Fermi Seminar

UofC/FNAL Timing Planning

March 17 2018

Action Items

- Could a “center” for fast timing be founded with UofC and FNAL levering the resources engineering/tech/facilities/labs at FNAL and Henry’s foundational work of the past 15 years at UofC plus University funds and resources
  - Build within the projects that DOE is pushing – work out details-- ask funding/proposal process (Helmut M)
  - Think more (can it be consortium of projects?) Write white papers etc
- How do we add funding for students (grad/undergrad) from DOE/NSF/Foundations? or elsewhere? Can be incubator for detector instrumentation training for young researchers
  - Programs exist
- How do we go from technology to physics and vice versa in the era of picosecond and femtosecond timing?
- Do we care about advances in fast imaging from medical developments (and other areas) and any synergies
  - Careful if it comes from outside the SC ; its “work for others”
- Have not answered the 1 ps question Henry asked in full detail

What are you thinking?

- 1 ps physics
- Detector development not sensor

Anatoly Ronzhin

- Tribute (no prints, informal discussions– make it work)

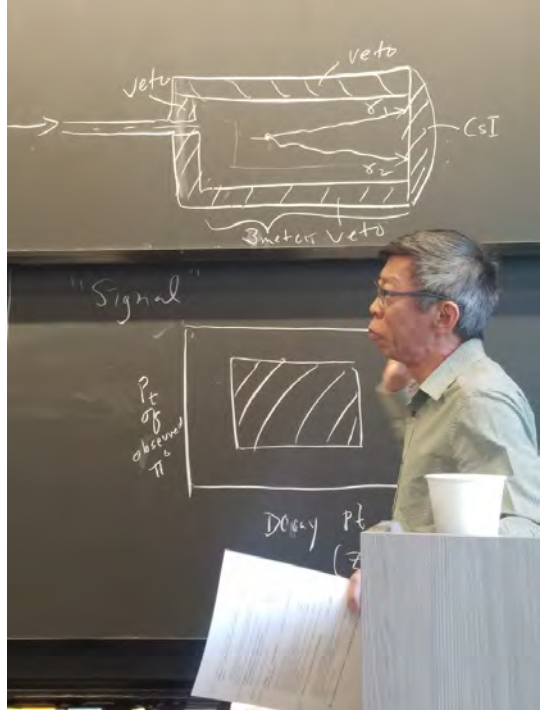
People and Facilities

- UofC & Fermilab
- Confluence of universities with FNAL
  - Detector facilities beyond industry (e.g. SIDET, and other physics based instrumentation facility)
  - Lab pre-eminent in facilities

Joe Lykken

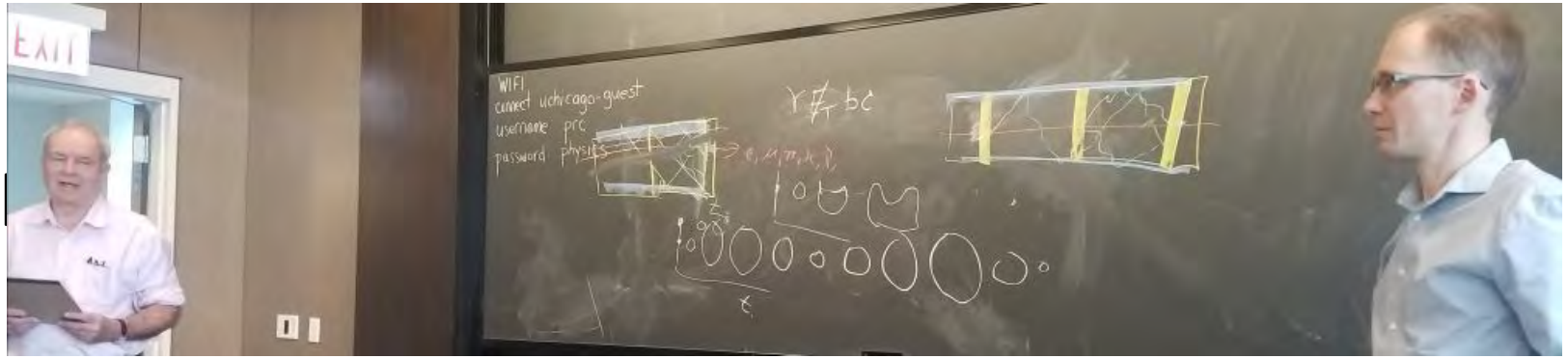
- 2 B USD program 20 years from now
- Upgrades/add-ons/vision for instrumentation
- FNAL partners w/ Universities (UofC obvious)
- No idea where the DM program will be 20 y from now **BUT**
  - Pulling technologies from other areas
  - Consilience with QIS
  - Precision measurements (g-2, mu2e, nu's)
  - "if I can do 2 or 3 orders of magnitude better what can I do"
  - People and spare cycles
  - Broad view of the scope and program at FNAL (SDSS was controversial 20 years ago, not now) → expand the definition of HEP
  - **Synergies with UofC under-exploited – new opportunities given maximally enlightened leadership**
- HL-LHC and beyond era → HE-LHC (20 y program but REALLY?)
  - But what differences in the detectors for that and what physics motivations??

Wah KOTO $K_L \rightarrow \pi(\gamma\gamma)\nu\nu$

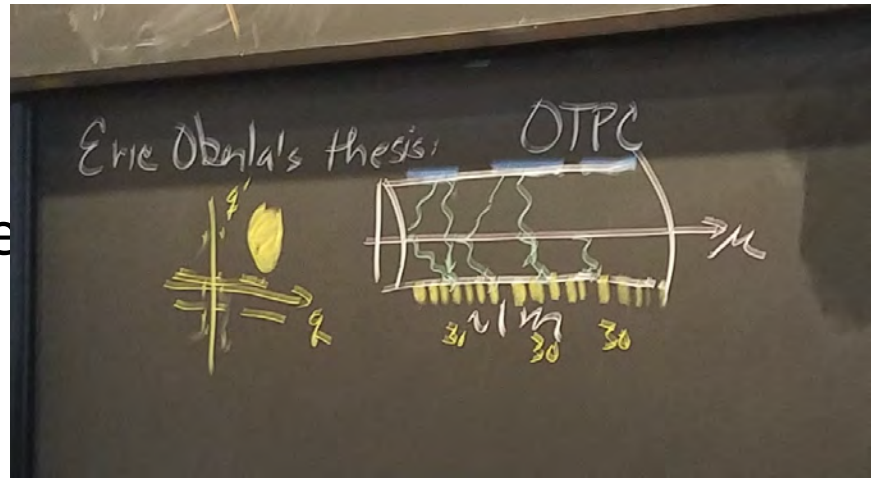


- 3 years SM reach (STEP1) order a few events
- 100 SM events (J-PARC) 3 years to build and 3 years to run (2-3 months useful time/year)
- $m^2=2E1E2(1-\cos\theta)$
- Observables: E1 E2 theta, z
- WANT to measure **P1** and **P2** for step 2 in all the detector
- 4pi detector and open the acceptance → instrumentation of side veto
- STEP1 stack of layers of 6 m long Pb with read out on the side
- STEP2 add perp to the beam scinitillator → time delay, angle, direction → ps project (0.5 ns resolution currently cannot measure the angle) → with a few **ps you measure everything and beat all the backgrounds**
- Forward CsI (time delay in the readout –ps timing can it help with the direction
- Geometry + ps timing
- Right now few hundred ps timing
- A. Para: 1. get timing of the incoming kaon (delay between kaon and photon) -- 2 path difference of the two photons (KOPIO wanted to do the kaon time measurement)
- Gato: you don't need – build a high granularity imaging calorimeter with
- Z =(p1/p2)-- 0.5% level measruement BobT 1ps=300 microns
- BOBT p->targe (30 cm?)t ->K ADAM: segment the target? STEP2 roataing target – tech details
- **1ps → FULL BGR UNDERSTANDING**

Henry OTPC E

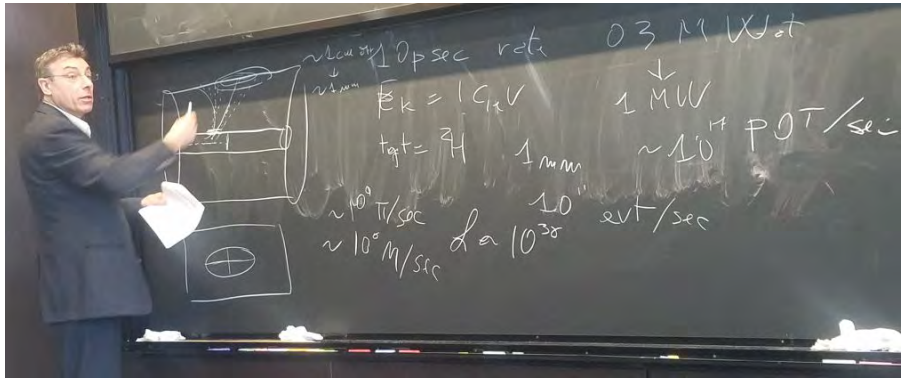


- Tracking in water
- Playing tricks in the time domain
- Separate pi-K up to 20 GeV with current TOF
- **Like Liouville's theore**m (play accelerator tech game
- Add water in the volume of a TOF (longer + mirror)
  - On axis spot-> circle -> bigger
  - Off axis spot -> funny things
  - Tilted → funnier
  - Measure angles and positions
  - Even with single sensor
  - γMETbc (from CDF- stop signature in GMSB, also SM low threshold- timing can be good)



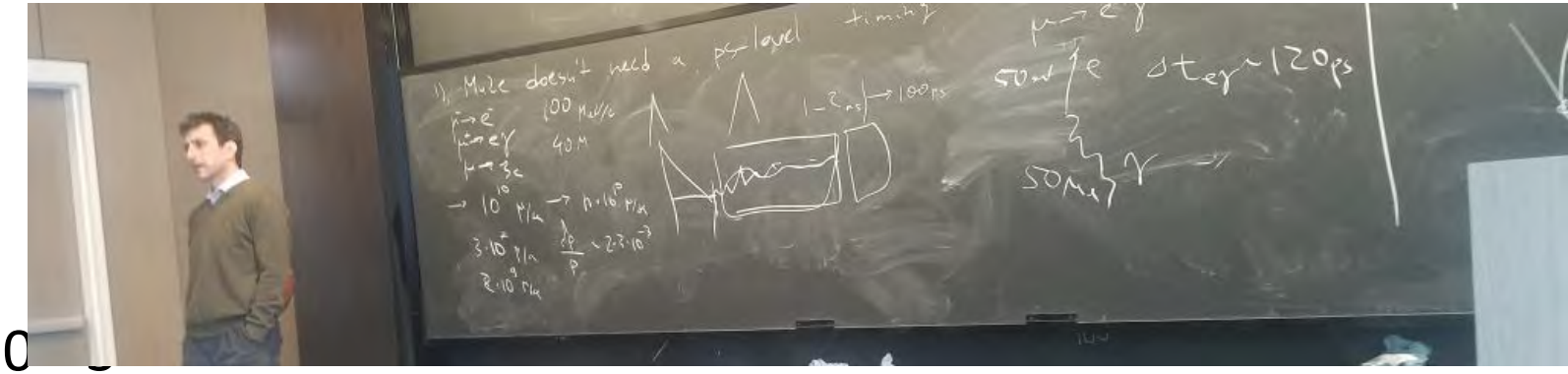
Gatto/Luciano (η factory)

- **OTPC (version gaseous) low energy beam (2 GeV p)** experiment
- 10 ps /pe (3 mm) in fixed target experiment
  - In a solenoid for e
  - Slice in time is slice in thickness of the radiator (reduce multiple scattering)
  - Many photons and many layers



- **Improvements w/timing**
  - Track reconstruction direction
  - β
  - TOF (μ-π separation at 6σ) up to 1 GeV
  - ++
- Hungary p+Li7→ Be→ γ(2e) (5th force experiment anomaly)
  - 17 MeV boson (photophobic)
  - Can do a p+H2→He3+γ(ee) (DarkLight in JLAB 10-100 MeV)

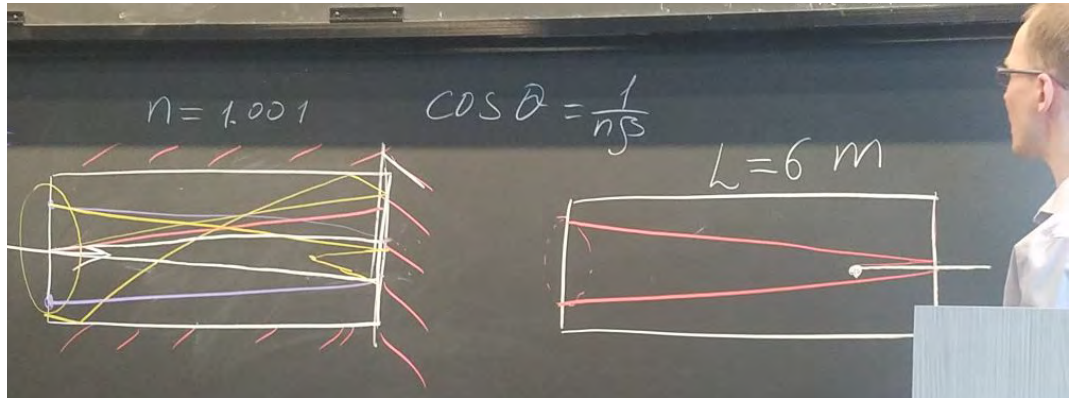
Pasha



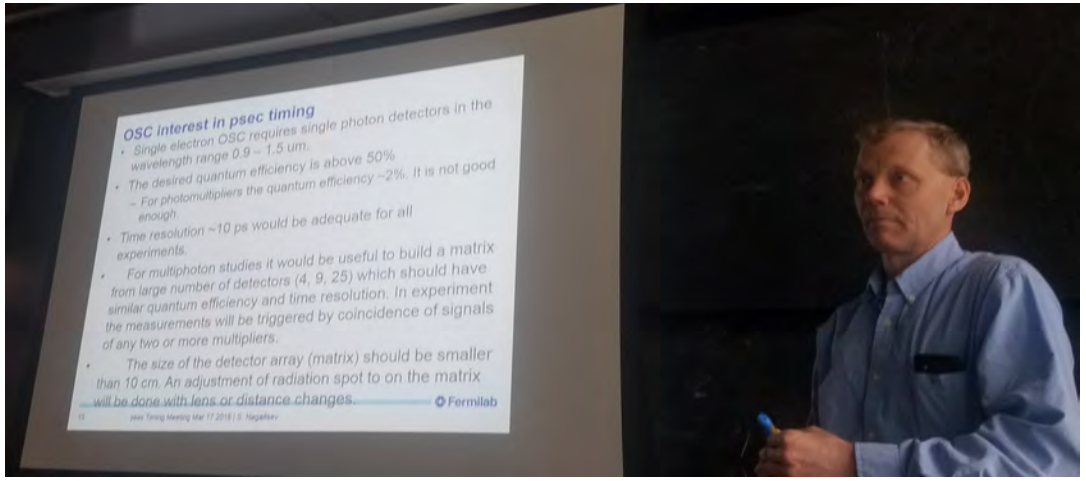
- **μe** high precision dP/P 2-3 10
- Stopped muons : 10^10 mu/sec→ PIP-II→ huge (N10^10) mu/s
- **Think what can we do with muons beyond mu2e**
- Beam background: π lifetime; e-μ separation 1-2 ns ; momentum scales 100 MeV/s (non-relativistic muons) (electrons at 40 MeV) -- With 100 ps resolution good e-μ separation
- **μeγ** MEG 120 ps (background limited) → improve by an order of magnitude energy and timing measurement at 50 MeV (10 ps timing) enough now MEG 3 10^7 with 10 ps timing can do it with 10^10
- **μ3e** 10 MeV 50 ns?
- **Frontier:** Ultralight sensors for precision tracking in low energy
- BOBT Access to the early muon decay spectrum -(muon lifetime experiments over a long range)

Andrei Elagin – RICH tracking in gas w/timing

- limited by photon statistics (Lipton)
- Reflection games
- In LAr 40 cm ellipse (optically LAr and water similar)
- Optical high pressure TPC (thinking is needed)
- With 1ps in the evolution – disambiguation of how many tracks ?
- How does it compare with normal RICH?
- How does ring evolves?
- What does timing add?
- DIRC more than RICH

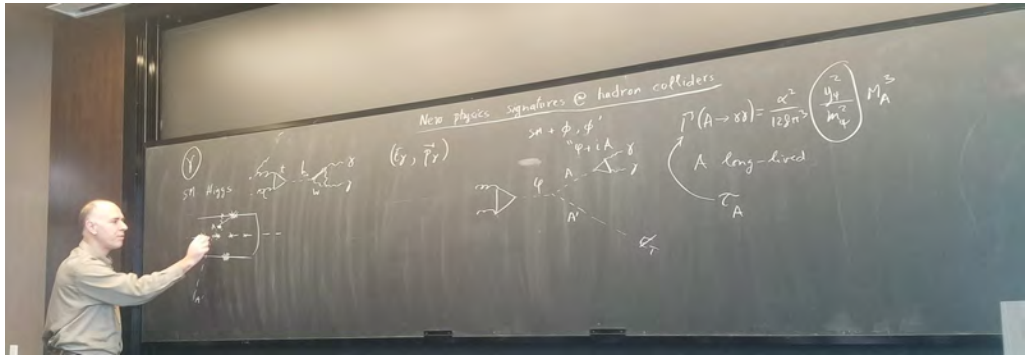


Sergei – ps in acceleration

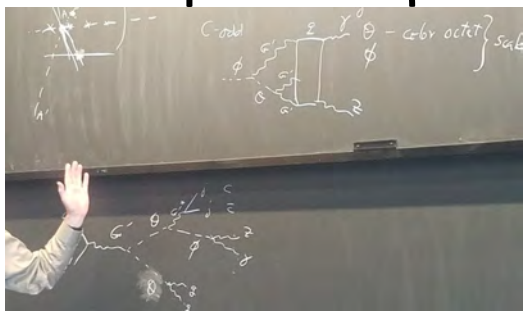


- Chirps and ps bunch structures (generating)
- @SLAC plasma wakefield acceleration
- Attosecond sync for X-ray imaging (pump and probe lasers/undulators etc) LSs (synchronizing)
- Measuring ps intervals (IOTA) quantum properties of undulator radiation, optical stochastic cooling (going from strong pulses to single particle pulses)
- **Quantum science : Picosend resolution for 500 nm photons (move from quasiclassical to full quantum understanding of QED)**

Bogdan NP@HC (LLPs γ,τ)



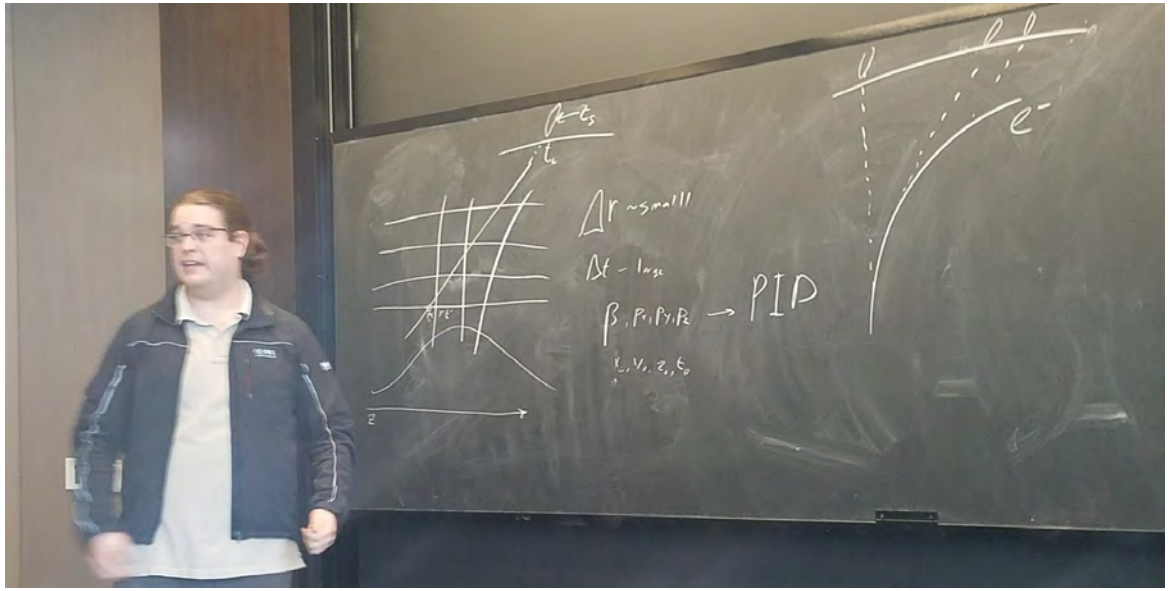
- SM Higgs, SM+scalars (ϕ(ϕ+ιA) ϕ')
- ϕ-> AA' → γγ A' A =100 GeV long lived, and A' MET → MET+ displaced γ's
  - Use timing to get the decay vertex with precision
  - Lifetime of A, width → underlying physics scale



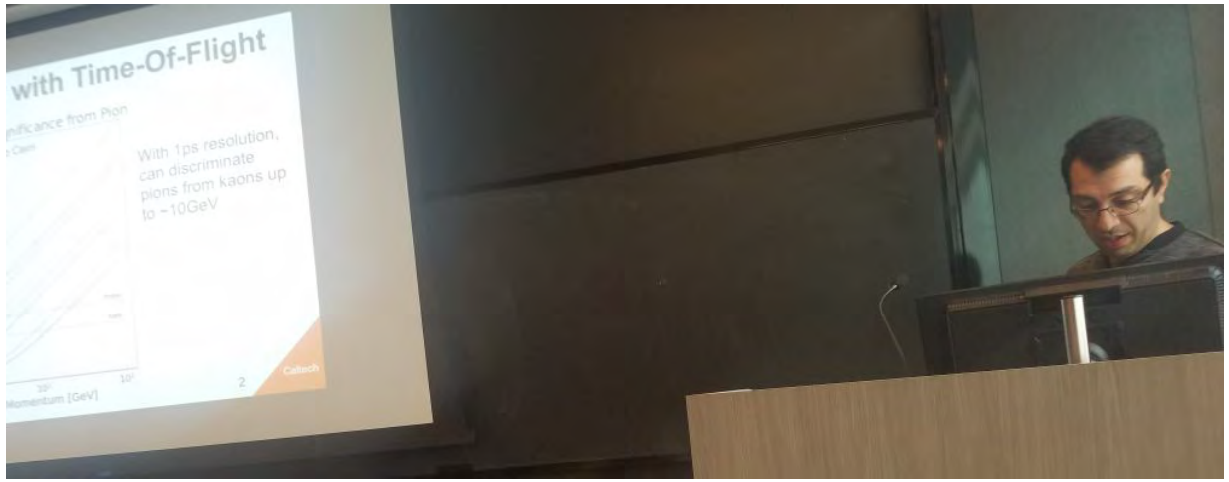
- More generic η→ AA→ 4γ
- SU(3)xSU(3)→ SU(3) g+G'(heavy gluon - color octet spin 1) color octet scalar θ, ϕ(C-odd) three loops decay with ϕ(G's) → Zγ (+cc) long lived and prompt etc
- Taus in NMSSM large tanβ λ_τ= 0.087 mm, γ_τ=150 $\lambda=\lambda_\gamma$=1 cm (π+π0)
- MarcelaC Heavy Higgs-> H+X ? (to follow-up)

Lindsey, fast timing tracking/LLPs

- PID with tracking up to 10 GeV
- fs timing or large tracking volumes remove the need for calorimetry
- **“the timing will tell you everything you need to know”**



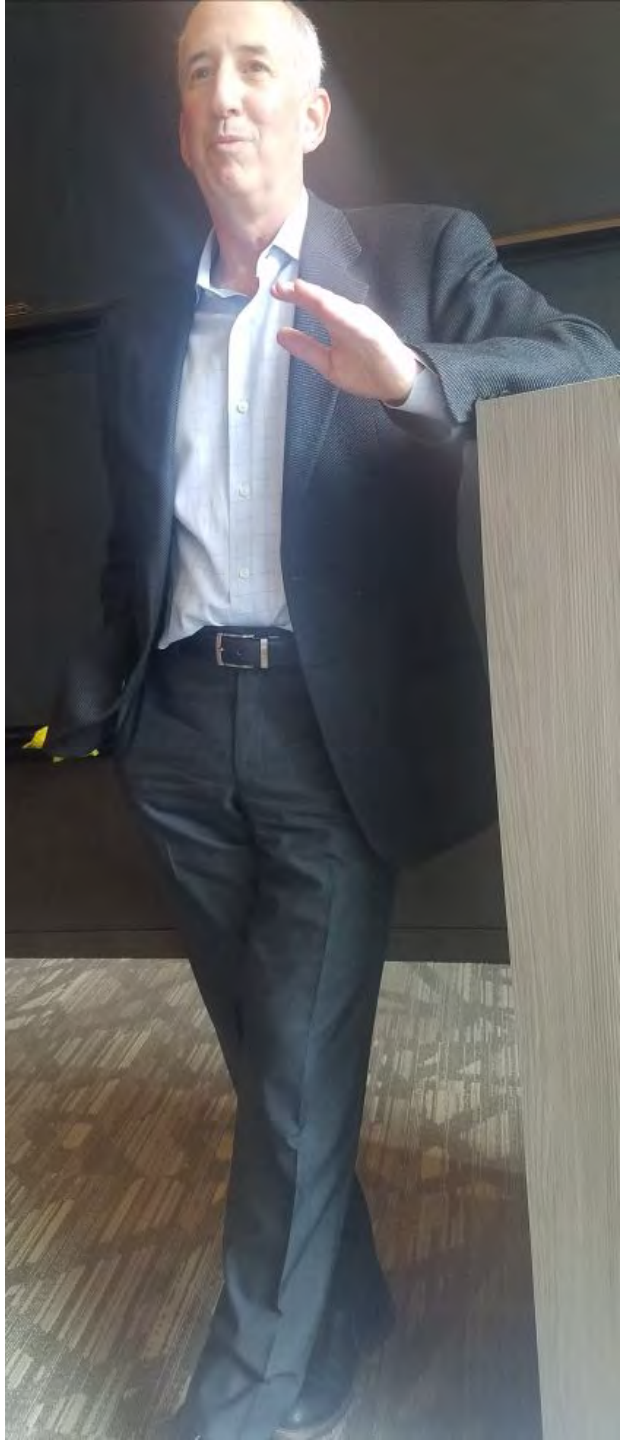
Artur, Hadron Collider



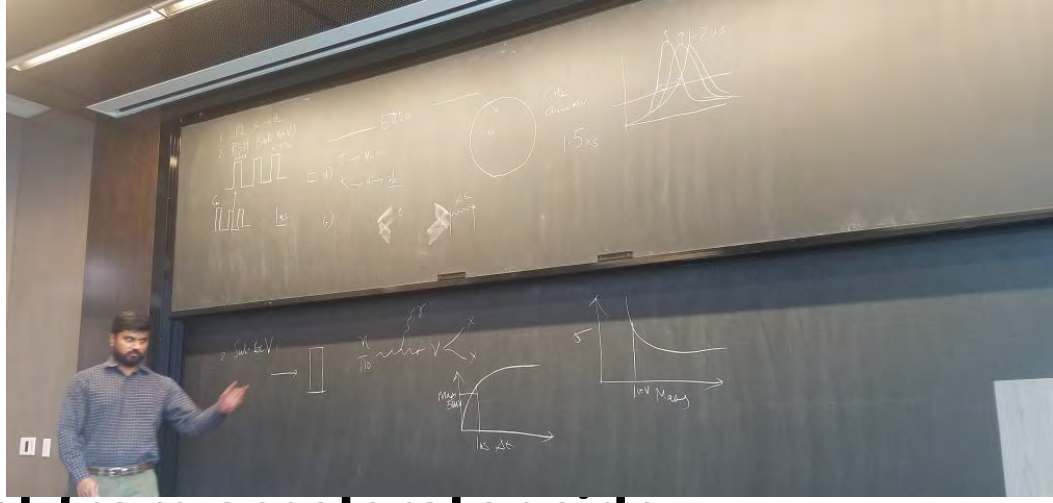
- Pile-up
- Higgs
- physics objects (MET etc)
- SUSY characterization (stop measurement)
- PID (SM and exotics)
- LLPs
- **Need to answer question of 1 ps value**

Eric Isaacs

- All great new physics and science emerges from new instruments (Cronin)



Dharmapalan: SBN/DUNE

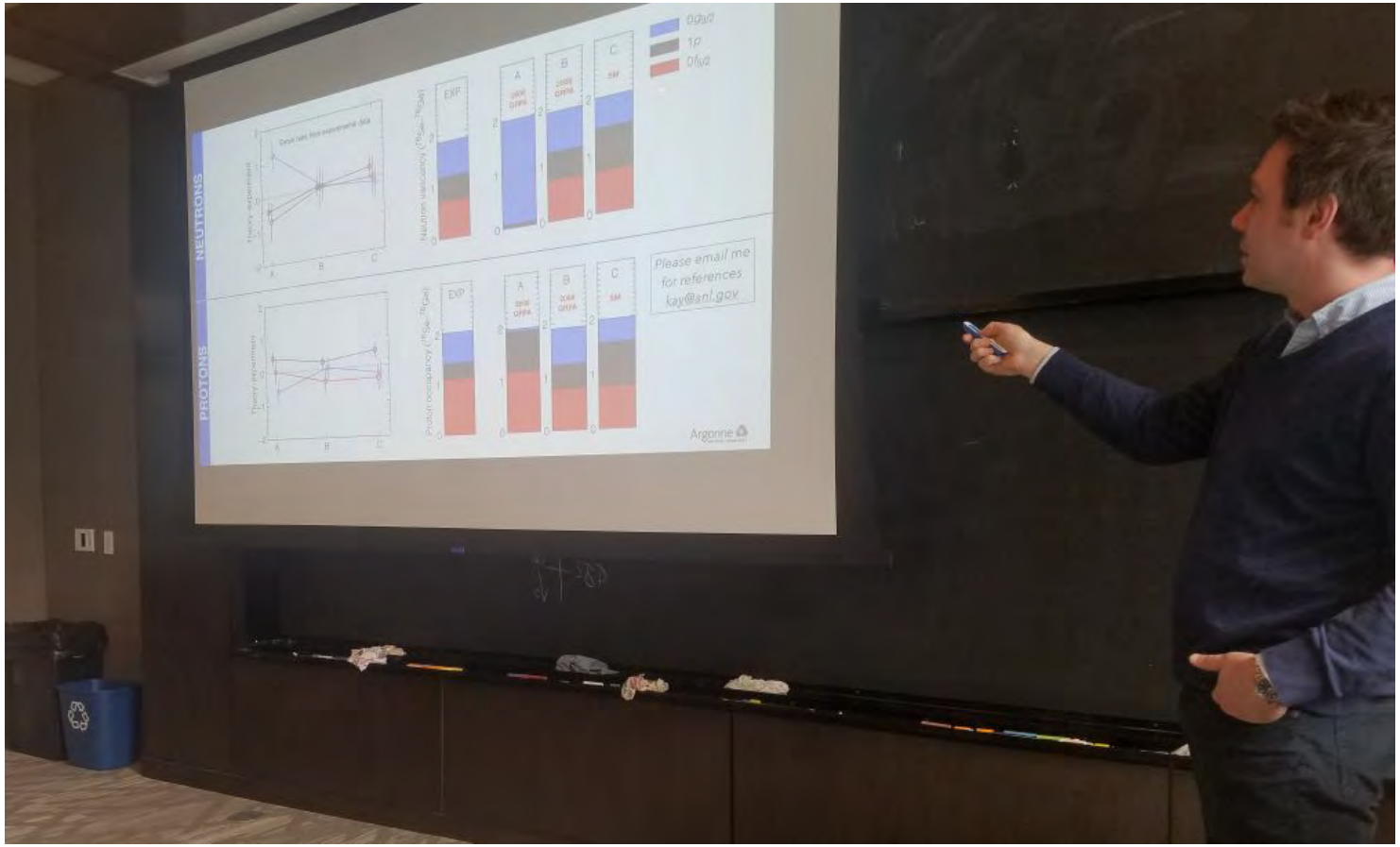


- **Beam time structure information v important from accelerator side**
- Oscillation side
  - Background separation
    - (1ns – beam & reco resolution) MiniBOONE
  - Need beam and reco resolution at the same
- Light DM (sub GeV)
  - Down to 50 MeV with 1ns → below 50 MeV needs ps
- **Tracking in the target?**
- **DUNE Is moving away from timing (LAr is slow) but maybe some ideas on the Cerenkov component (not much thought on this)**

Pedro 0νββ (10^44 ps)

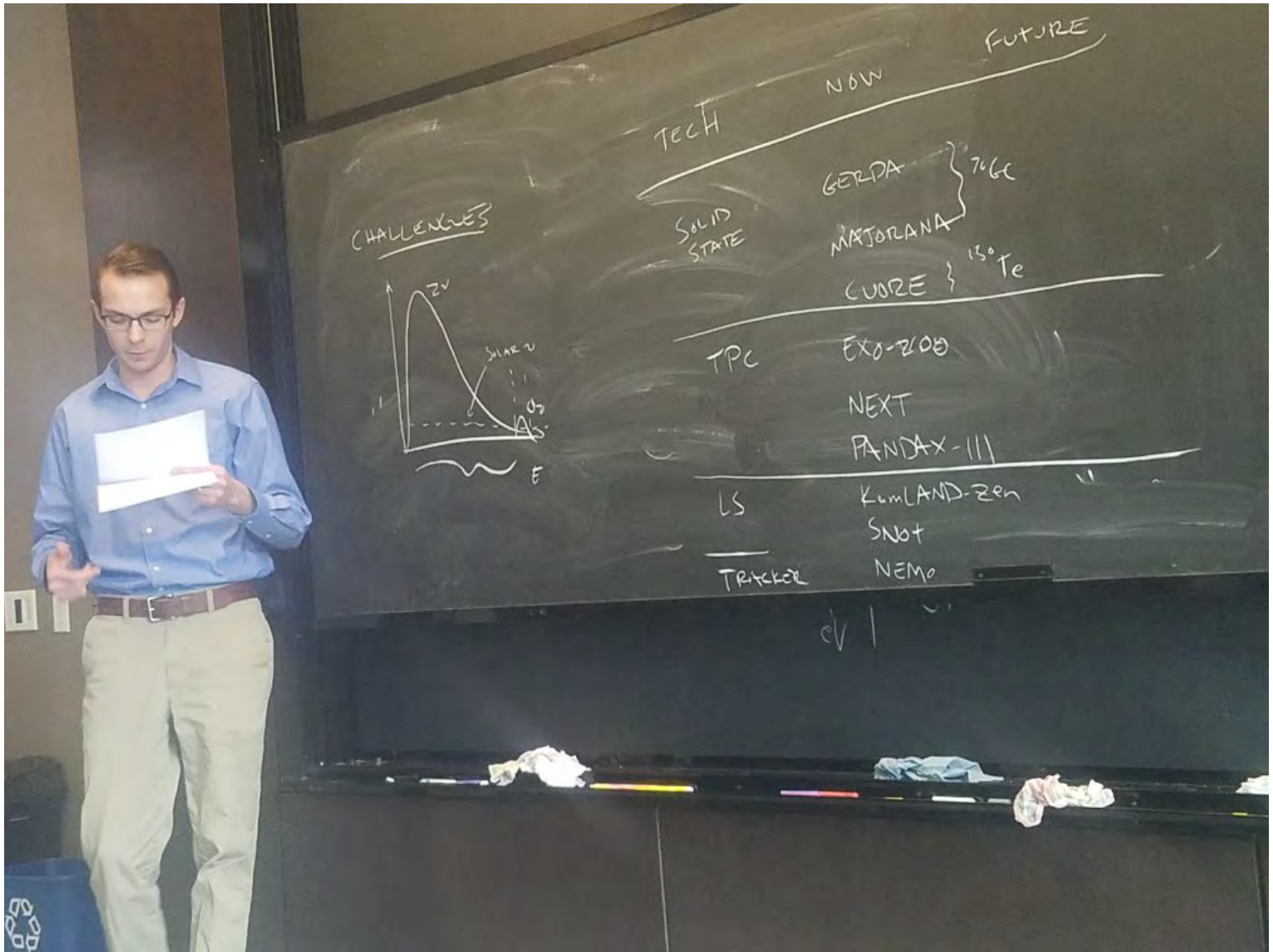
Ben, g_A quenching, NMEs

- Calculations/nuclear matrix elements problem



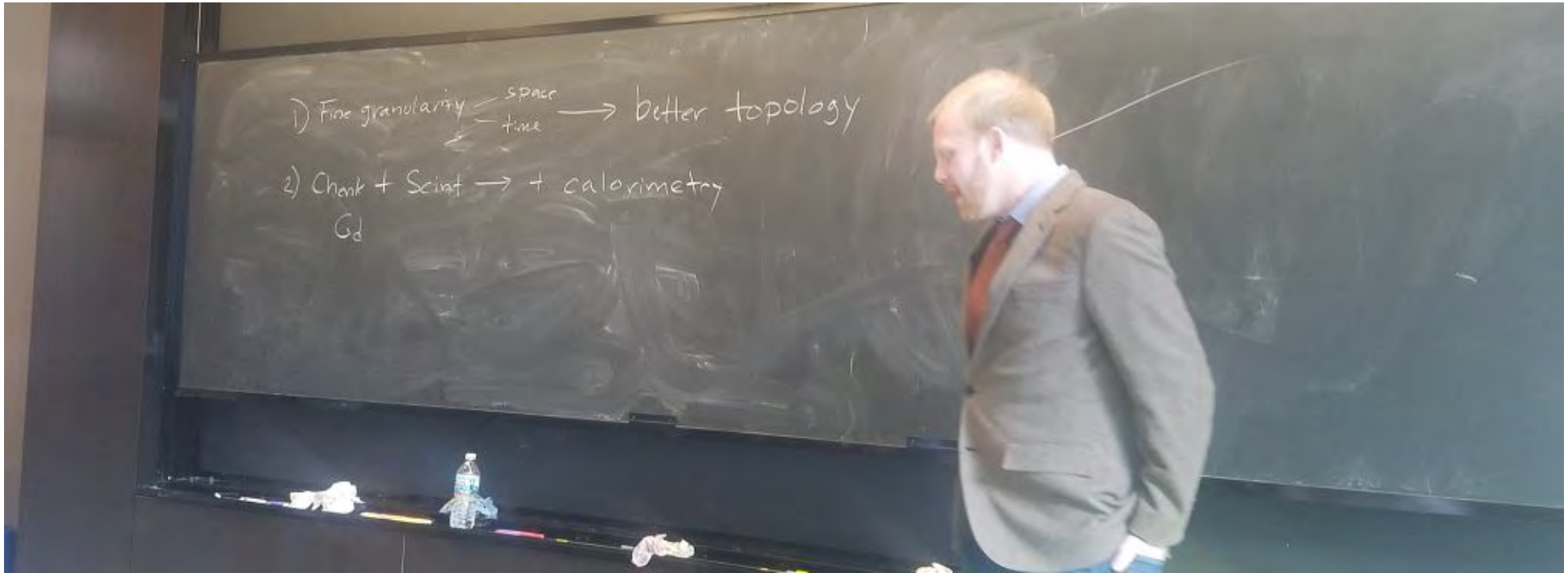
Andy VLLSD 0νββ

- ββ kinematics

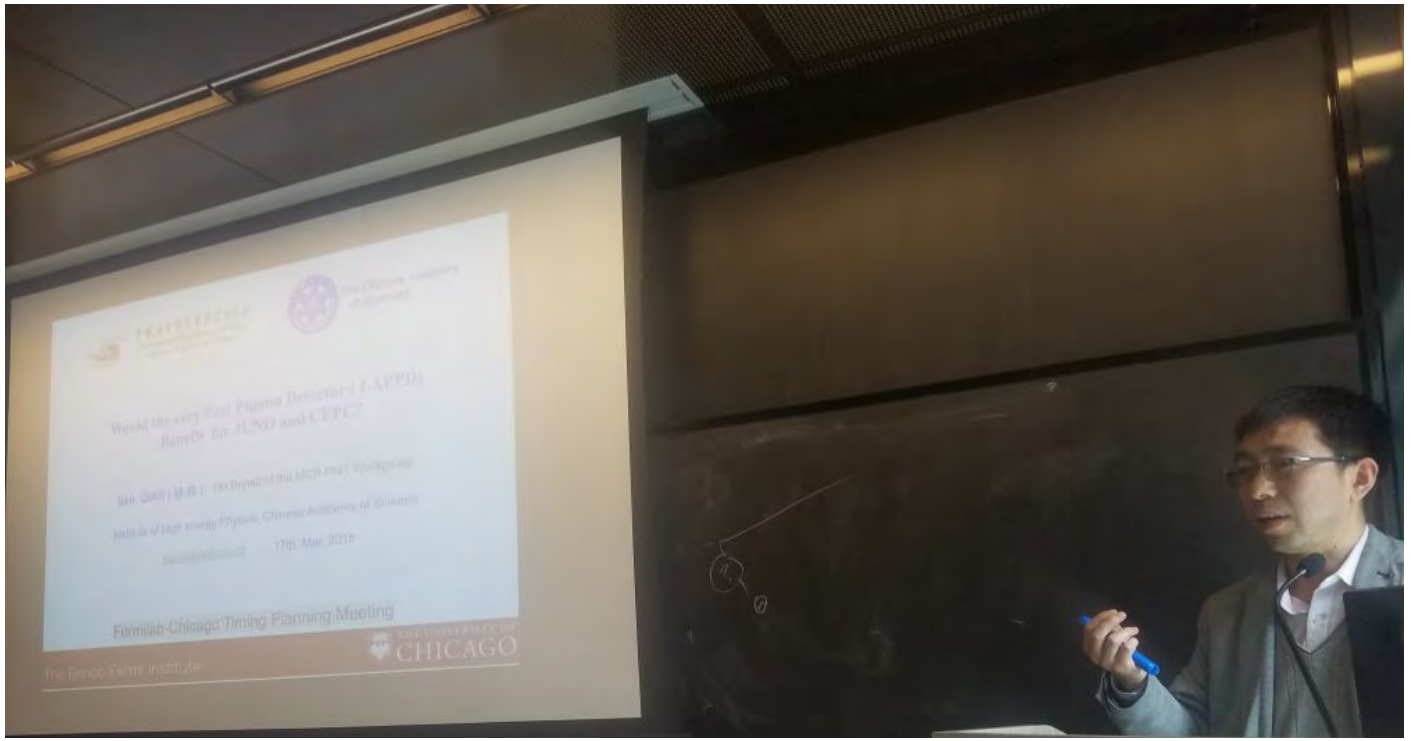


Matt, VLDirLSD (THEIA)

- Fine granularity (space, time) → better topology
- Cherenkov + Scint separation → +Calorimetry
- Imaging
- Water back to the LBNF program

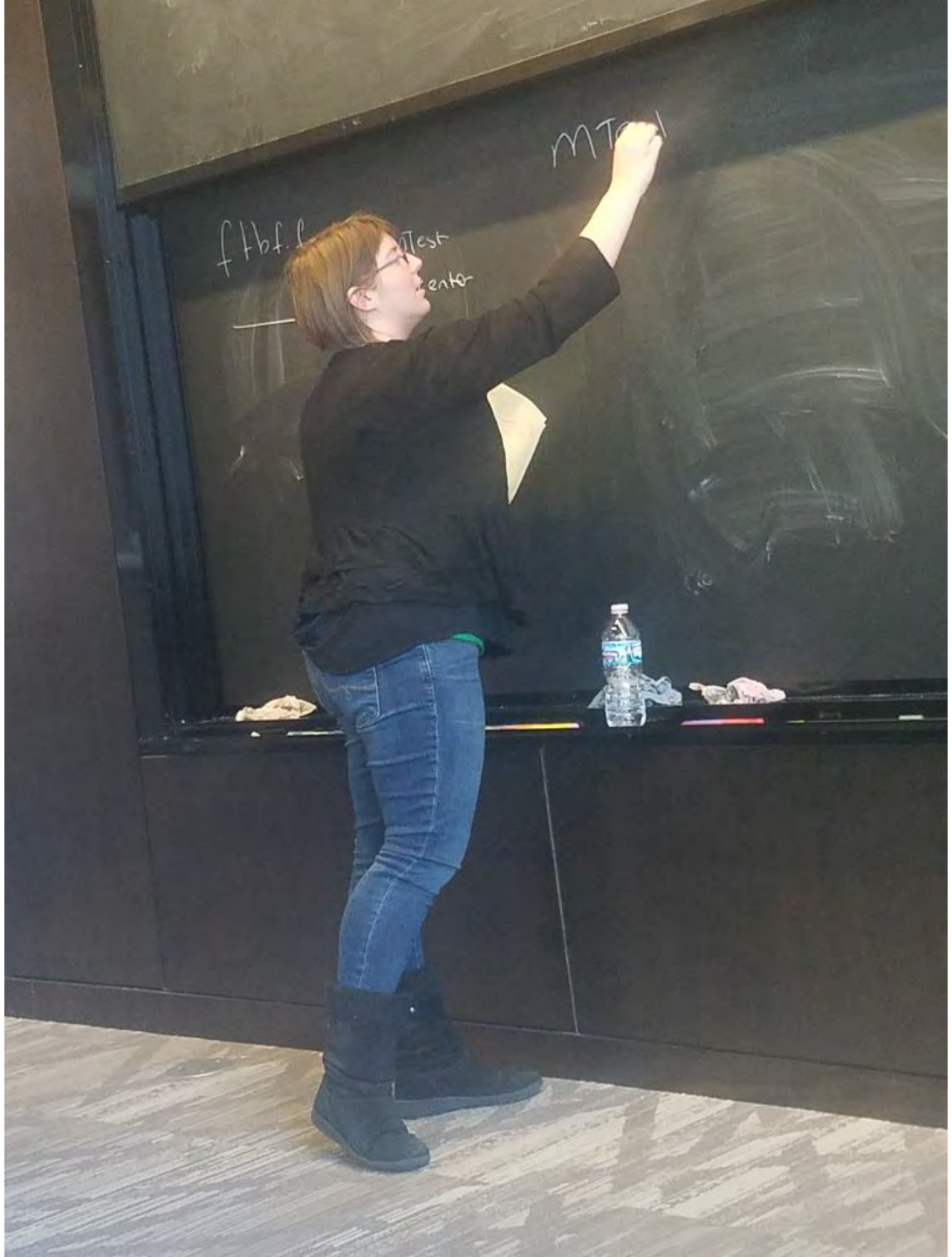


Qian (JUNO, CECP)



Scinitllation rings and angles → extended tracklet objects and dE/dx

Mandy, Test Beam



Dmitri : Future

Panel

2003- Aspen Exptl Summary Talk

Visions of Where Are We Going In Experimental Particle Physics

Detectors Continued

My choice for development is time-of-flight (!?). Precise measurement of the 3-vector, the point of origin, and the particle type gives *all the information possible about each particle.*

If we could measure with $\sigma = 1$ psec (yes) in a path length of 1.5m (e.g. CDF), get $1\,\sigma$ $\pi - K$ separation at $p_T = 25$ GeV.

Is this crazy?

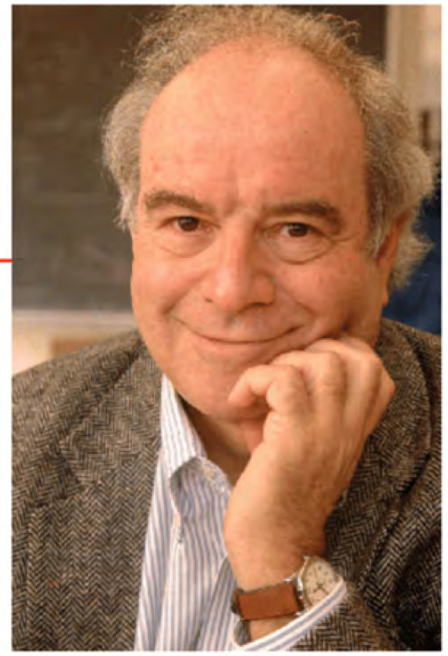
- There exist GaAs Schottky photodiodes with $\sigma \sim 1$ psec, so no law of nature precludes it.
- Need a fast source of light- e.g. Cherenkov radiation.
- Light cannot bounce- has to go straight in.
- Need spatial resolution $< 300\mu$m for $\delta t = 1$ psec.
- Find the collision 'start' time by measuring the time of tracks relative to each other.
- Have to calibrate entire volume *in situ*- need lots of π, K, p,...

So, could we build an outer layer for a central (solenoidal) detector with good spatial resolution and segmentation such that **for every track with $p_T < 25$ GeV we measure not only p_x, p_y, p_z, but also its flavor content?**

HJF Aspen Winter Conference Jan. 19-26, 2003

Light11 Ringberg Castle

"Invitation from Joe Lykken and Maria Spiropulu- led to psec TOF"



Perspectives on Physics and on CMS at Very High Luminosity, HL-LHC

Alushta,Crimea, Ukraine, May 31 **2012**

Fast Timing Devices for the HL-CMS

Maria Spiropulu

California Institute of Technology

Scope of Fast Timing Systems

- For the HL and HE/HL LHC:
  - pile-up background removal (major motivation of fast TOF systems in HL)
  - association of a photon with its production vertex in the presence of high pile-up (this would require the conversion of the photon and a simultaneous precision measurement of the time and position, killer app $H \to \gamma\gamma$)
  - searches for heavy charged particles with short lifetimes (GSMB, AMSB etc)
  - measure flavor flow of the quarks (e.g. $t\bar{t} \to W^+b + W^-\bar{b} \to e^+\nu b + c\bar{s}\bar{b}$) by measuring precisely the mass of relativistic particles (requires < 10 ps resolution)
  - in general Particle ID
  - missing mass searches for the Higgs (see e.g. http://hepwww.rl.ac.uk/accel/forum/2007/Cosenerswattsapr07.pdf forward physics)
- other: medical, geophysics, chemistry, accelerator etc