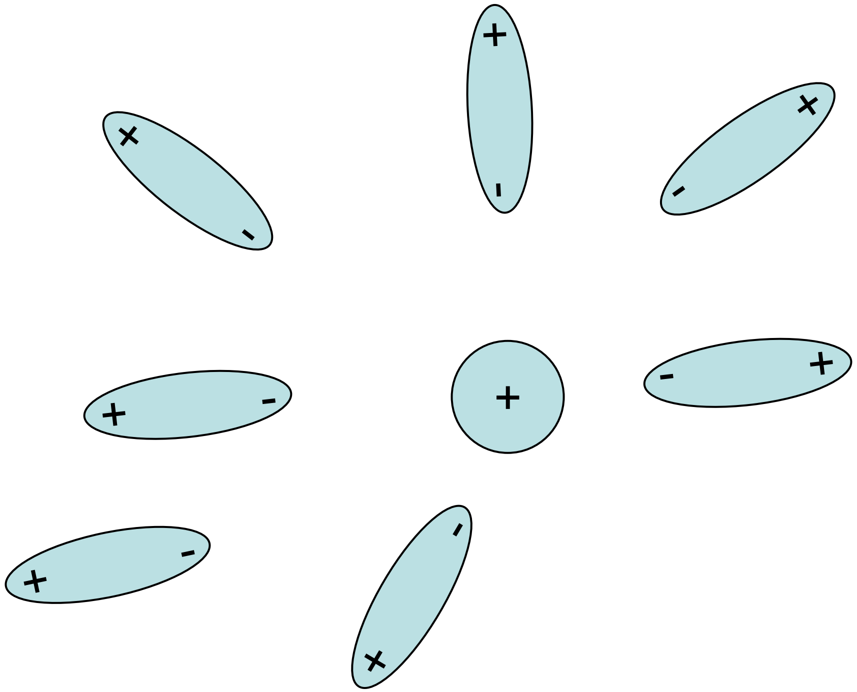


F_2HCCHF_2

Symmetric
No dipole moment

Fluorine atoms (blue) attract
electrons and so are negative

Moving ion slowed by cloud of polar molecules



Symmetric $C_2F_4H_2$ should have normal ion speed