APEX Fast Trigger and PID Capability

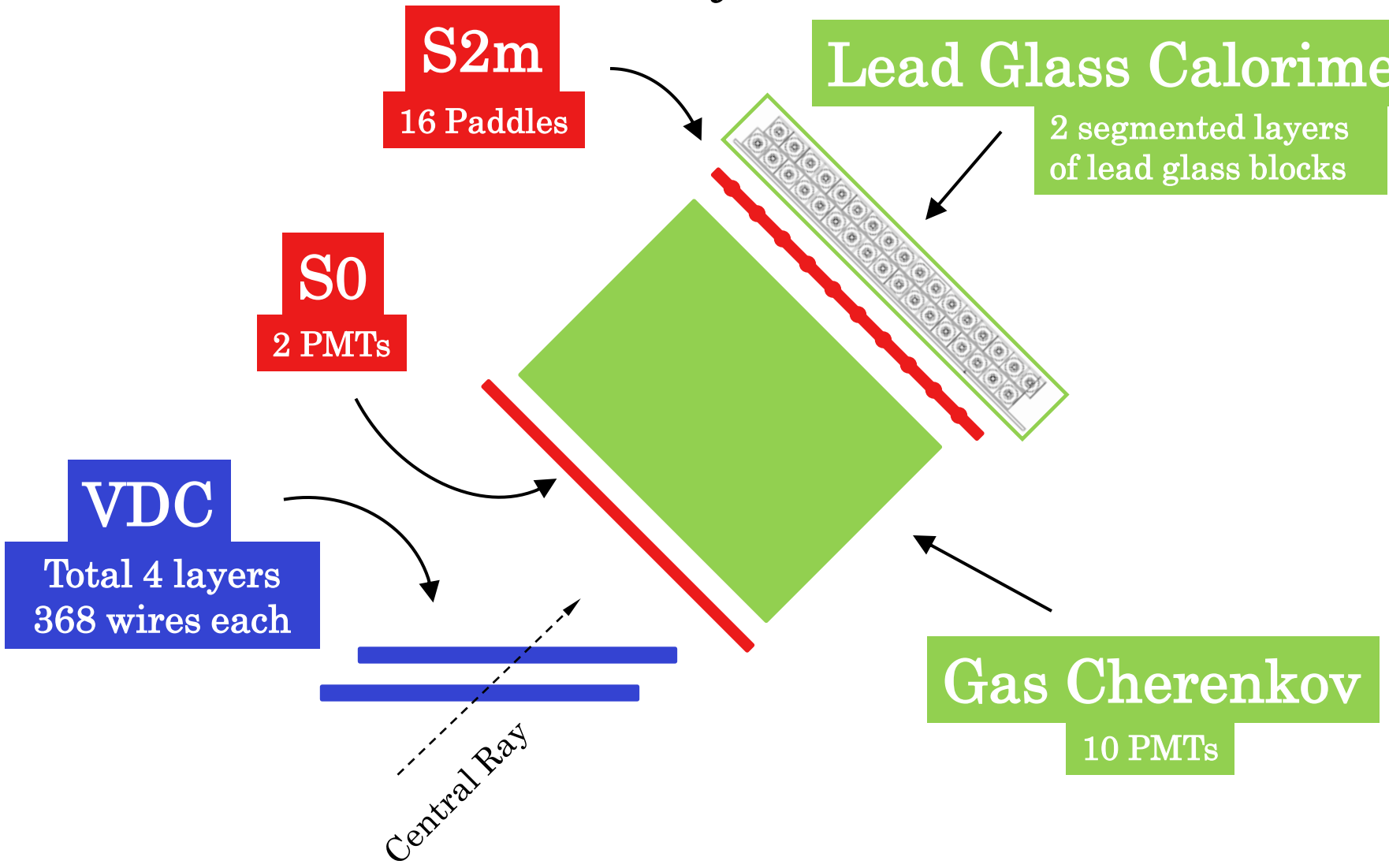
Eric Jensen
The College of William & Mary
Sergey Abrahamyan
Yerevan Physics Institute

For the APEX Collaboration

APEX Fast Trigger and PID Capability

- Components of HRS trigger/PID
- Scheme and performance of trigger
- Calibration and performance of PID
- Projected PID in other kinematics
- DAQ rates and dead time

High Resolution Spectrometer Detector Layout

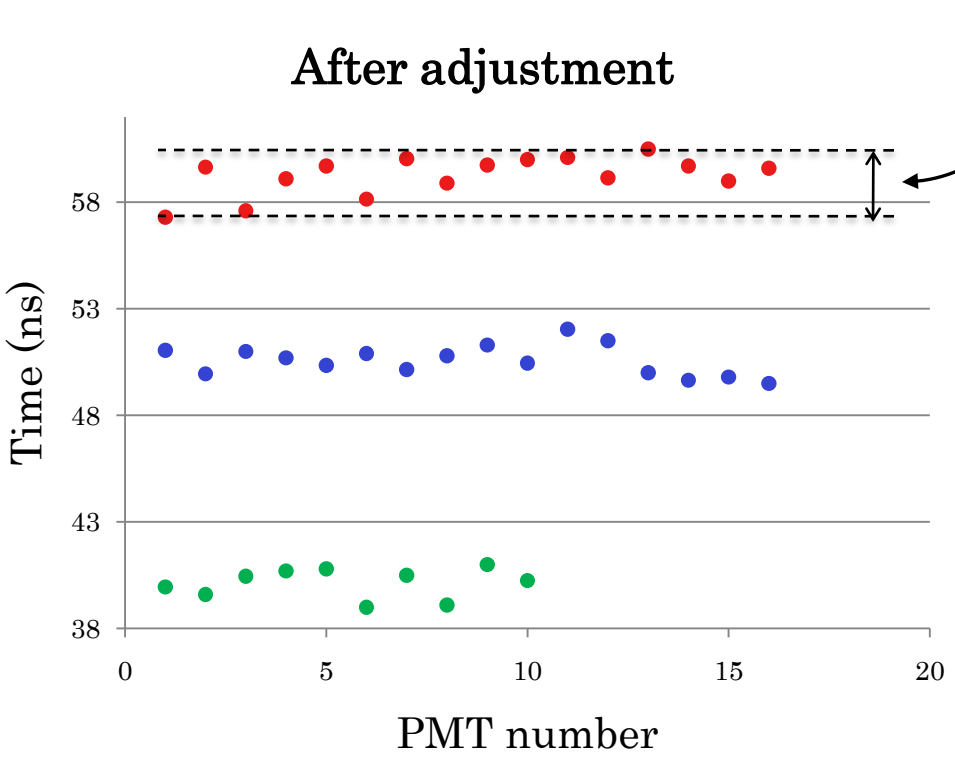


Trigger Logic

- Electron Arm Trigger (T1)
  - Electron S2m
- Positron Arm Trigger (T3)
  - Positron S2m
- Coincidence Trigger (T4)
  - Electron S2m + Positron S2m
- "Golden" Coincidence Trigger (T6)
  - Electron S2m + Positron S2m + Positron Gas Cherenkov

Timing Alignment in Hardware

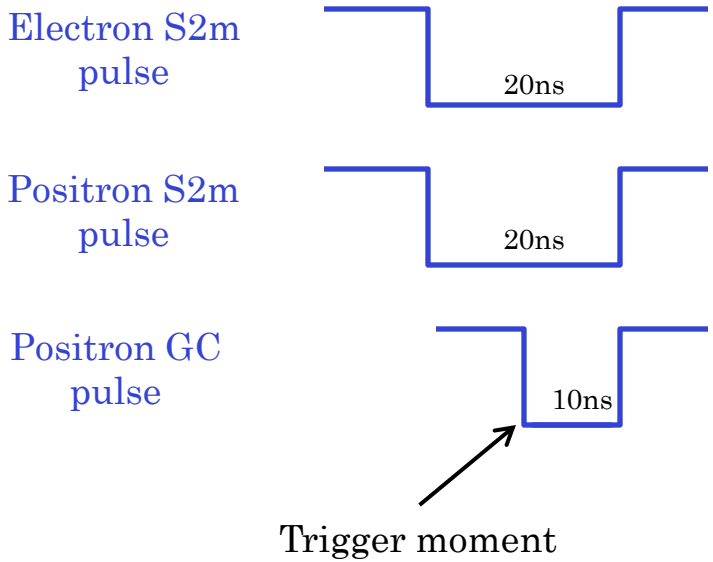
- Run at high rates, small timing gate is important
- Must align timing of the trigger detectors
  - S0 counter as a reference
  - Inserted 1–5 ns delay cables



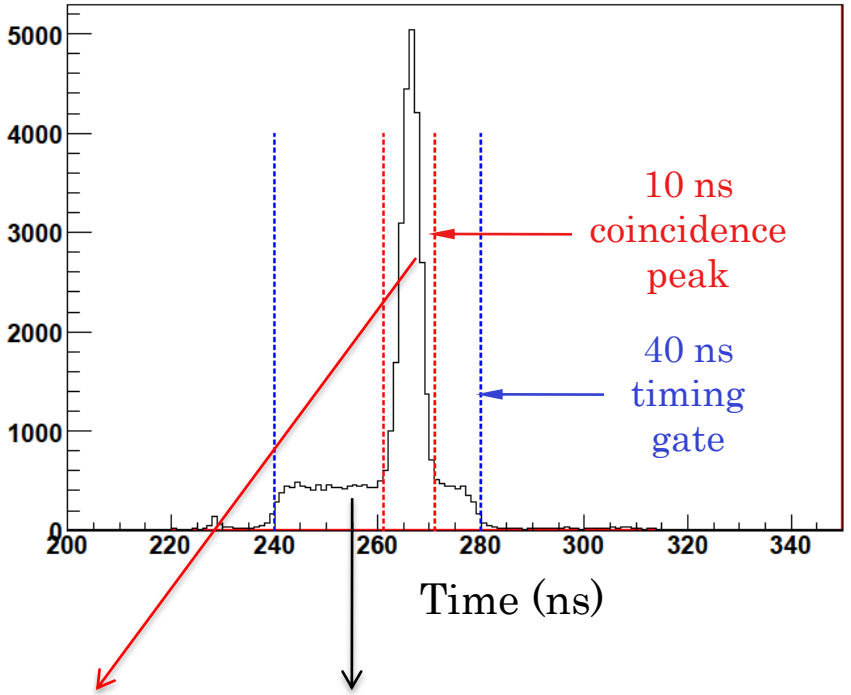
	σ	Spread
Electron S2m	0.9 ns	3.2 ns
Positron S2m	0.7 ns	2.6 ns
Positron GC	0.7 ns	2 ns

Coincidence Timing

Trigger Timing Diagram

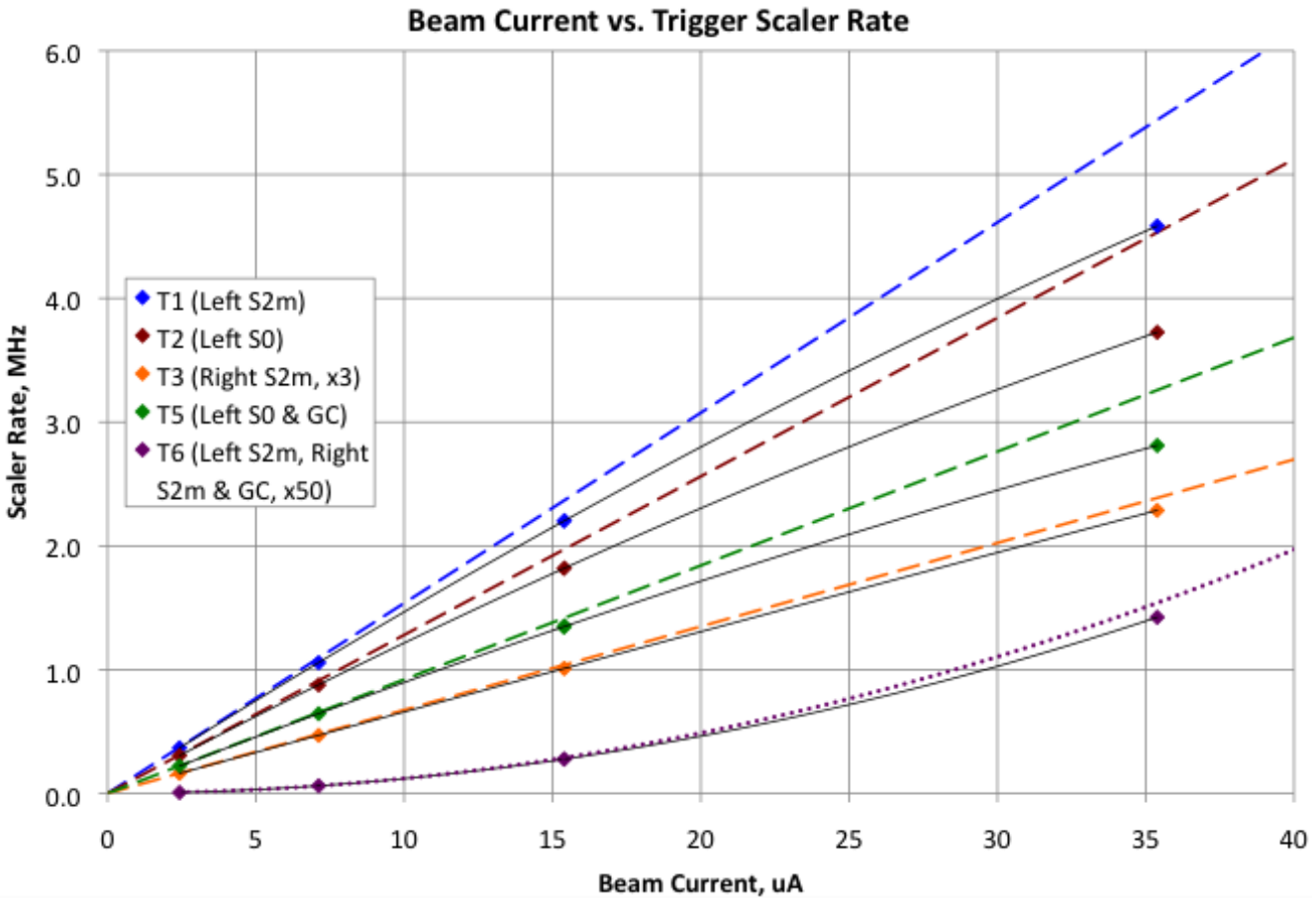


Time difference between Electron S2m and trigger



Under test run conditions: signal / background is ~ 5/1
For proposed experiment: signal / background expected to be ~ 1/4
which improves in off-line to ~ 12/1

Triggers Performance



Observed dead time in the detector system is ~35 ns per single arm trigger

Overall T6 ("golden" coincidence) dead time less than 8% up to electron arm detector rates of 5 MHz

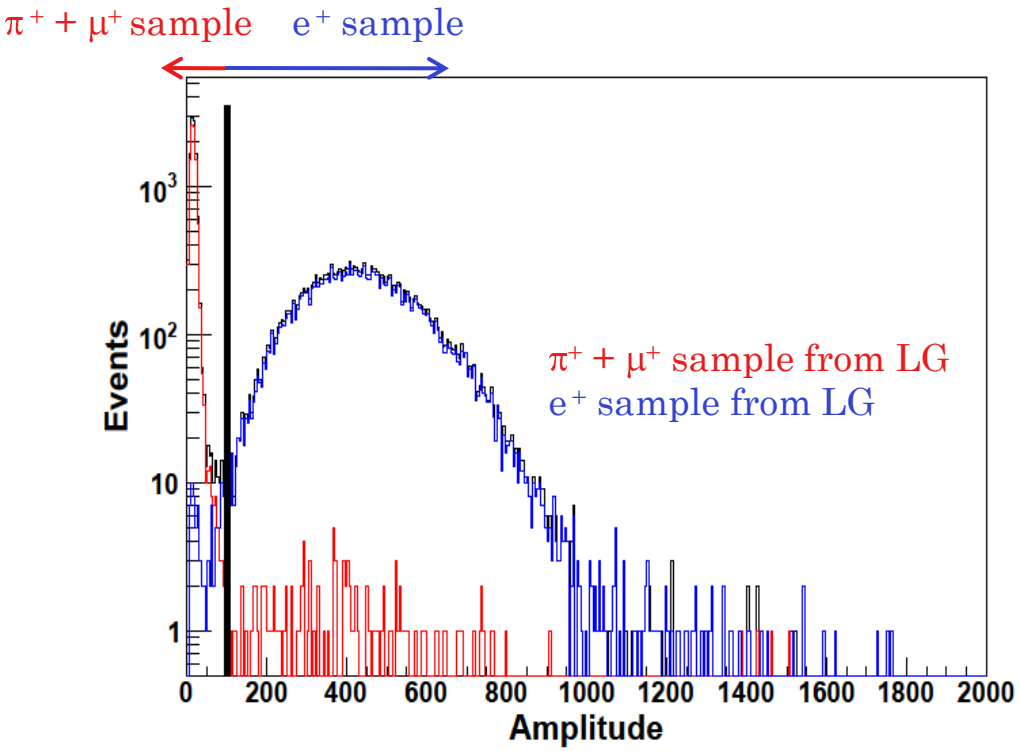
Particle Identification Requirements and Reality

Using the Tantalum target: 2.2 GeV running

- Observed ratio of the rates $e^-/(\pi^- + \mu^-) \sim 50/1$
- Observed ratio of the rates $e^+/(\pi^+ + \mu^+) \sim 1/1.5$
- PID should provide e/meson ratio in online sample of 10/1
- Positron arm needs a factor of 15 rejection of meson background
- Gas Cherenkov and lead glass calorimeters used for this purpose

Gas Cherenkov in Positron Arm (low rate)

2 μA on Pb Target
Positron arm rate – 57 kHz

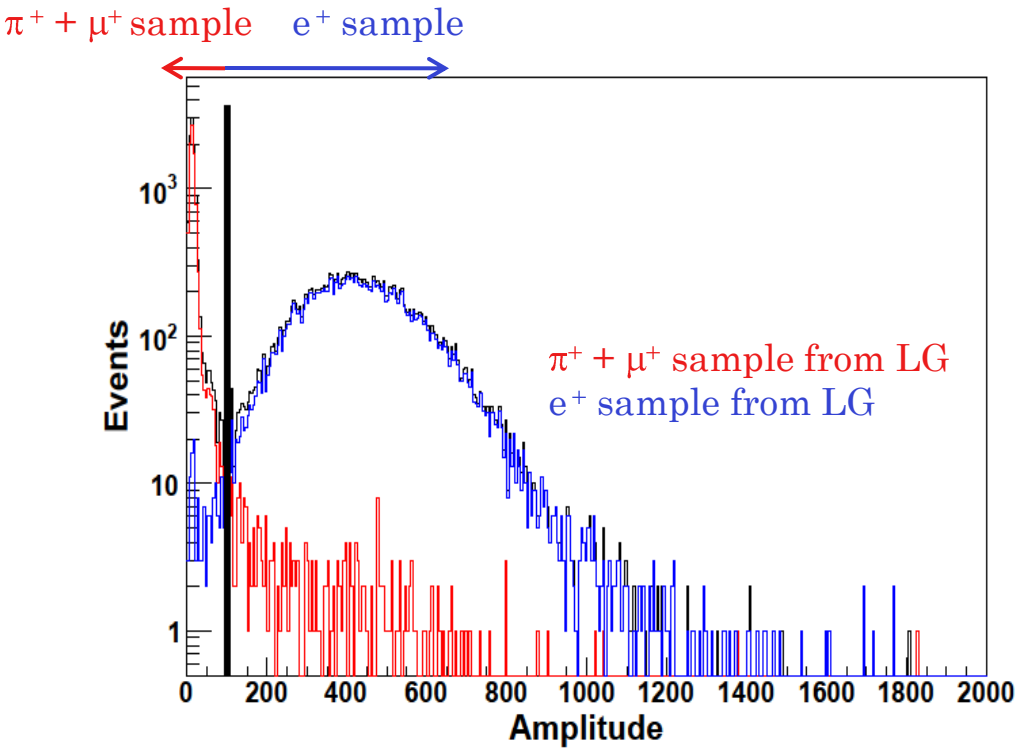


Electron detection eff.	0.995
Meson rejection eff.	0.987

Meson background rejected by a factor of 75

Gas Cherenkov in Positron Arm (high rate)

30 μA on Pb Target
Positron arm rate – 765 kHz
(close to maximum expected rate)



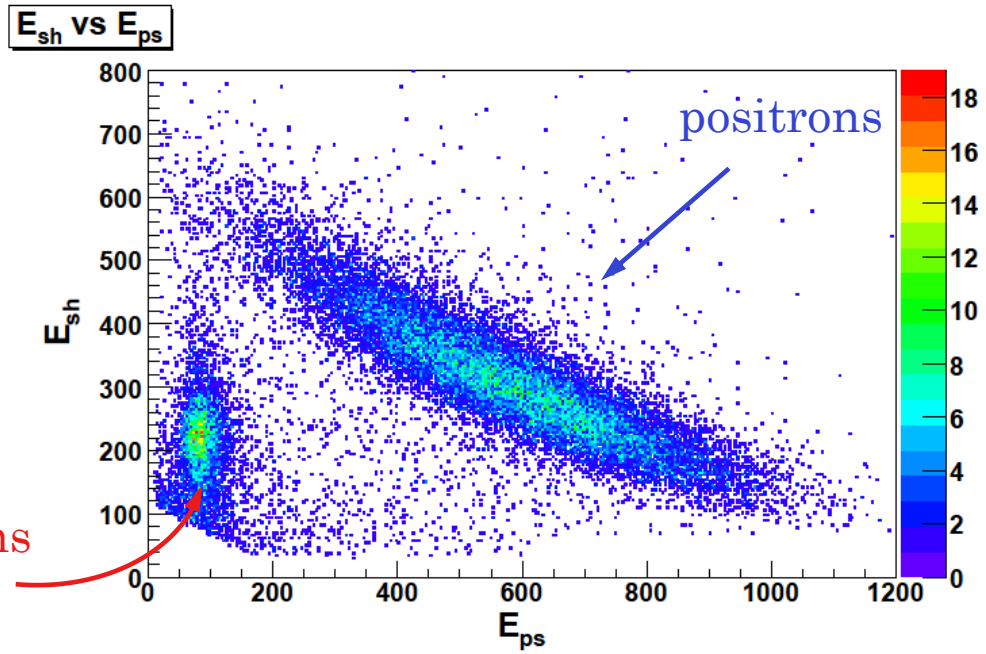
Electron detection eff.	0.992
Meson rejection eff.	0.970

Meson background rejected by a factor of 30

This analysis didn't use timing and coordinate information

Lead Glass Particle ID in Positron Arm (high rate)

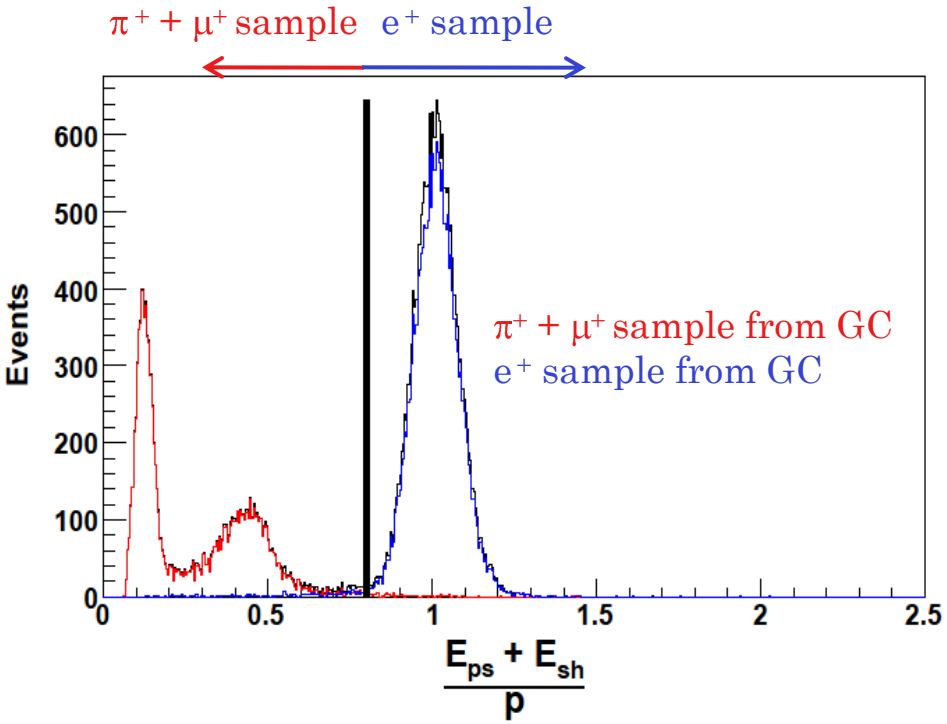
30 μA on Pb Target
Positron arm rate – 765 kHz



- E_{PS} – Energy deposition in 1st layer
- E_{SH} – Energy deposition in 2nd layer
- p – Particle momentum

Lead Glass Particle ID in Positron Arm (low rate)

2 μA on Pb Target
Positron arm rate – 57 kHz



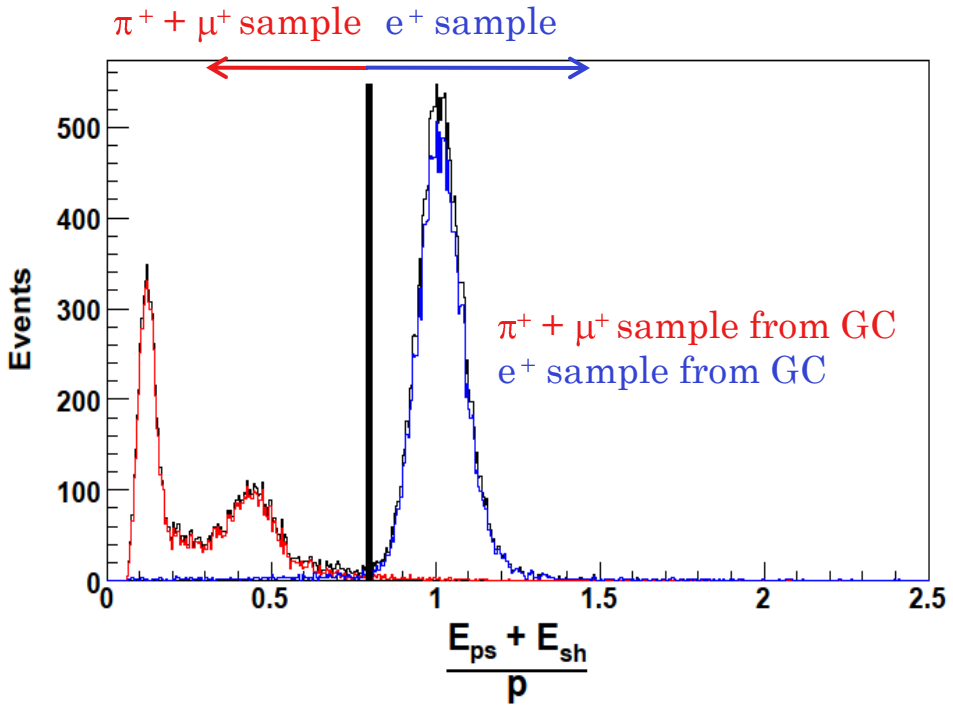
Electron detection eff.	0.983
Pion rejection eff.	0.990

Meson background rejected by a factor of 100

- E_{PS} – Energy deposition in 1st layer
- E_{SH} – Energy deposition in 2nd layer
- p – Particle momentum

Lead Glass Particle ID in Positron Arm (high rate)

30 μA on Pb Target
Positron arm rate – 765 kHz



Electron detection eff.	0.977
Pion rejection eff.	0.985

Meson background rejected by a factor of 60

This analysis didn't use coordinate information

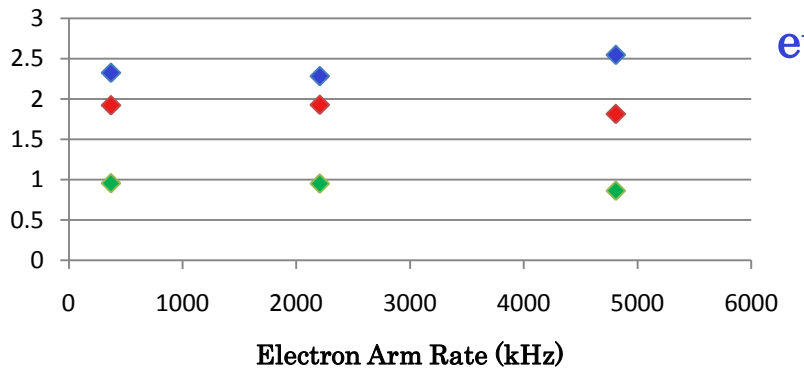
- E_{PS} – Energy deposition in 1st layer
- E_{SH} – Energy deposition in 2nd layer
- p – Particle momentum

Current Dependence of Particle Yield

Charge Normalized Particle Yield Corrected to Dead time: $\frac{kHz}{\mu A}$

Beam current	Electron trigger rate	Positron trigger rate
2 μA on **Pb**	210.5	32.4
11 μA on **Pb**	251.8	39.0
28 μA on **Pb**	203.3	34.1
72 μA on **Ta**	2.50	0.46
143 μA on **Ta**	2.31	0.44

Particle Ratios on Pb

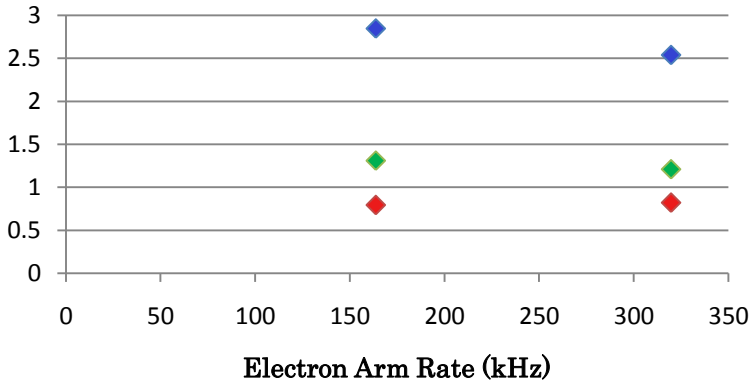


e^-/π^- (x 1/20)

e^+/π^+

μ^+/π^+

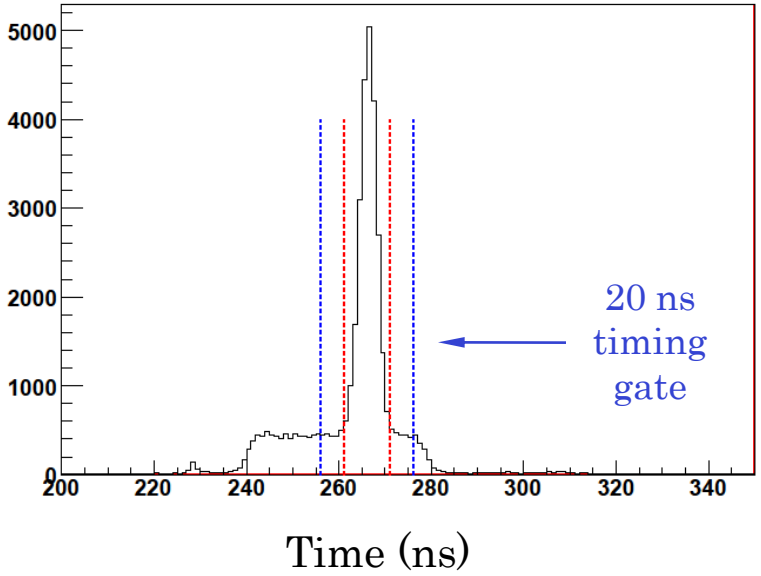
Particle Ratios on Ta



DAQ rates and dead time
2.2 GeV full luminosity

- A 20 ns coincidence gate would acquire a rate of 3.1 kHz
- DAQ dead time is 10% for 4 kHz

Time difference between Electron S2m and trigger



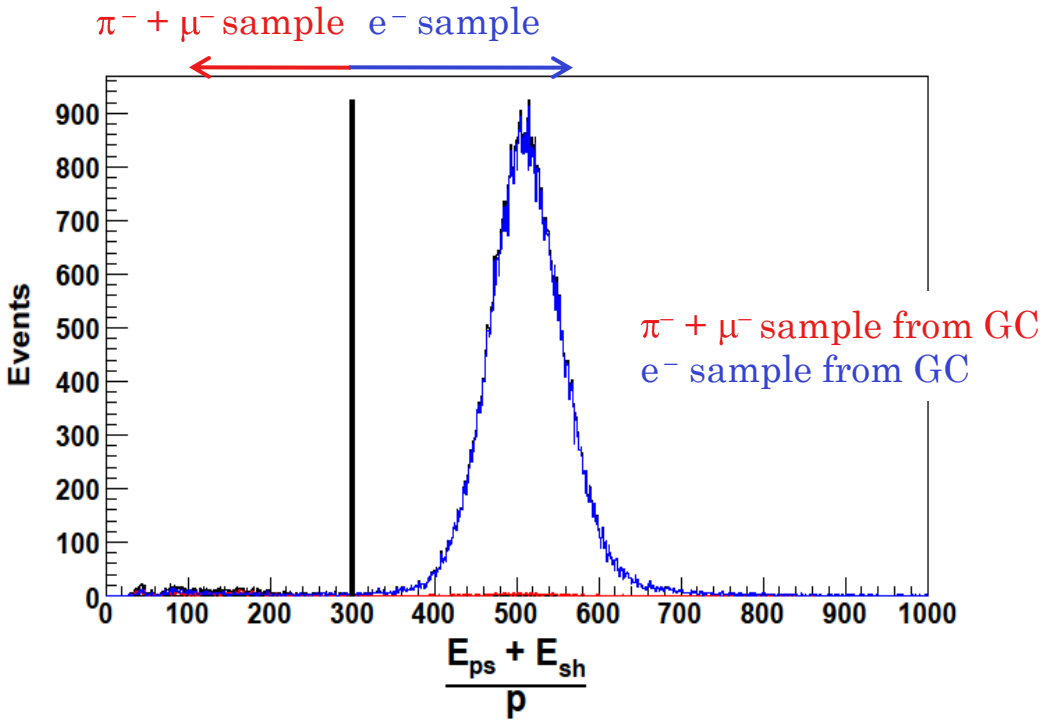
Concluding Remarks

- 10 ns ONLINE coincidence timing peak for e^+e^- signal events
- Particle ID from the shower detector allows to reduce pion content in positron sample below 5%
- Gas Cherenkov allows further reduction of pion background by at least a factor of 10
- Rates and particle ID are stable up to high intensities

Test run results obtained to maximum rates projected for APEX data taking

Lead Glass Particle ID in Electron Arm (low rate)

2 μA on Pb Target
Electron arm rate – 370 kHz



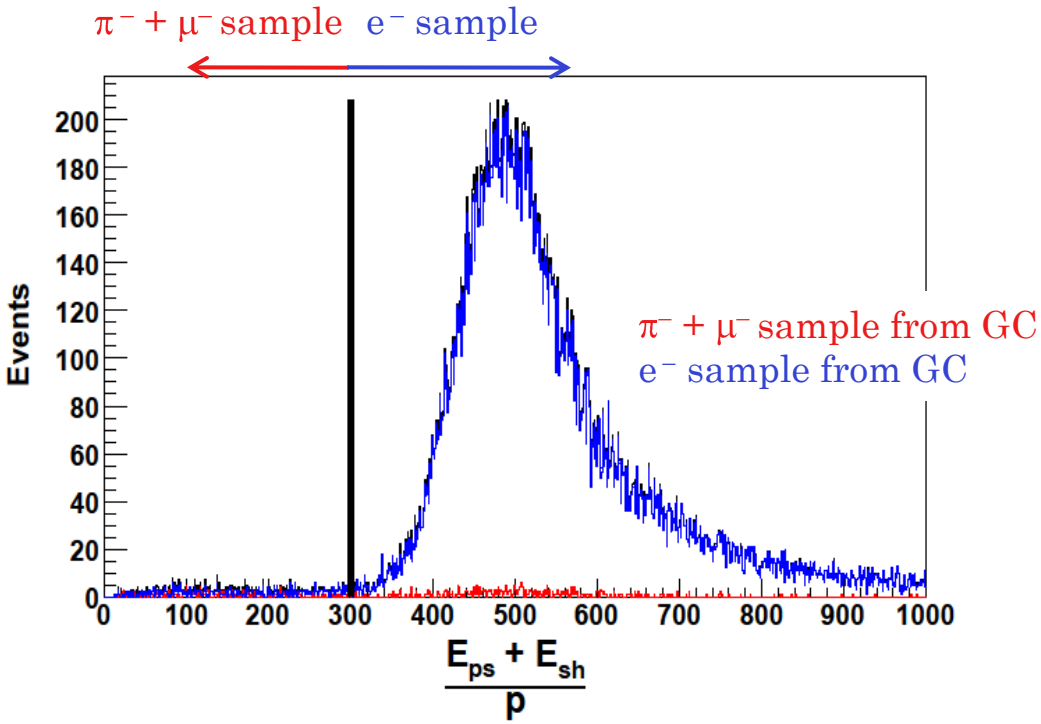
Electron detection eff.	0.989
Pion rejection eff.	0.650

Meson background rejected by a factor of 3

- E_{PS} – Energy deposition in 1st layer
- E_{SH} – Energy deposition in 2nd layer
- p – Particle momentum

Lead Glass Particle ID in Electron Arm (high rate)

30 μA on Pb Target
Positron arm rate – 765 kHz



Electron detection eff.	0.987
Pion rejection eff.	0.325

Meson background rejected by a factor of 1.5

- E_{PS} – Energy deposition in 1st layer
- E_{SH} – Energy deposition in 2nd layer
- p – Particle momentum

Projected rates in full experiment

Expected rates according to the APEX proposal

Settings	**A**	**B**	**C**	**D**
Beam Energy (GeV)	2.3	4.5	1.1	3.3
Singles (negative polarity)				
e^- (kHz)	4,500	700	6,000	2,900
π^- (kHz)	640	2,200	36	2500
Singles (positive polarity)				
e^+ (kHz)	31	3.6	24	23
π^+ (kHz)	640	2,200	36	2500

Projected rates in full experiment

Using observed e/p ratio in the APEX test run

Settings	**A**	**B**	**C**	**D**
Beam Energy (GeV)	2.3	4.5	1.1	3.3
Singles (negative polarity)				
e^- (kHz)	4,500	700	6,000	2,900
π^- (kHz)	100	2,200	36	1,000
Singles (positive polarity)				
e^+ (kHz)	31	3.6	24	23
π^+ (kHz)	100	2,200	36	1,000
Offline rejection, π^-	N/A	30	N/A	3
Obtained/Projected	10	64	N/A	15
Offline rejection, π^+	30	6,000	15	500
Obtained for π^+	1,800			
Projected for π^+	7,500	7,500*	7,500	7,500*

Projected DAQ rates in full experiment

Settings	A	B	C	D
Beam Energy (GeV)	2.3	4.5	1.1	3.3
π+ rejection = 30				
10 ns timing gate (Hz)	1,548	772	1,515	1,960
20 ns timing gate (Hz)	3,097	1,544	3,029	3,920
π+ rejection = 50				
10 ns timing gate (Hz)	1,486	502	1,486	1,560
20 ns timing gate (Hz)	2,971	1,005	2,972	3,120

Reasonably below 4 kHz