Signal and Background Reactions in APEX

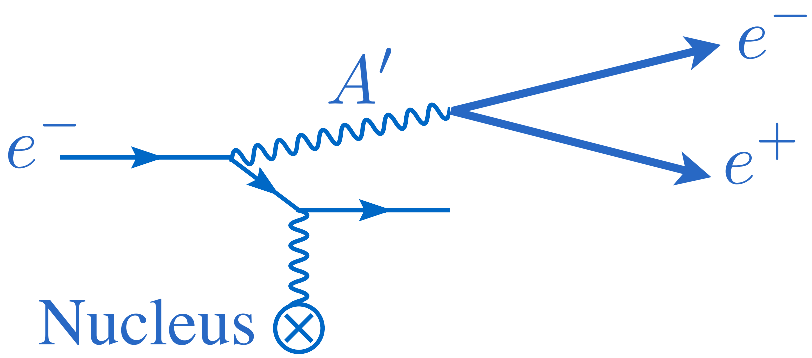
- Why do we need high rates?

- Expected rates from simulations, and impact on conceptual design

- **Checking rates against data in test run**

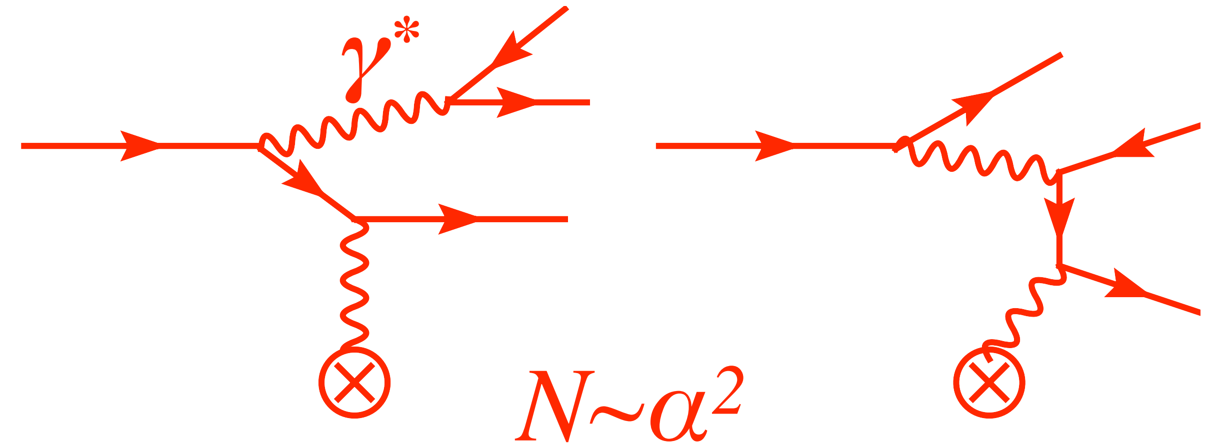
APEX Goal: Search for New Boson A′

Production diagrams analogous to photon bremsstrahlung



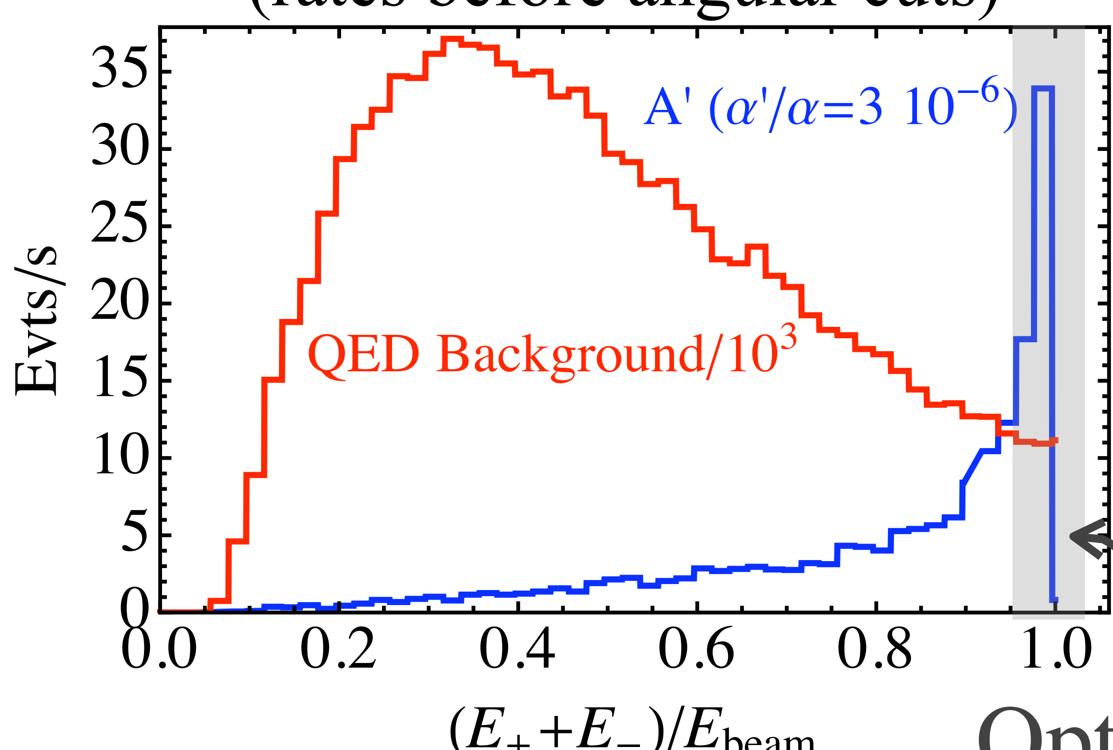
A′ decays promptly to e^+e^-, $\mu^+\mu^-$, or $\pi^+\pi^-$

QED Backgrounds



Strategy: measure e^+e^- mass spectrum precisely

(rates before angular cuts)



A′ products carry full beam energy!

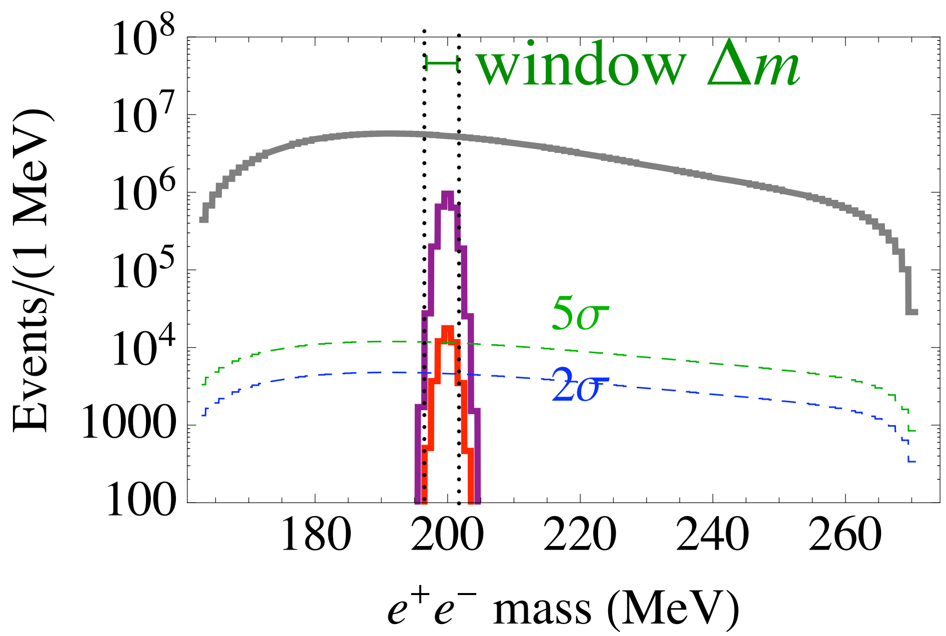
– Distinctive kinematics
– Assists in background suppression

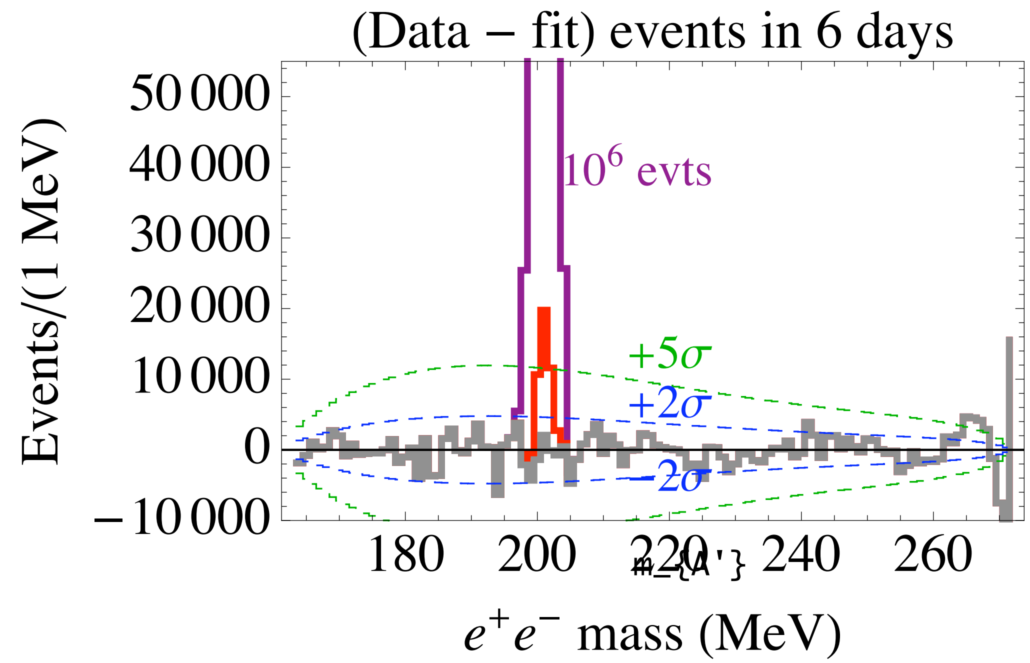
Optimal kinematics for A′ search

Narrow Resonance Search

To identify A′ signal, must study invariant mass distribution

$$m_{A'} \approx \sqrt{E_+ E_-}(\theta_+ + \theta_-)$$





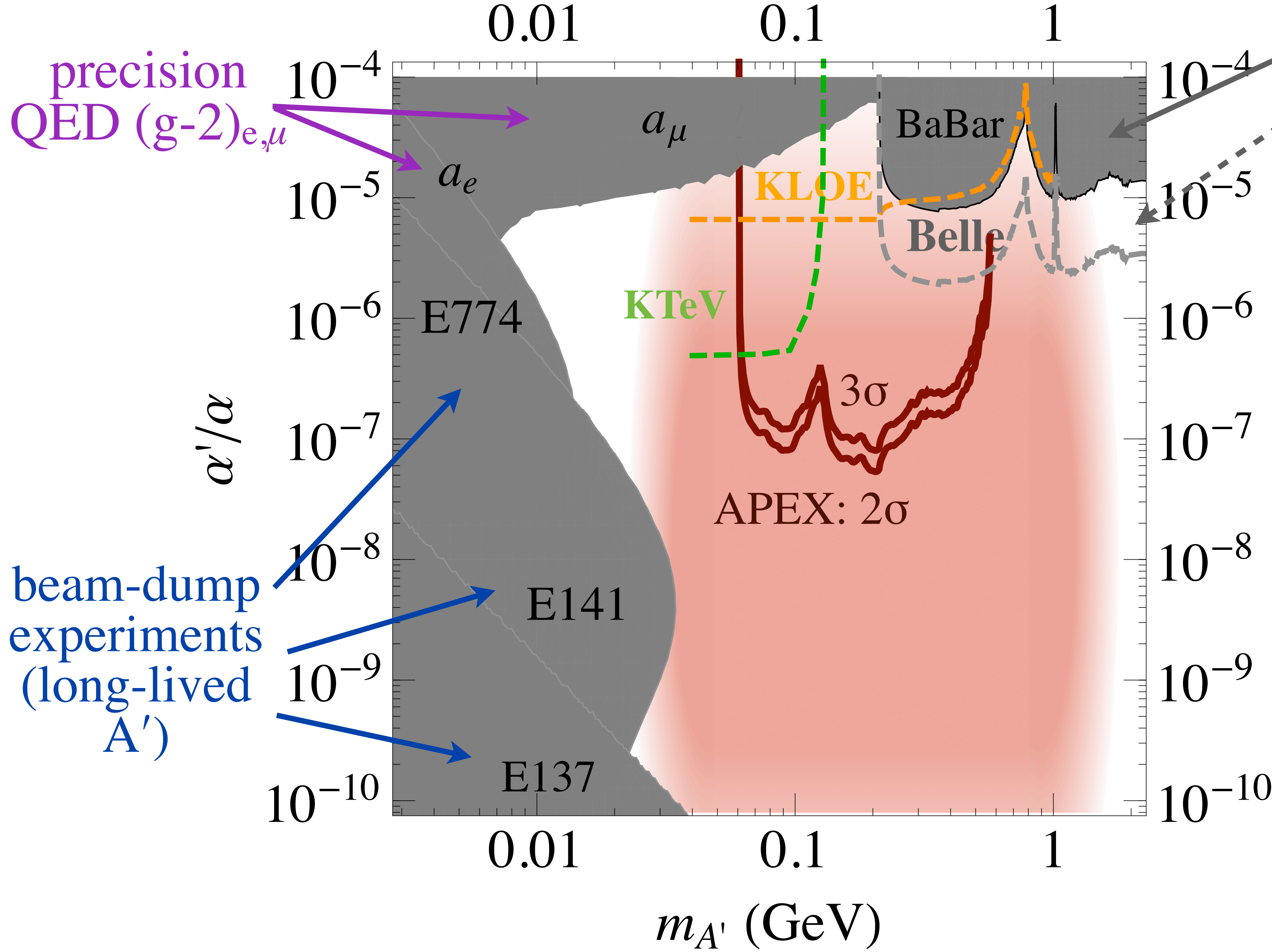
In mass window Δm: $$\frac{S}{\sqrt{B}} \sim \frac{\alpha'}{\alpha^2}\sqrt{N_{QED}\left(\frac{m_{A'}}{\Delta m}\right)}$$

To search at small α', need:

★High e^+e^- statistics

★Excellent mass resolution

Existing limits and APEX Sensitivity



Gray regions: excluded (2σ) by past experiments

Dashed lines: estimated 2σ sensitivity of other possible searches in existing **KLOE**, **KTeV**, and **Belle** data.

No past experiment has **sufficient statistics and mass resolution** to see A′ if its coupling is below the dotted lines.

This is a theoretically motivated region
– relevant for dark matter – predicted by grand unification

Expected Rates

- Singles rates in each spectrometer

- Accidental coincidence rates (dominate trigger)

- True e^+e^- coincidences

Numbers in this talk correspond to:

Beam energy:	*2.3 GeV*
Central angle:	*5°*
Central momentum:	*1.145*
Target:	*4.25% X_0 W*

(appropriate for test run)

Test run will check these calculations!

Expected Rates

- Negative arm:
  - dominated by Coulomb-scattered e^-: 4.5 MHz
  - π^- rate 0.64 MHz
- Positive arm:
  - π^+ rate 0.64 MHz ⇒ gas Cherenkov signal rate 6.4 kHz (1%)
  - QED e^+ singles 31 kHz dominate gas Cherenkov signals
  - e^+ from π^0 decay: 2 kHz

  Note: π/e ratio $\propto A/Z^2$ ⇒ high-Z important!

  W: $184/74^2$ → 0.034
  M: $96/42^2$ → 0.054 (50% worse than W)
  Al: $27/13^2$ → .16 (5x worse than W)
  C: $12/6^2$ → 0.33 (10x worse than W)

- We will check all of these in test run
  - e^+ from π^0 decay (only significant for 4.4 GeV running) can be enhanced by using lower-Z target

Trigger setup

- 20 ns coincidence between S0-P and S0-N
- 40 ns coincidence between S0-P and positive-polarity gas Cherenkov counter

Accidental coincidence

- e^+e^- Accidental: (4.5 MHz) x (33 kHz) x (20 ns) = 3.0 kHz
- 1% leakage of π^+e^- Accidental:
  (4.5 MHz) x (6.4 kHz) x (20 ns) = 0.58 kHz
- Total accidental rate 3.6 kHz

Accidental coincidence (offline)

- Total accidental trigger: 3.6 kHz
  - Offline reduction to 75 Hz
    - → 2ns timing: factor of 10
    - → tracks from same zig-zag plane: factor of 4

      (for higher energy settings, factor of 5-20 additional π rejection also required)

True coincidence

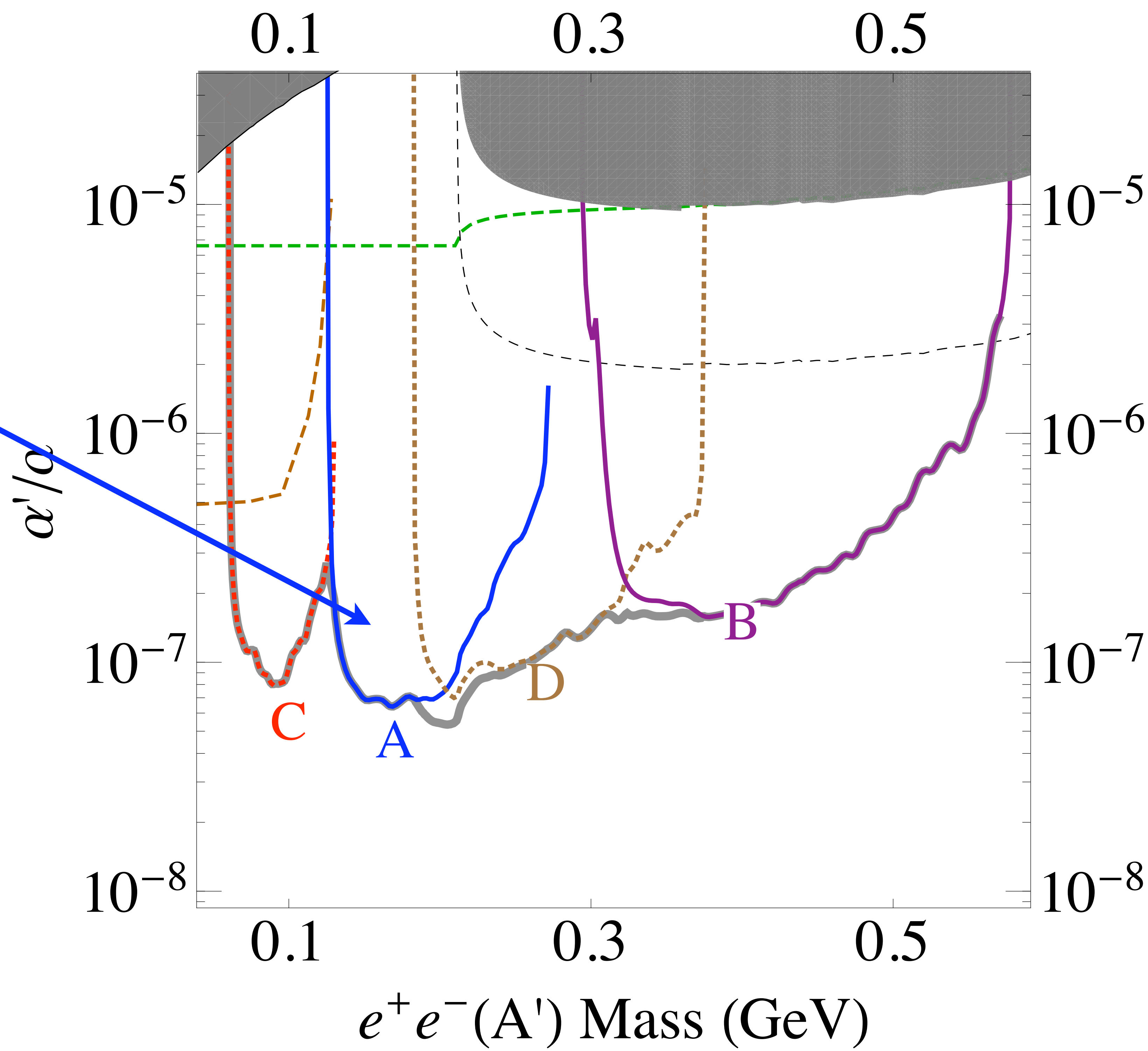
- QED trident: 610 Hz
- Hard radiation + conversion: 35 Hz

Summary: Test Run Rate Measurements

- Singles in each arm, with and without gas Cherenkov signal (e^+, $\pi^\pm$, and e^-)
- Coincidences within 2ns window
  - Demonstrate timing, vertex rejection of accidentals
  - Demonstrate π rejection needed for high-energy settings
- e^+ rates from π^0 enhanced in running with lower-Z target

Possible Physics with Test Run

Test-run data will be collected near "Setting A"



Experimental Design: Count Rates and Trigger (75 μA current)

Settings	A	B	C	D
Beam energy (GeV)	2.302	4.482	1.1	3.3
Central angle	5.0	5.5	5.0	5.0
Target T/X_0	4.25%	10%	0.58%	10%
Central momentum (GeV)	1.145	2.230	0.545	1.634
Singles (negative polarity)				
e^- (MHz)	4.5	0.7	6.	2.9
π^- (MHz)	0.64	2.20	0.036	2.50
Singles (positive polarity)				
$\pi+$ [p] (kHz)	640.	2200	36.	2500.
e^+: QED (kHz)	31.	3.6	24.	23.
e^+: π^0 decay (kHz)	2	7	0.03	9
Total e^+ (kHz)	33.	10.6	24.03	32.
Trigger/DAQ				
Accidental trigger(kHz)	3.55	0.47	2.93	3.33
True coinc. trigger (kHz)	0.65	0.09	0.36	0.6
Total trigger (kHz)	4.20	0.56	3.29	3.93
Offline Signal & Background Rates				
QED e^+e^- (Hz)	610	70	350	530
Two-step (Hz)	35	15	5	75
Accidental Background (Hz)	74	3.8	72	47

Main Trigger:
Coincidence of S0 signals in both arms (20 ns)
and
between S0 and Gas Cherenkov signals in positive arm (40 ns)

Each setting:
~10^8 QED e^+e^- events in 6–12 days

10,000 x more statistics than existing A′ searches in this mass range!

With offline analysis, **QED e^+e^- pairs dominate** over accidentals by factor of 5–20