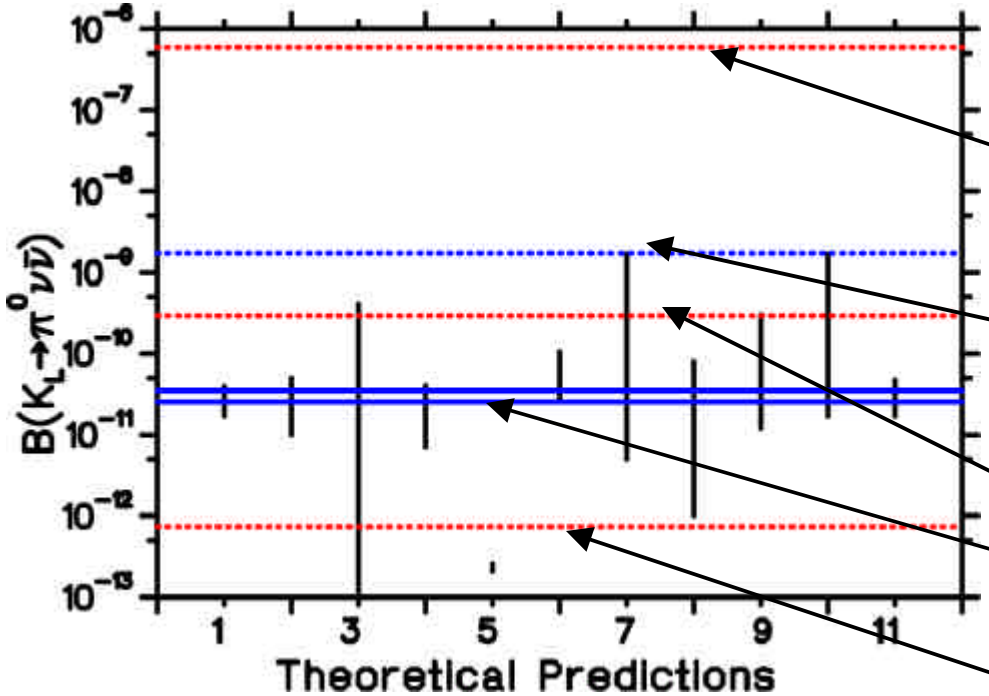
# KOPIO
# An Overview

**Michael Marx**

**May 14, 2004**

# KOPIO – A Window of Opportunity




Current experimental upper limit $K_L^0 \Rightarrow \pi^0 \nu \bar{\nu}$ branching ratio (BR) is **$5.9 \times 10^{-7}$** (KTEV)

Theoretical upper bound using $K^+ \Rightarrow \pi^+ \nu \bar{\nu}$ events is **$1.4 \times 10^{-9}$** ( Grossman-Nir)

KEK391a proposes to reach single event sensitivity of **$3 \times 10^{-10}$**

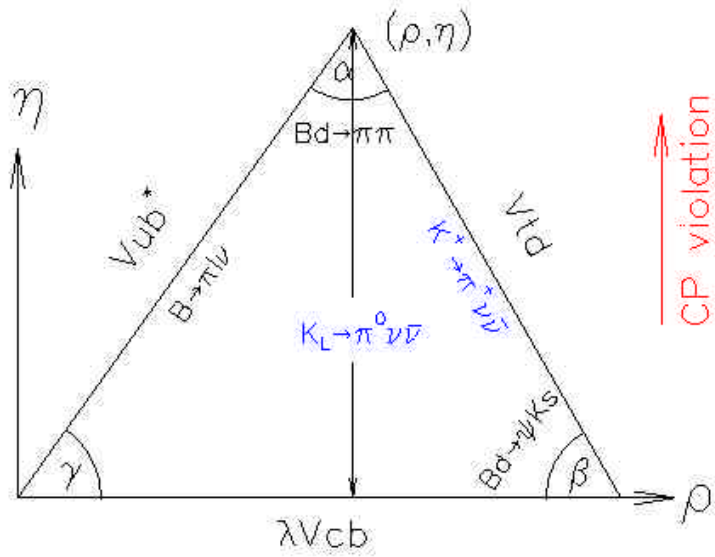
Standard Model predicts BR of **$3 \times 10^{-11}$**

KOPIO proposes to measure the BR with **40 events** at the Standard Model level; and with a single event sensitivity of below **$10^{-12}$**

- **KOPIO improvement over KTEV from**
  - **More acceptance ( x 5.6)**
  - **Predominant $\pi^0$ decay ( x 83)**
  - **More decaying K's ( x 800)**
- **KOPIO proposes unique method to defeat backgrounds (e.g. $K_L^0 \Rightarrow \pi^0 \pi^0$ BR is $10^{-3}$)**
  - **Microbunched proton beam and pancake neutral beam allows high flux, $K_L$ velocity measure and vertex localization**
  - **Measuring K velocity allows work in CoM**
  - **Measuring $\gamma$ directions and energy allows kinematic selection**
- **E787/949 experience with high efficiency $\gamma$ vetos**

**Over a dozen theoretical models incorporating new physics predict BR's in this window**

# Standard Model CP Violation




**Four super-clean processes will challenge the Standard Model:**

| | | |
|---|---|---|
| $K_L^0 \to p^0 n \bar{n}$ | $\mathrm{Im}(V_{ts}^* V_{td})$ | KOPIO $\left\{ \text{"Jarlskog invariant"} \ \lvert J_{CP} \rvert \quad 2A_{\Delta} = \lvert \mathrm{Im}\, V_{ts}^* V_{td} \rvert \lambda \left(1 - \frac{\lambda^2}{2}\right) \right\}$ |
| $K^+ \to p^+ n \bar{n}$ | $\lvert V_{ts}^* V_{td} \rvert$ | E949, ~~CKM~~ |
| $B_d \to \psi K_S$ | $\sin(2\beta)$ | BABAR, BELLE, CDF, D0 |
| $\frac{x_s}{x_d}$ | $\left\lvert \frac{V_{ts}}{V_{td}} \right\rvert$ | CDF, D0, LHCB, BTEV |

## The Process:

$$K_L^0 \to p^0 u\bar{u}; p^0 \to gg; g \to e^+e^-$$

Probability $\sim 3\times 10^{-11} / K_L^0$ decay

## The Challenge:

– Sufficient number of $K_L^0$'s for this rare decay.
(Requires the AGS – the most intense source in the world.)

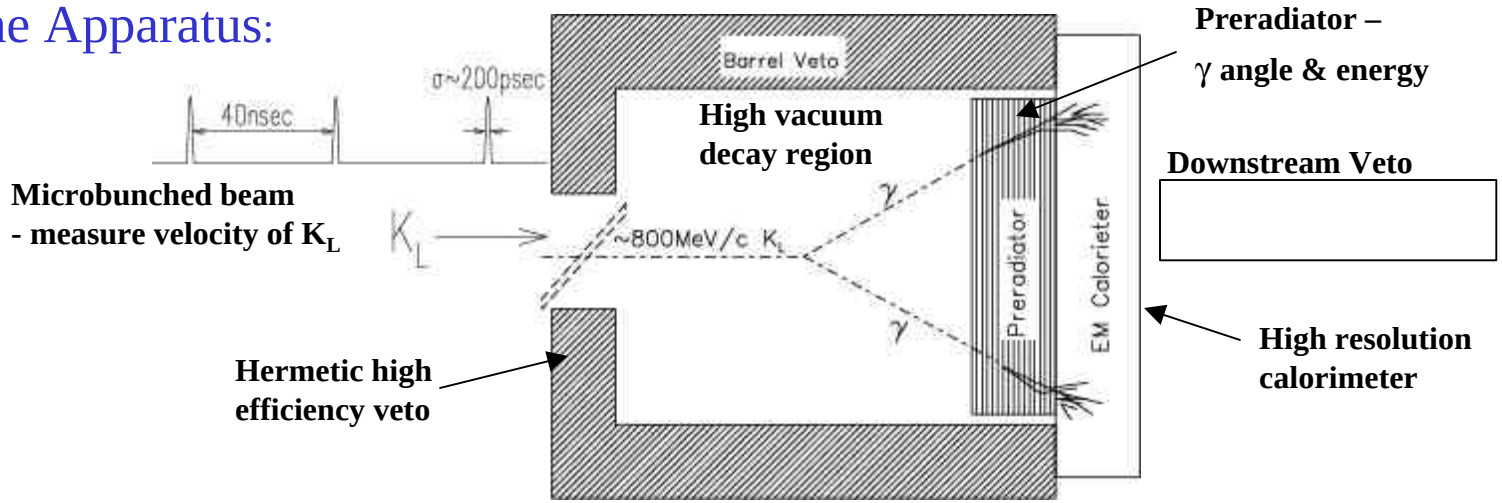
- Must discriminate $K_L^0 \to p^0 u\bar{u}$ from similar decays,
e.g., $K_L^0 \to p^0 p, {}^0$ which are $10^8$ times more probable

## The Method:

– Measure the time of flight of the $K_L^0$'s
(Allows kinematic selection to reject backgrounds.
Requires the low energy $K_L^0$'s available at the AGS.)

- Measure the converted e+/e- to extract the γ direction.
- Measure the γ energies with high precision.
- Insure that no other detectable particles are emitted in the decay.

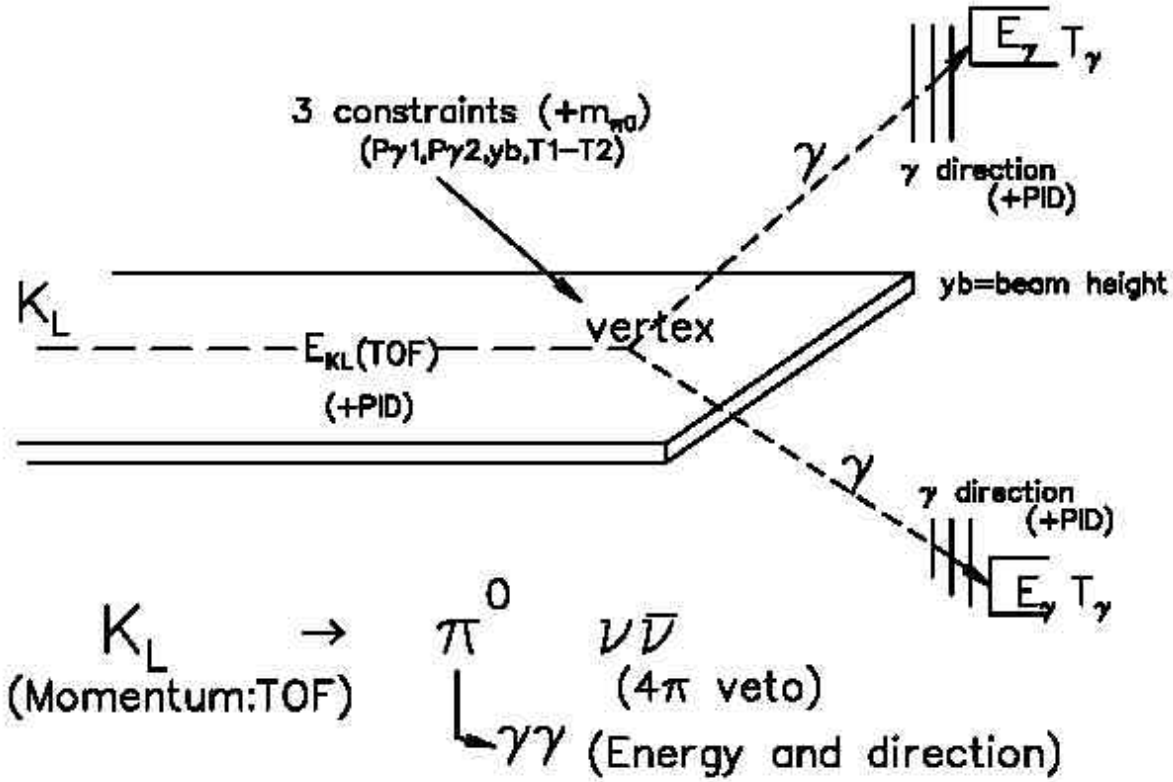
## The Apparatus:



# Kinematics

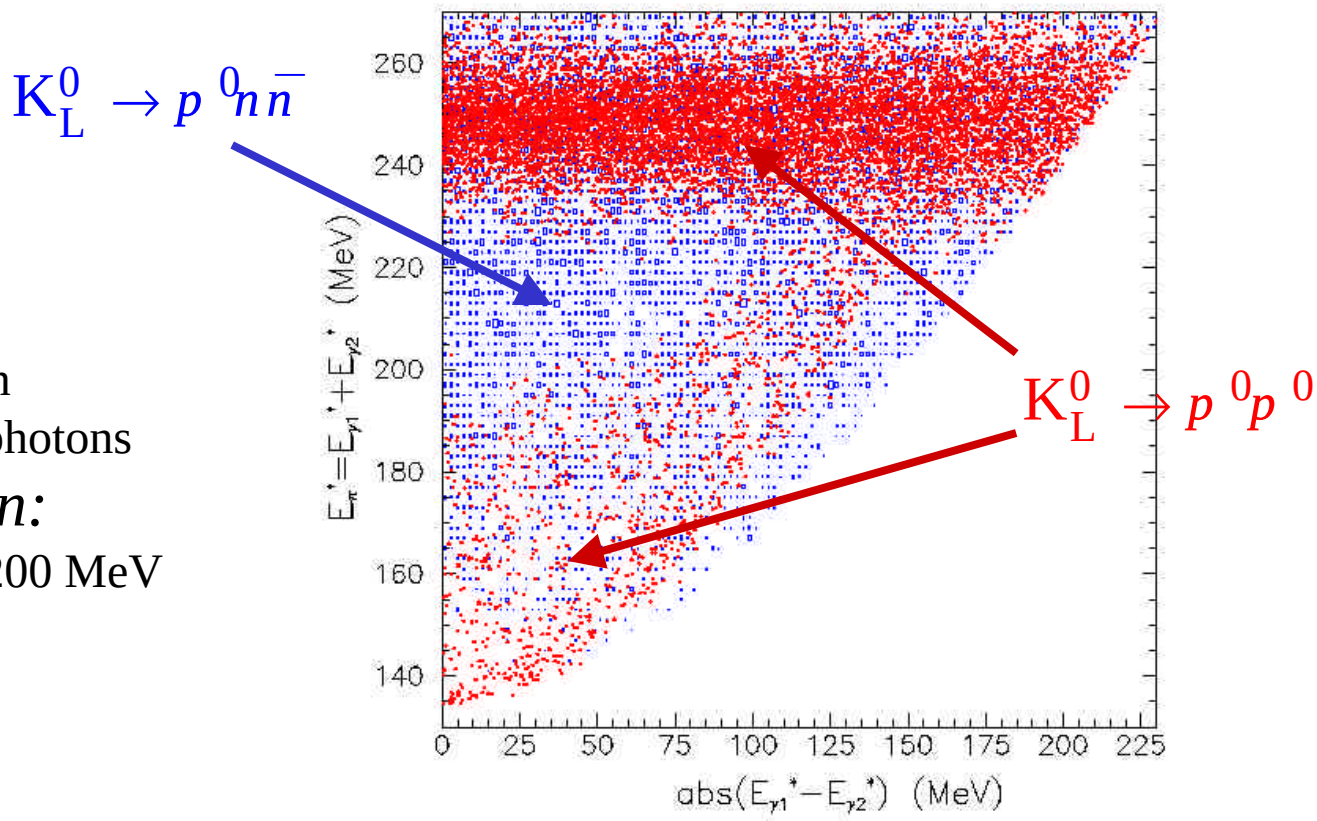
Full kinematic reconstruction and particle identification

- Preradiator: $\gamma$ direction, energy, PID
- EM Calorimeter: $\gamma$ energy
- RF bunched beam: $K_L$ energy and PID
- Vertex reconst.: $K_L$ direction (3 constraints)



# Kinematic suppression of backgrounds
# Goal: 40 Events with S/B >2

$$E^*_{p^0} \ vs. \left| E^*_{g1} - E^*_{g2} \right|$$




*Kinematic reconstruction*

Eliminate events with missing low energy photons

*Photon detection:*

Inefficiency $10^{-4}$ at 200 MeV

***Arizona State University*** J.R. Comfort

***Brookhaven National Laboratory*** D. Beavis**,** I-H. Chiang, A. Etkin, J.W. Glenn, A. Hanson, D. Jaffe, D. Lazarus, K. Li, L. Littenberg, G. Redlinger, C. Scarlett, M. Sivertz, R. Strand

***University of Cinncinnati*** K. Kinoshita

***IHEP, Protvino**** G.Britvich, V. Burtovoy, S.Chernichenko, L, Landsberg, A. Lednev, V. Obraztsov, R.Rogalev, V.Semenov, M. Shapkin, I.Shein, A.Soldatov, N.Tyurin, V.Vassil'chenko, D. Vavilov, A.Yanovich

***INR, Moscow*** A. Ivashkin, *D.Ishuk*, M. Khabibullin, A. Khotjanzev, Y. Kudenko, A. Levchenko, O. Mineev, N. Yershov and *A.Vasiljev*.

***INFN-University of Perugia*** G. Anzivino, P. Cenci, *E. Imbergamo*, A. Nappi, M. Valdata

***KEK*** M. Kobayashi

***Kyoto University of Education**** R. Takashima

***Kyoto University*** *K. Misouchi, H. Morii*, T. Nomura, N. Sasao, *T. Sumida*

***Virginia Polytechnic Institute & State University*** M. Blecher, *N. Graham*, A. Hatzikoutelis

***University of New Mexico*** B. Bassalleck, N. Bruner, D.E. Fields, J. Lowe, T.L. Thomas

***University of Montreal**** J.-P. Martin

**State University of New York at Stony Brook** N. Cartiglia, *I. Christidi*, M. Marx, P. Rumerio, D. Schamberger

***TRIUMF*** P. Amaudruz, M. Barnes, E. Blackmore, A. Daviel, M.Dixit, J. Doornbos, P. Gumplinger, R. Henderson, N. Khan, A. Mitra, T. Numao, R. Poutissou, G. Wait

***University of British Columbia*** S. Begin, D. Bryman, M. Hasinoff, *J. Ives*

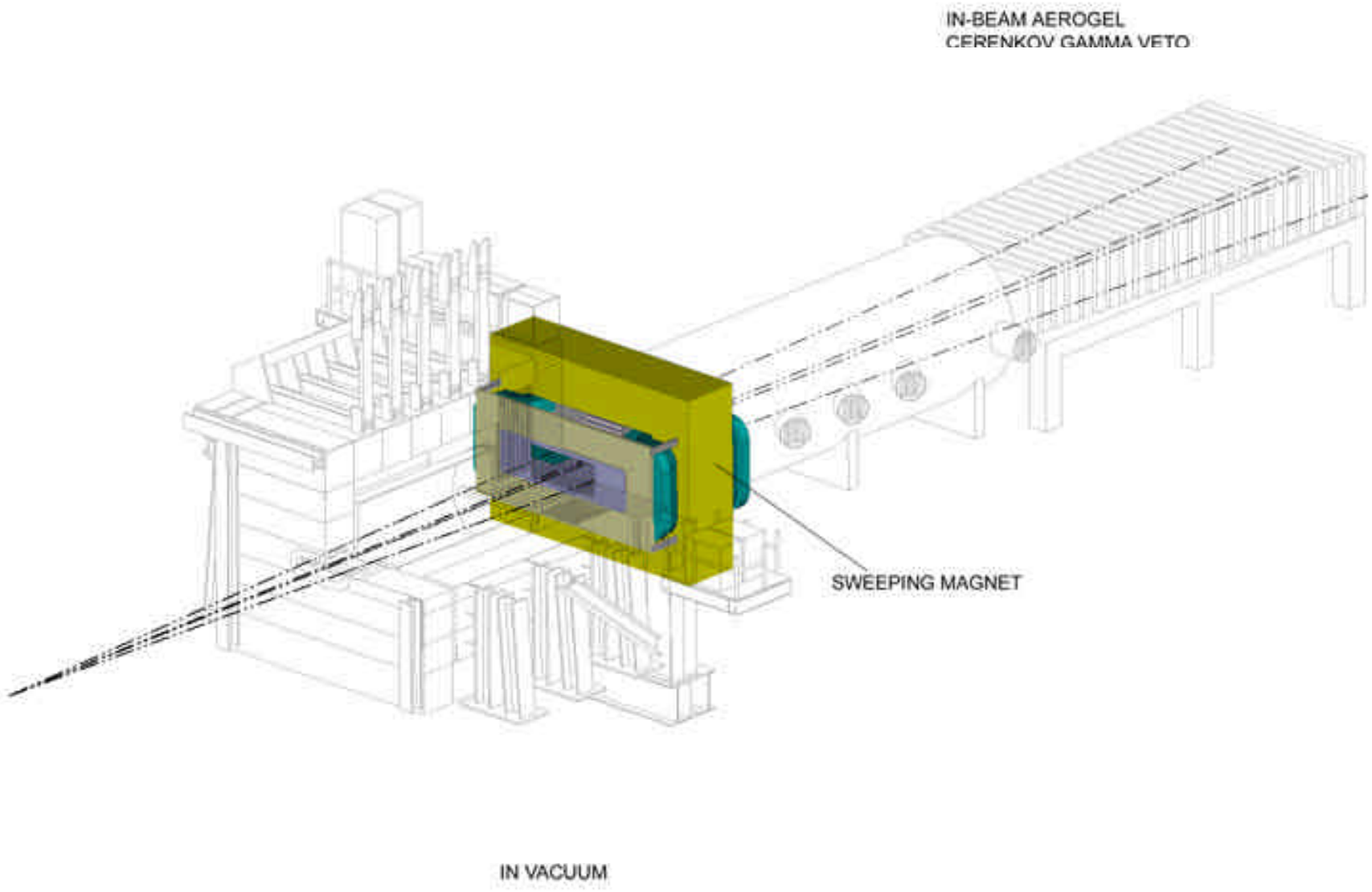
***University of Virginia*** E. Frlez, D. Pocanic

***University of Zurich*** P. Robmann, P. Trüol, A. van der Schaaf, *S. Scheu*

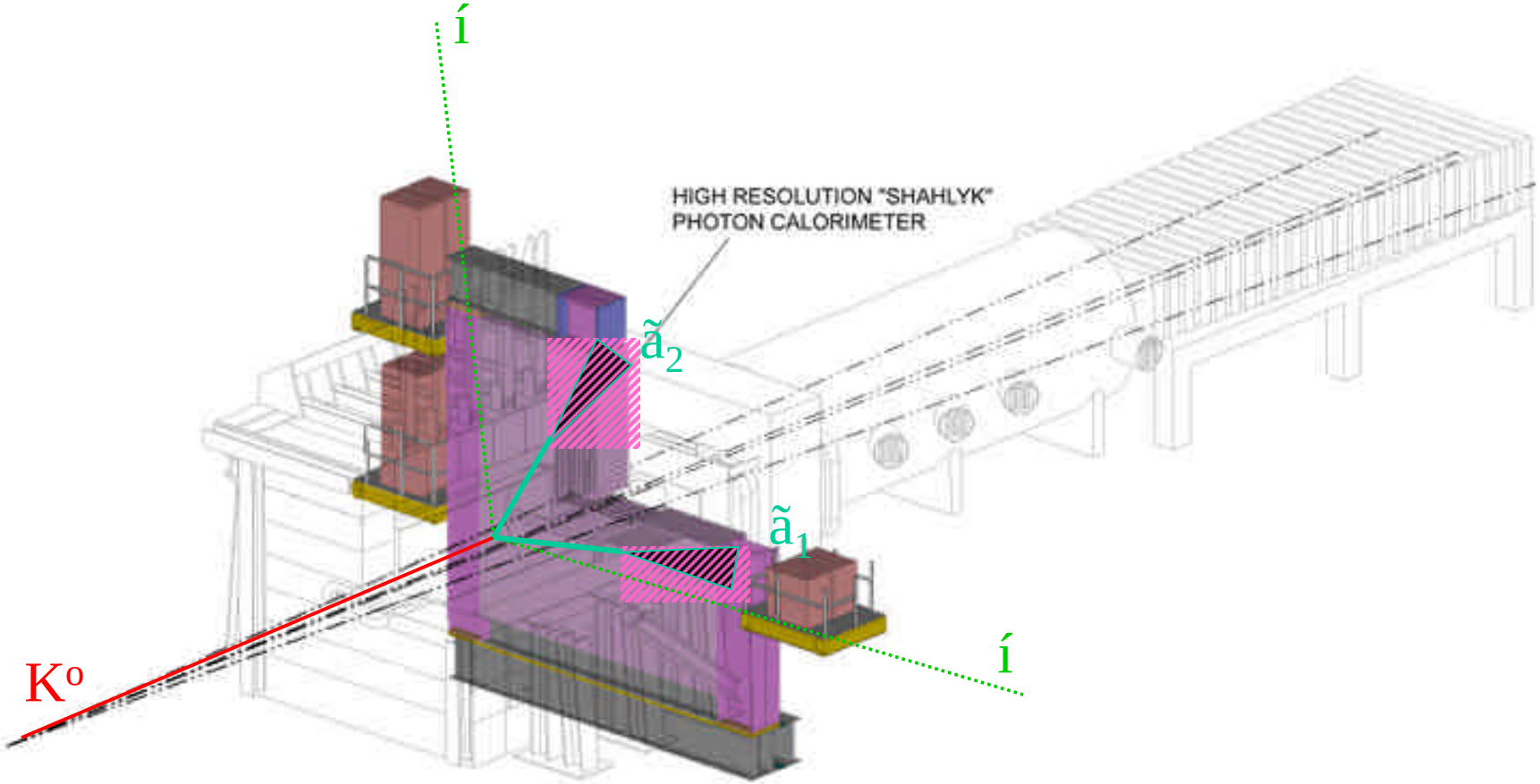
***Yale University*** G. Atoyan, S.K. Dhawan, V. Issakov, H. Kaspar, A. Poblaguev, M.E. Zeller

** New institution Grad students*

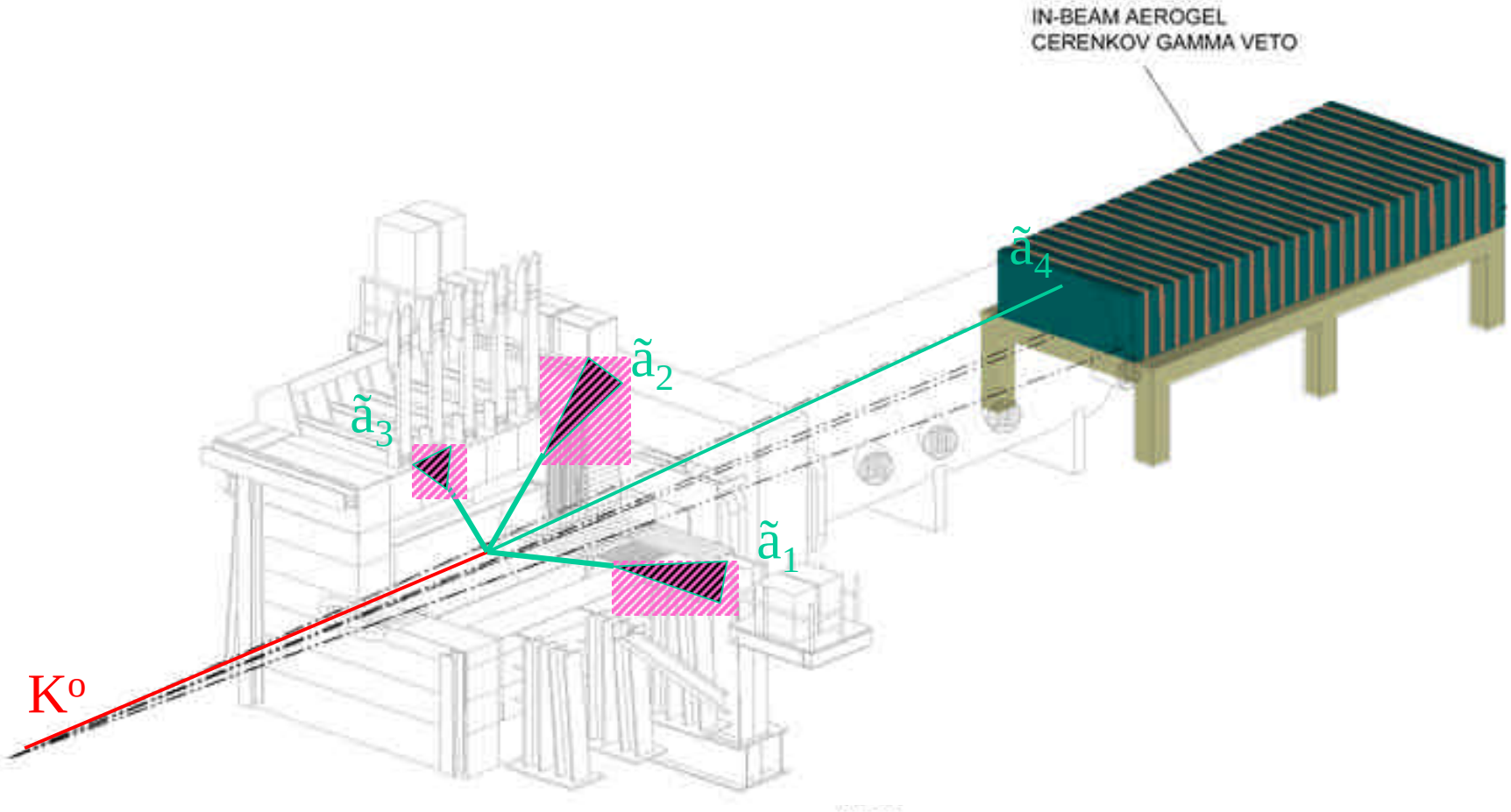
# KOPIO detector



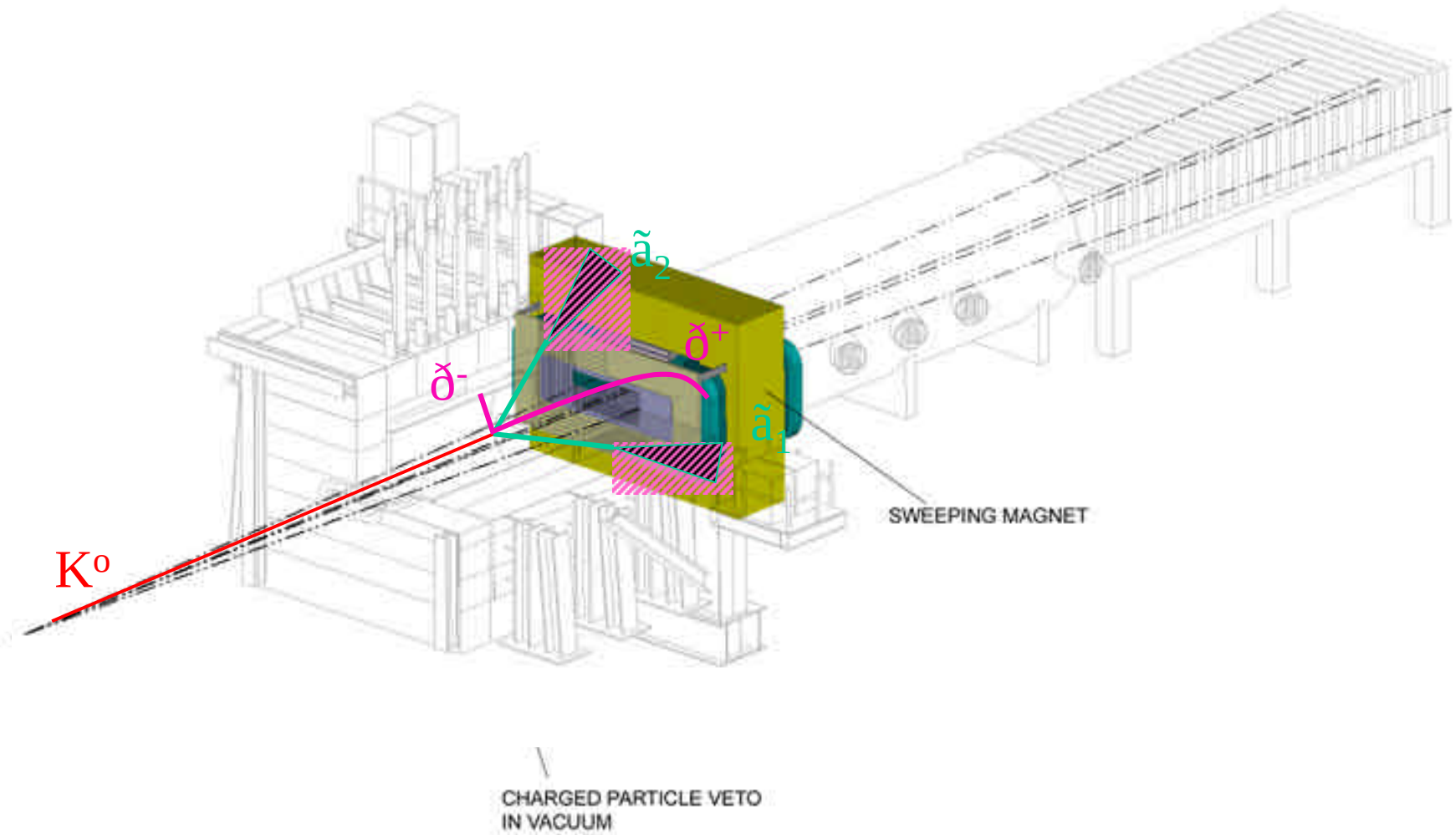
# Signal event ($K_L^o \to \delta^i \acute{\imath}\acute{\imath}$)

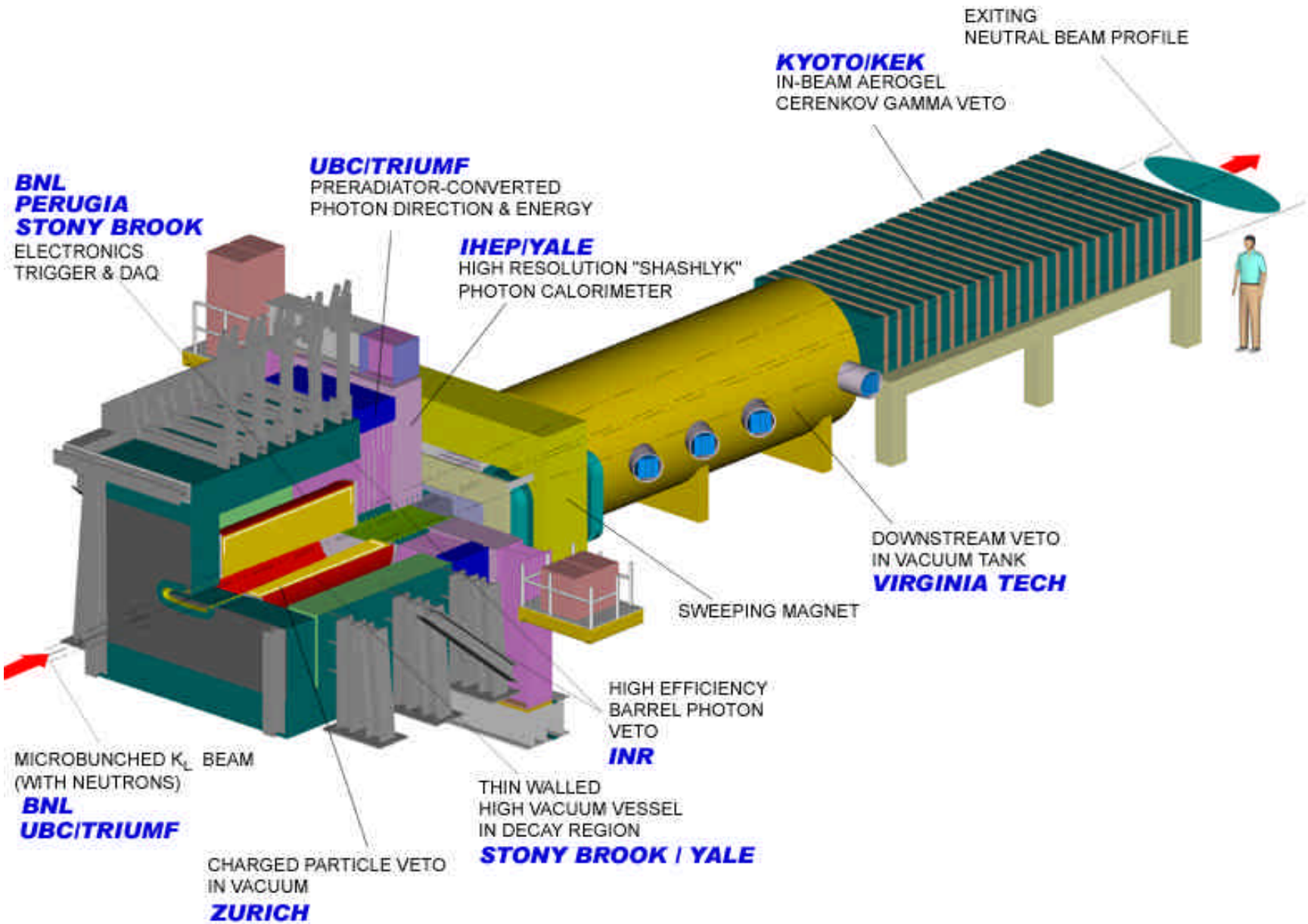


# $K_L^o \rightarrow \delta^i \delta^i$ background event



# $K_L^o \rightarrow ð^+ ð^- ð^ï$ background event




EXITING
NEUTRAL BEAM PROFILE
KYOTO/KEK
IN-BEAM AEROGEL
CERENKOV GAMMA VETO
UBC/TRIUMF
PRERADIATOR-CONVERTED
PHOTON DIRECTION & ENERGY
BNL
PERUGIA
STONY BROOK
ELECTRONICS
TRIGGER & DAQ
IHEP/YALE
HIGH RESOLUTION "SHASHLYK"
PHOTON CALORIMETER
DOWNSTREAM VETO
IN VACUUM TANK
VIRGINIA TECH
SWEEPING MAGNET
HIGH EFFICIENCY
BARREL PHOTON
VETO
INR
MICROBUNCHED $K_L$ BEAM
(WITH NEUTRONS)
BNL
UBC/TRIUMF
THIN WALLED
HIGH VACUUM VESSEL
IN DECAY REGION
STONY BROOK / YALE
CHARGED PARTICLE VETO
IN VACUUM
ZURICH

# KOPIO Schedule

- Have been in an R&D phase for 3 years
  - Most technologies mature
  - Little engineering or integration accomplished
- Receiving $2.5M this year for “advanced planning”
  - Initialize integration and configuration control
  - In process of rebaselining detector
  - Baseline review in early 2005
  - RSVP construction start in FY05 requested in NSF budget

# KOPIO Status Review

| | | |
|---|---|---|
| 10:30 | Overview | Marx |
| 10:45 | AGS Mods | Sivertz |
| 11:00 | Beams | Beavis |
| 11:15 | Vacuum | Marx |
| 11:30 | Preradiator | Numao |
| 11:45 | Calorimeter | Issakov |
| 12:00 | Charged Veto | VanderSchaaf |
| 12:15 | Photon Veto | Mineev |
| 12:30 | Lunch | |
| 2:00 | Catcher | Nomura |
| 2:15 | Trigger | Nappi |
| 2:30 | DAQ | Redlinger |
| 2:45 | FEE | Cartiglia |
| 3:15 | Simulation | Jaffe |
| 3:30 | Discussion | |

**Each Subsystem will discuss scope, status, and open issues**

**Time for discussion during lunch and at end**