

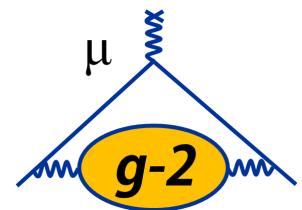


# g-2 Simulation Tools

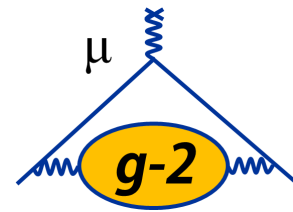
Renee Fatemi

FNAL Operational Readiness Review

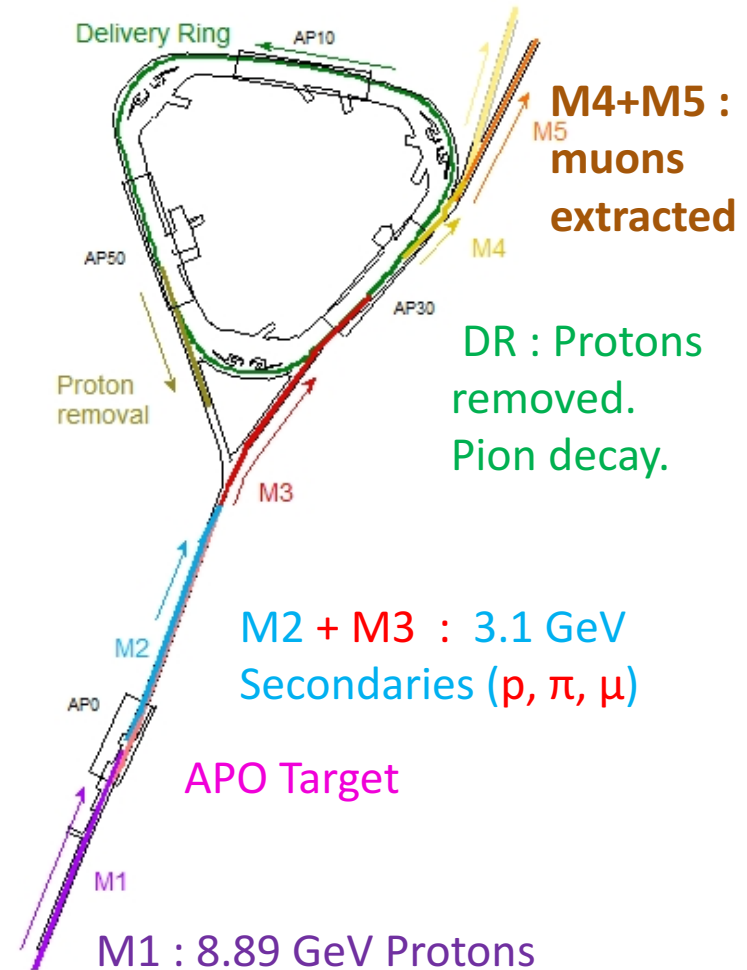
October 2, 2017



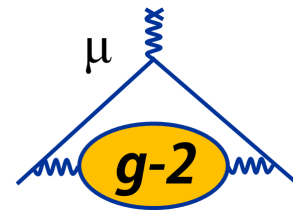
# What STUDIES do we need?



- I. Beam optics from target to storage ring injection
  - Model proton-target interactions
  - Track secondaries through beamlines and delivery ring
  - Predict # stored muons per protons on target (POT).
  - Necessary for beamline design and motivating running time.

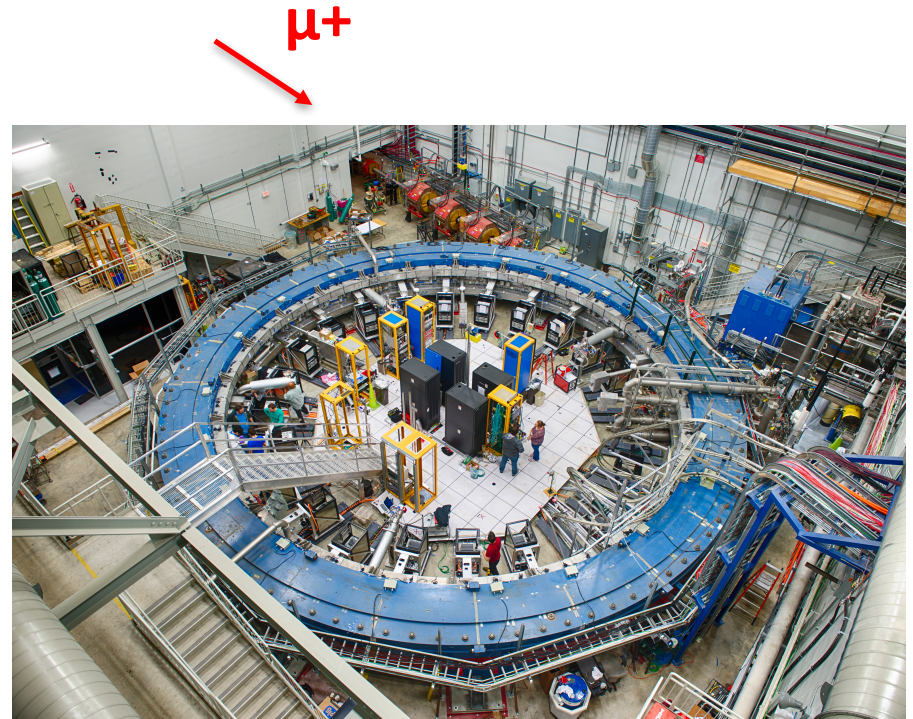


# What STUDIES do we need?

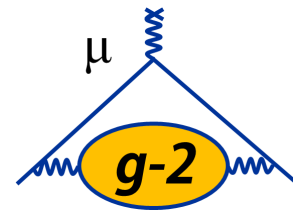


## II. Beam optics in the storage ring

- Optimize beam injection parameters into the inflector
- Optimize inflector, kicker and quad settings for maximal muon storage
- Study effects of non-optimal quad alignment and field settings on muon storage and motion around the ring.

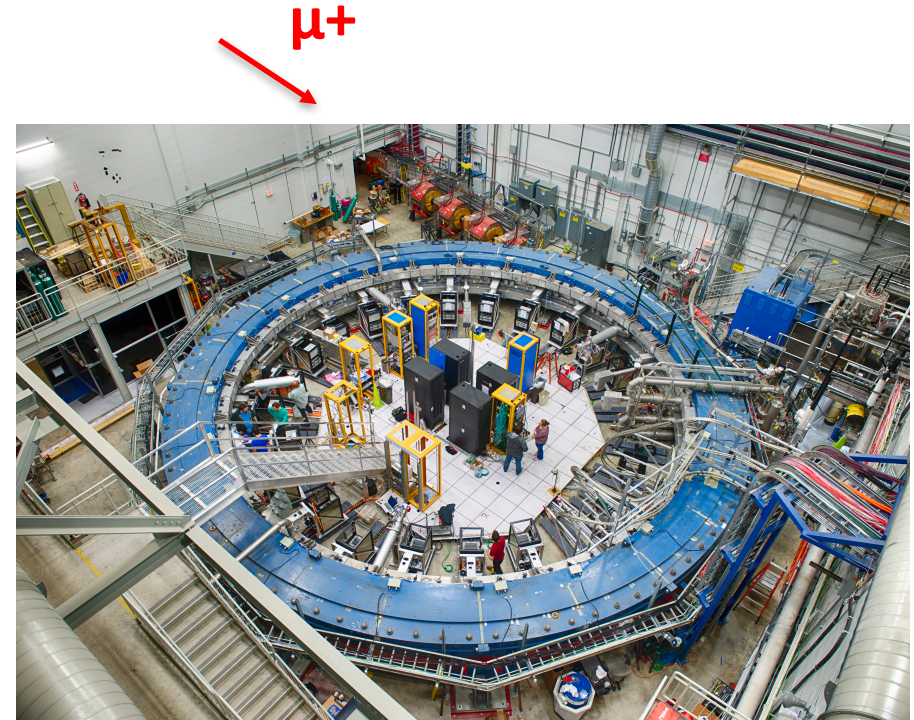


# What STUDIES do we need?

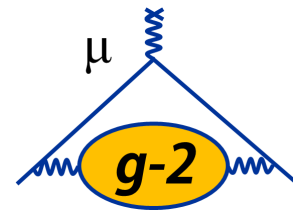


## III. Particle interactions with material in injection M5 line and storage ring

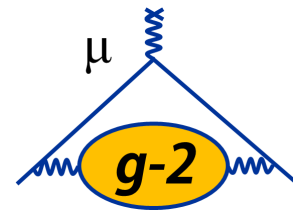
- Realistic distribution of decay positrons in order to
  - Develop calorimeter clustering and track reconstruction methods
  - Parameterize distributions as input for “fast” monte carlo simulations.
- Realistic muon injection and storage in order to
  - Study muon motion in the ring and interactions with collimators and fiber harps
- Study signature of systematic effects, for example lost muons



# What TOOLS do we have?

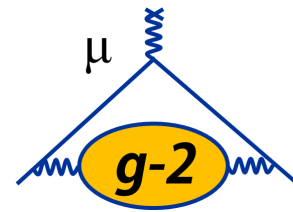


STUDY	PACKAGE	FUNCTION
1	MARS	Simulates interaction of proton beam with the target and produces distribution of downstream secondary particles.
1 & 2	G4BEAMLIN	A particle tracking simulation program based on GEANT4 and optimized for simulating beamlines. Includes particle interactions such as pion-muon decay and precession of the muon spin as well as interactions with materials.
1 & 2	COSY	Same functionality as G4BEAMLIN. Includes fringe fields as well.
1 & 2	BMAD	Simulates relativistic charged-particle dynamics in high energy accelerators and storage rings. Capable of tracking particle momentum and spin interactions with fields. Does not simulate material interactions.
2 & 3	GM2RINGSIM	Customized implementation of GEANT4 within ART framework. Simulates the interaction of particles with storage ring materials and tracks motion inside materials and fields. Package includes several particle guns.



## Snapshots from **Type 1** Studies

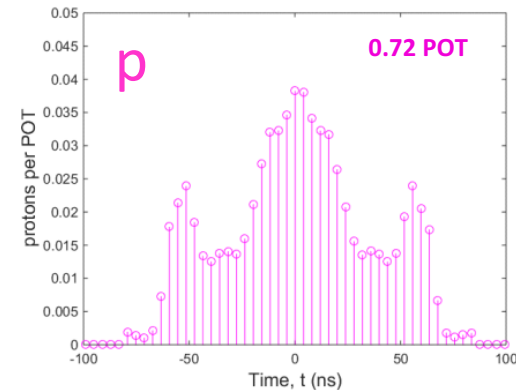
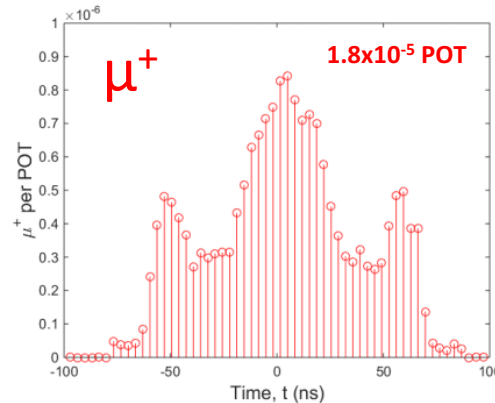
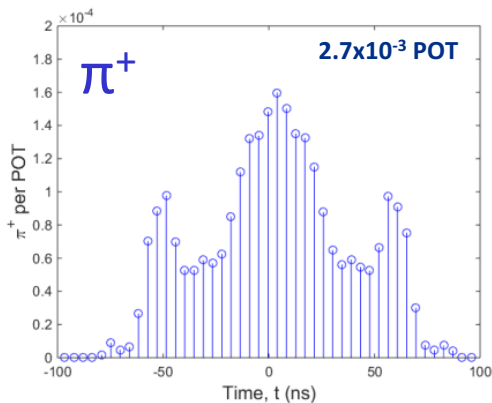
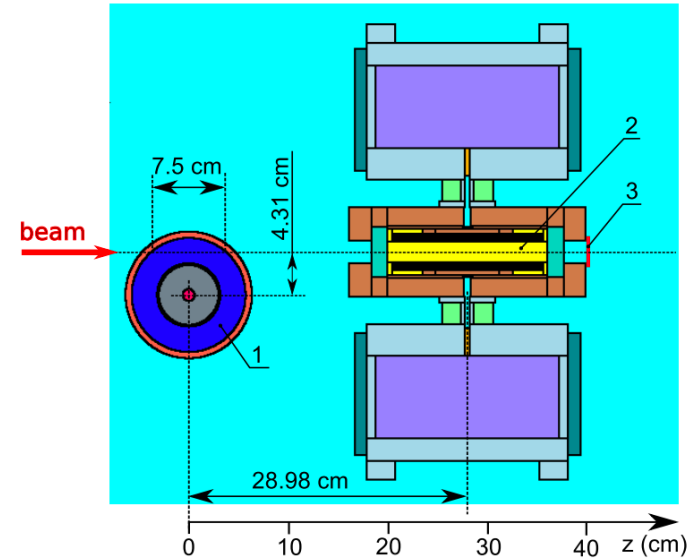
# MARS : Target Production



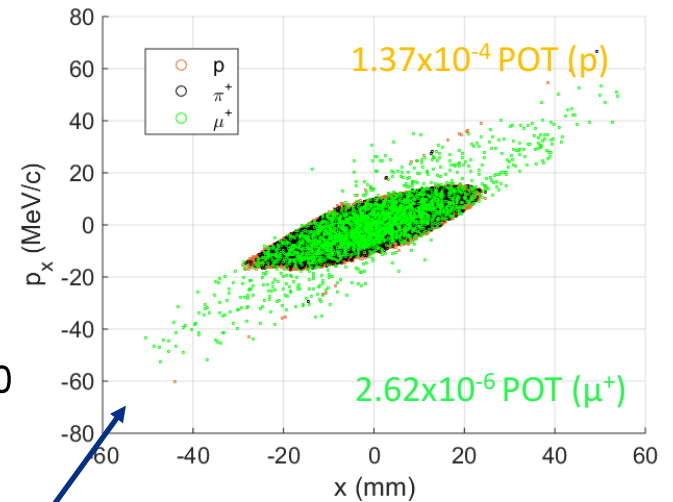
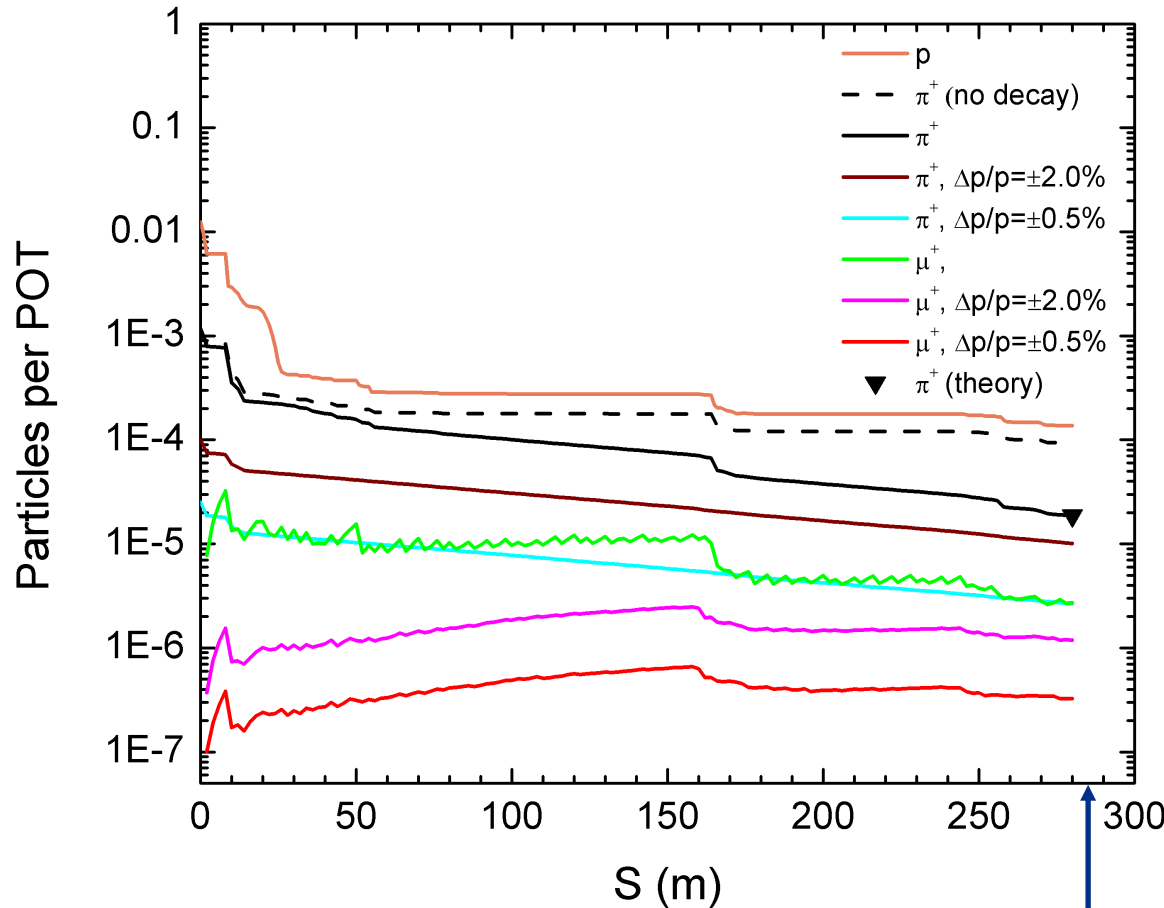
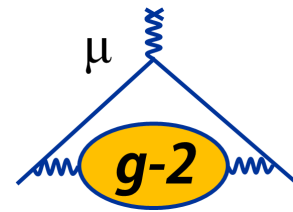
MARS used to model inconel target and lithium lens.

Simulate # secondaries/POT as a function of species after the TARGET

MARS output -> input to G4Beamline



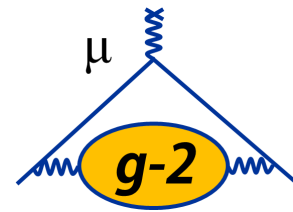
# G4BEAMLINE and COSY : M2 & M3 Lines



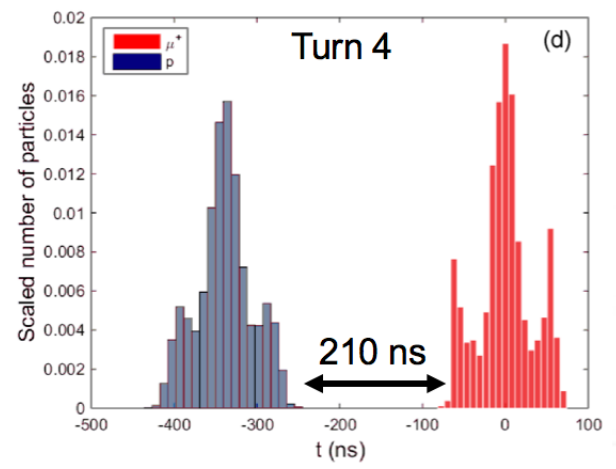
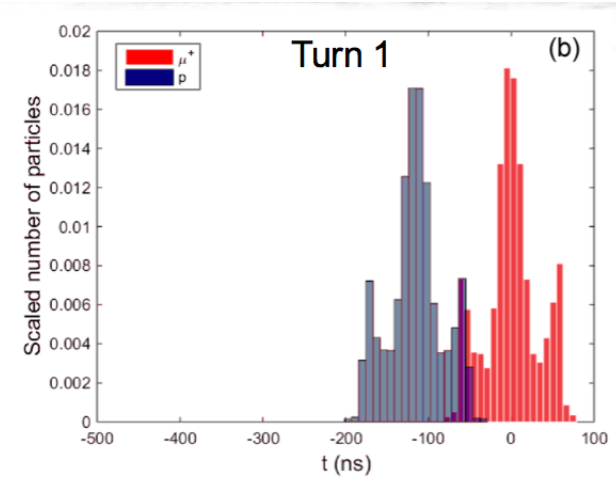
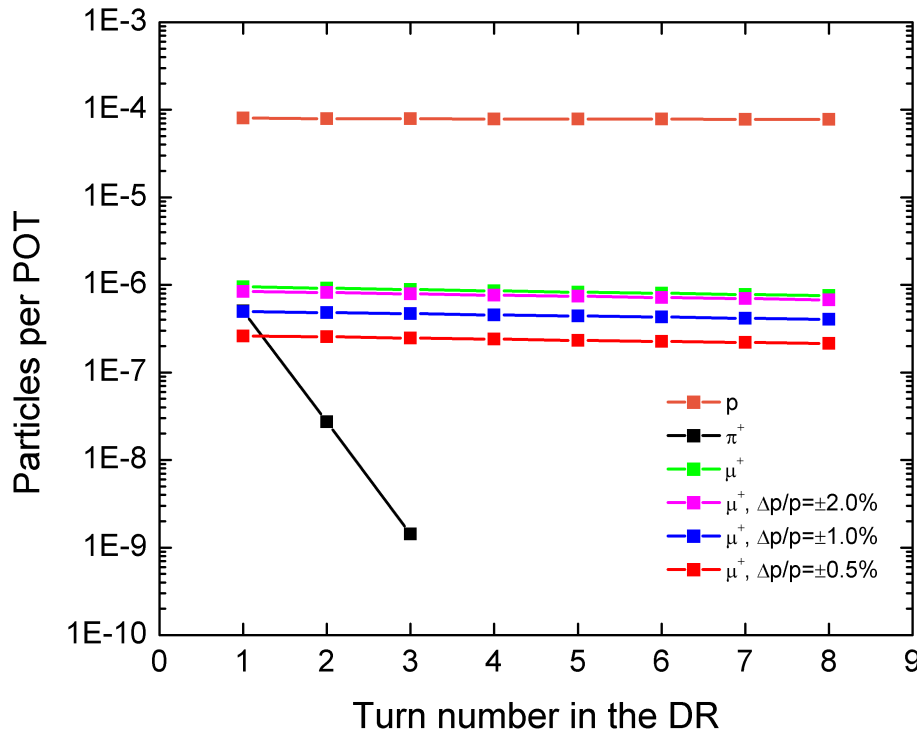
DR entrance



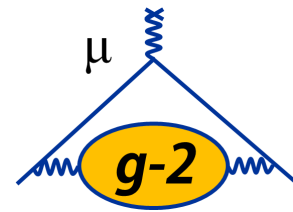
# G4Beamline and COSY : Delivery Ring



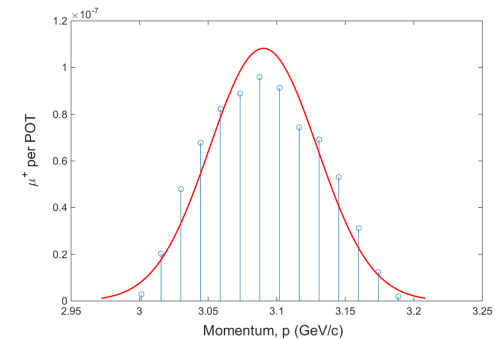
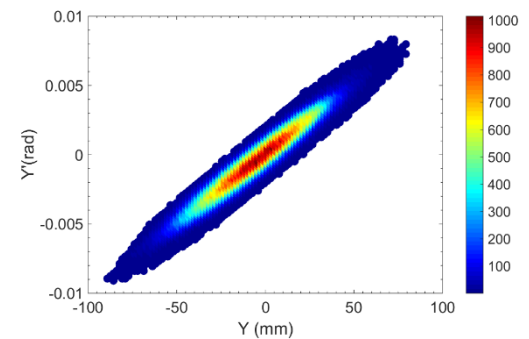
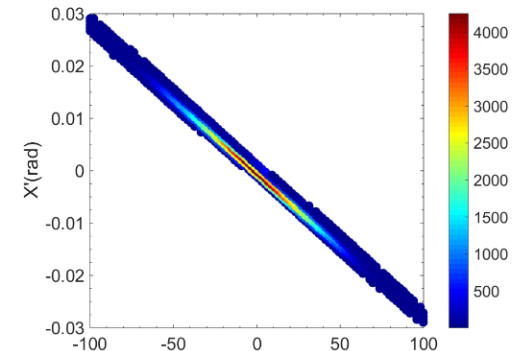
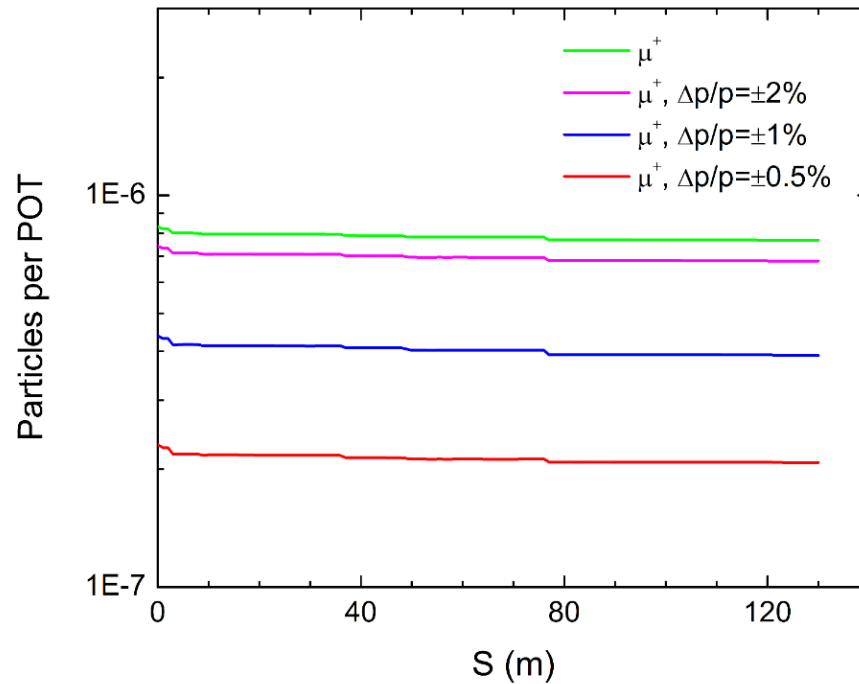
- ~All pions decay to muons by turn #3
- Protons increasingly lag behind decay muons.
- After 4 turns protons are ready to be kicked out of DR

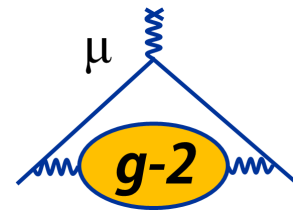


# G4Beamline and COSY : M4 & M5 Lines



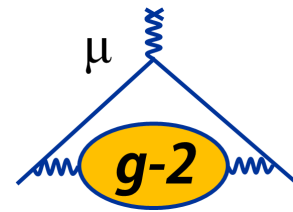
- Losses through M4+M5 are minimal
- Muon momentum and beam injection parameters at inflector are fed into



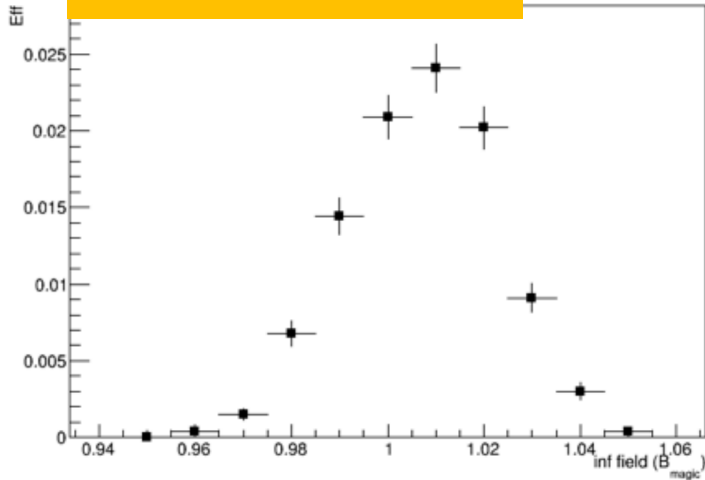


## Snapshots from **Type 2** Studies

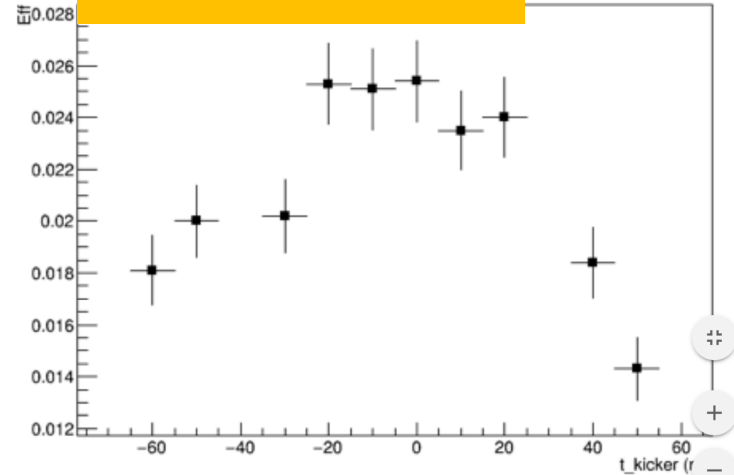
# BMAD : Ring Storage Parameters



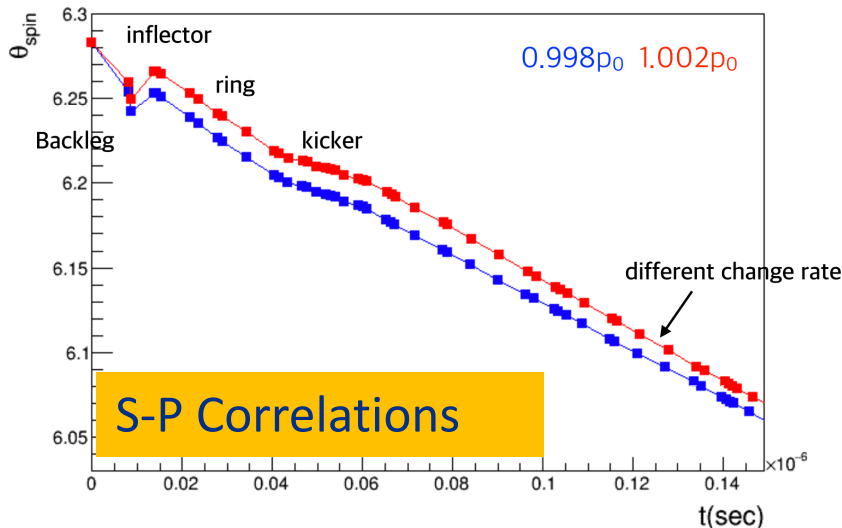
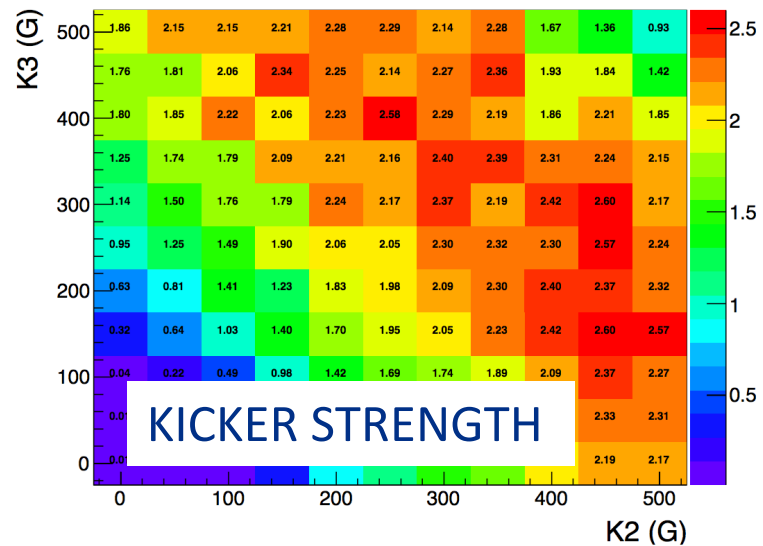
INFLECTOR FIELD



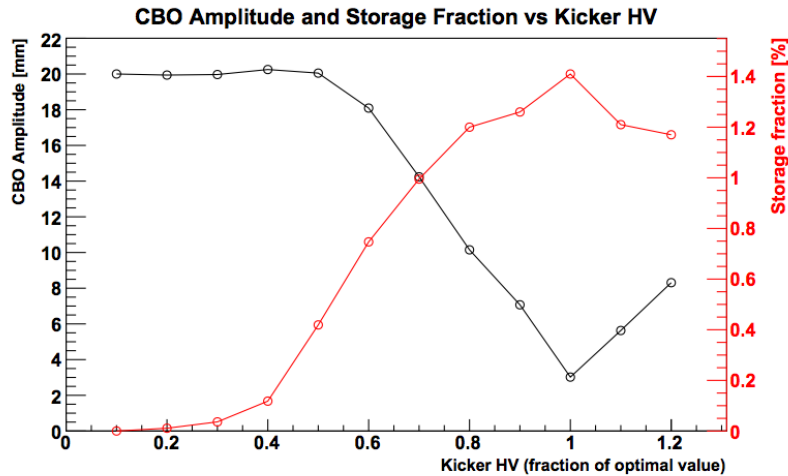
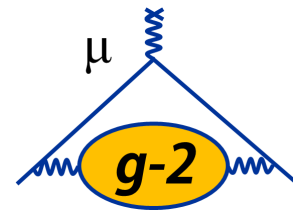
KICKER TIMING



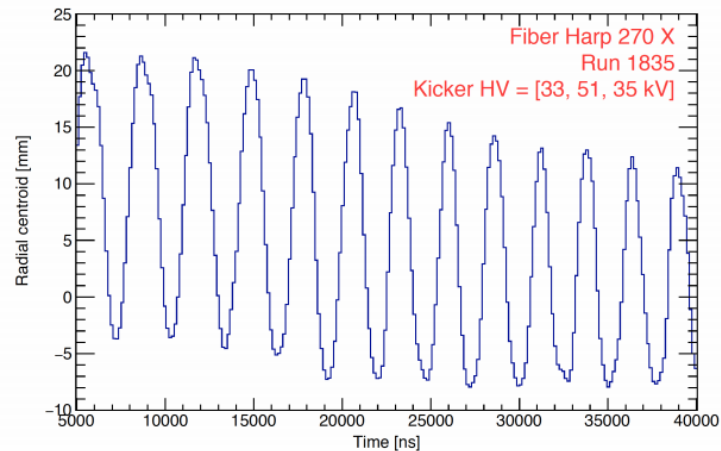
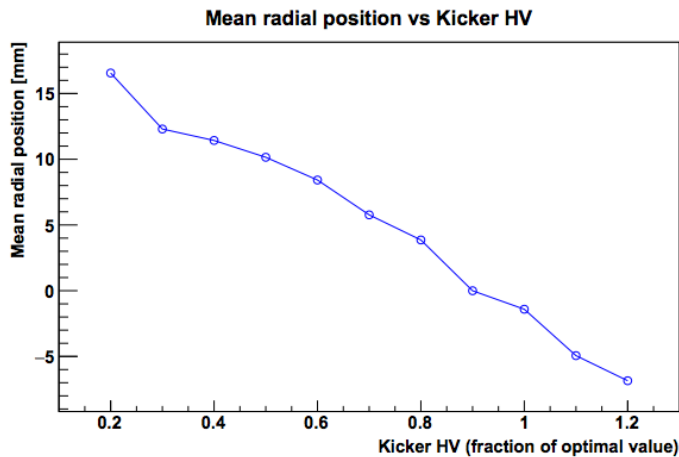
Eff(%) K1 = 270 G

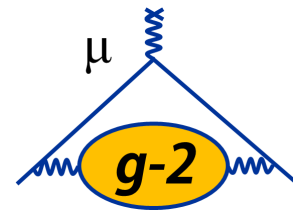


# GM2RINGSIM : CBO vs Kicker Strength



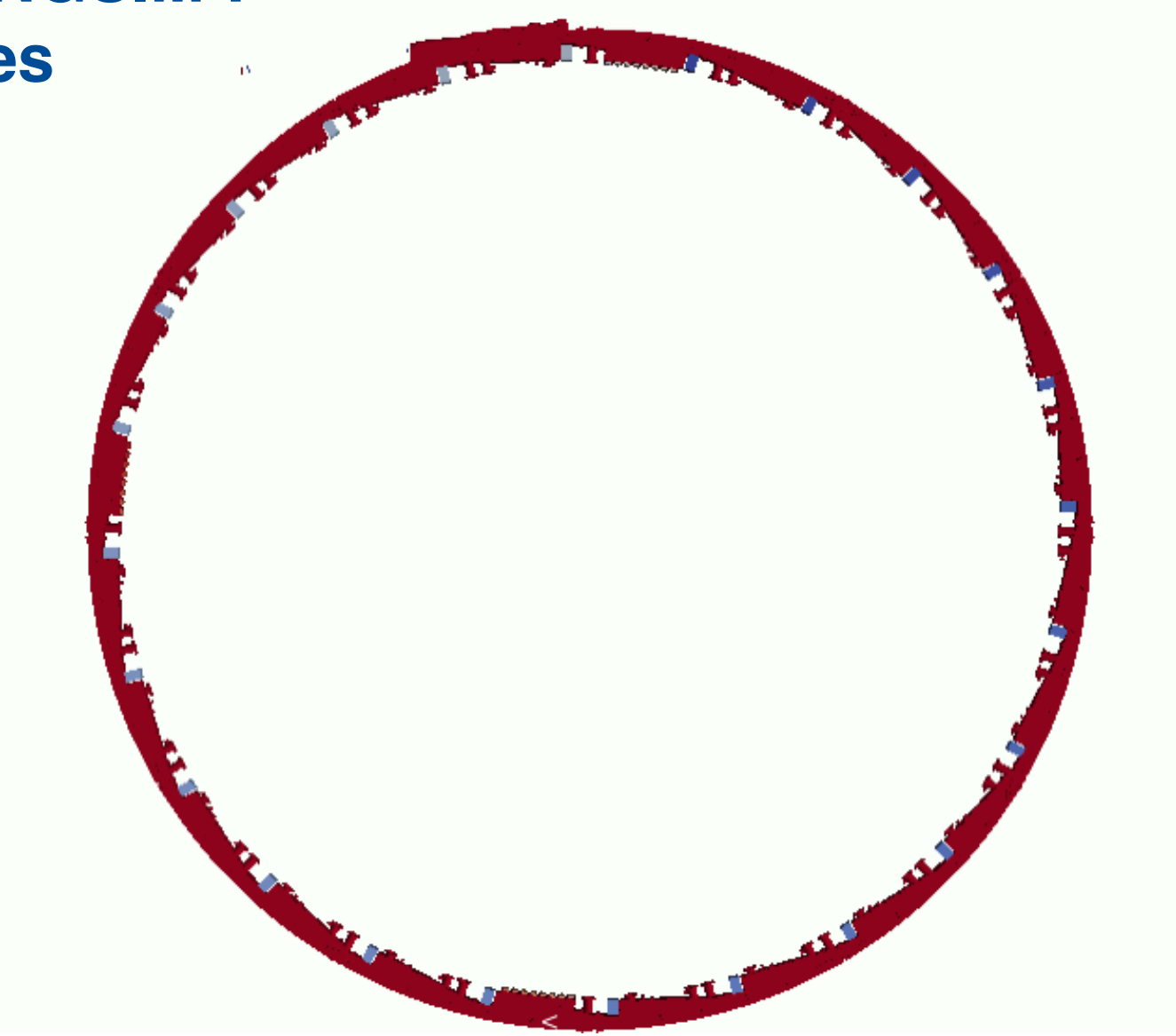
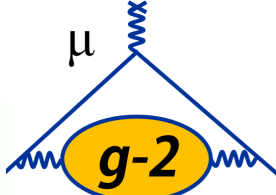
During commissioning CBO did not change with kicker field as expected. Use BeamGun to map out CBO and mean radial beam position as a function of kicker strength. GM2RINGSIM indicates kickers were running  $\sim 70\%$  of full field. Agrees well with BMAD analysis (see Dave Rubin's talk).



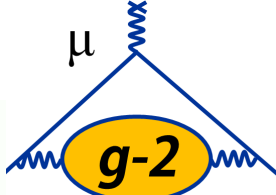


## Snapshots from **Type 3** Studies

# GM2RINGSIM : Features



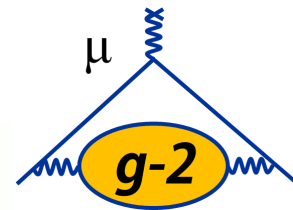
# GM2RINGSIM : Features



Constructed from a mix of native  
GEANT4 and CADMESH volumes.



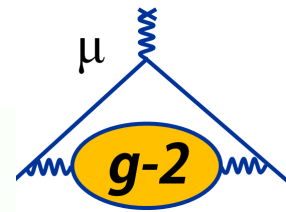
# GM2RINGSIM : Features



Constructed from a mix of native  
GEANT4 and CADMESH volumes.

Geometry integrated with complex  
time dependent magnetic and  
electric fields.

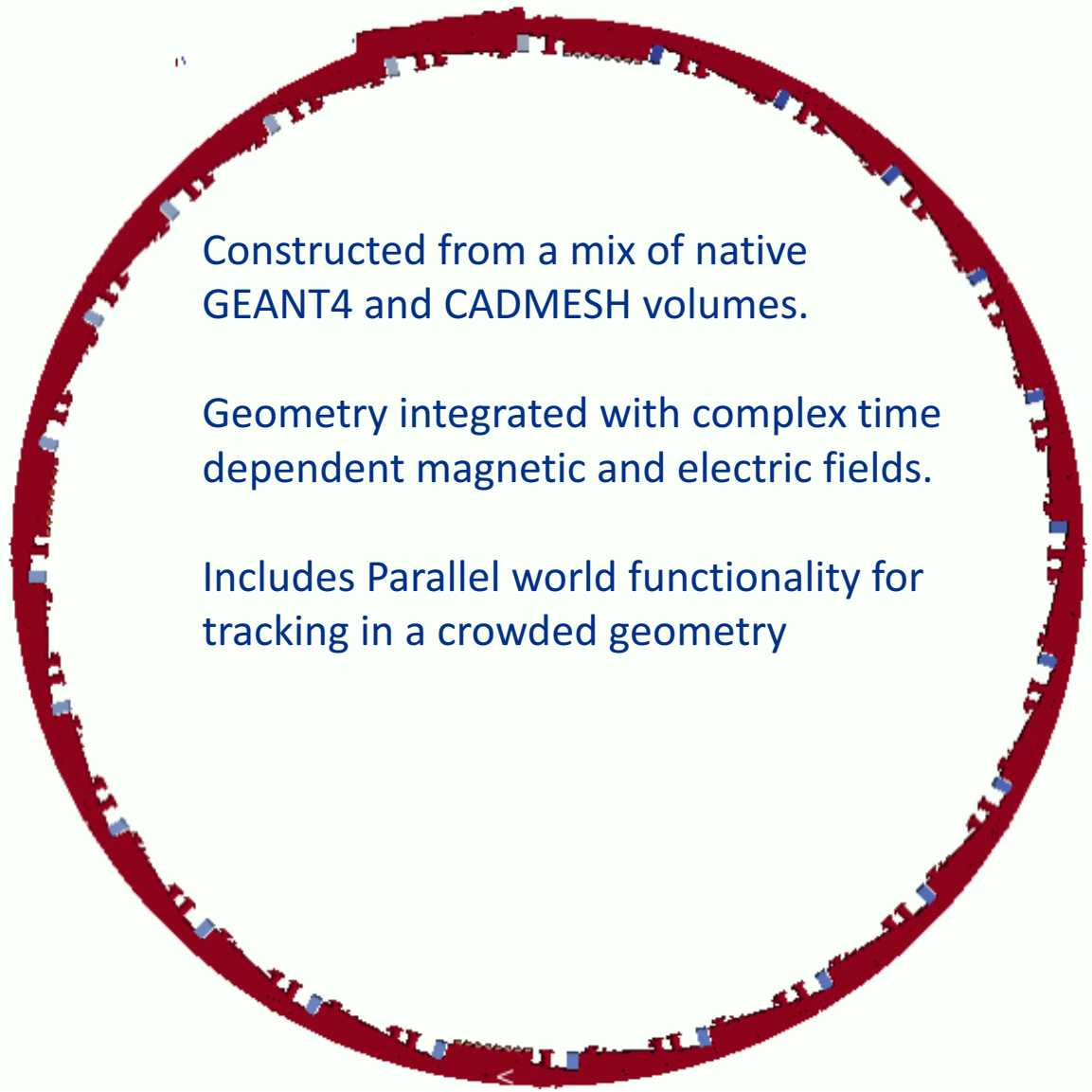
# GM2RINGSIM : Features



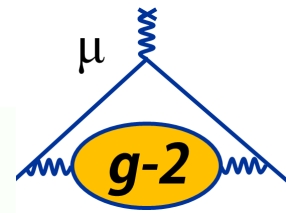
Constructed from a mix of native  
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Geometry integrated with complex time  
dependent magnetic and electric fields.

Includes Parallel world functionality for  
tracking in a crowded geometry



# GM2RINGSIM : Features



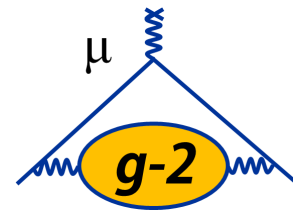
Constructed from a mix of native GEANT4 and CADMESH volumes.

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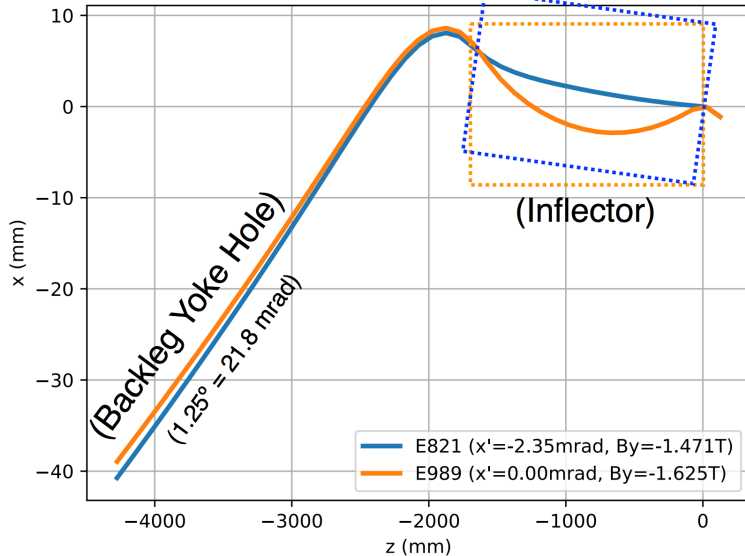
Includes Parallel world functionality for tracking in a crowded geometry

Includes an arsenal of particle guns:  
MIGun, DistroGun, GasGun, BeamGun

# GM2RINGSIM : Inflector Design



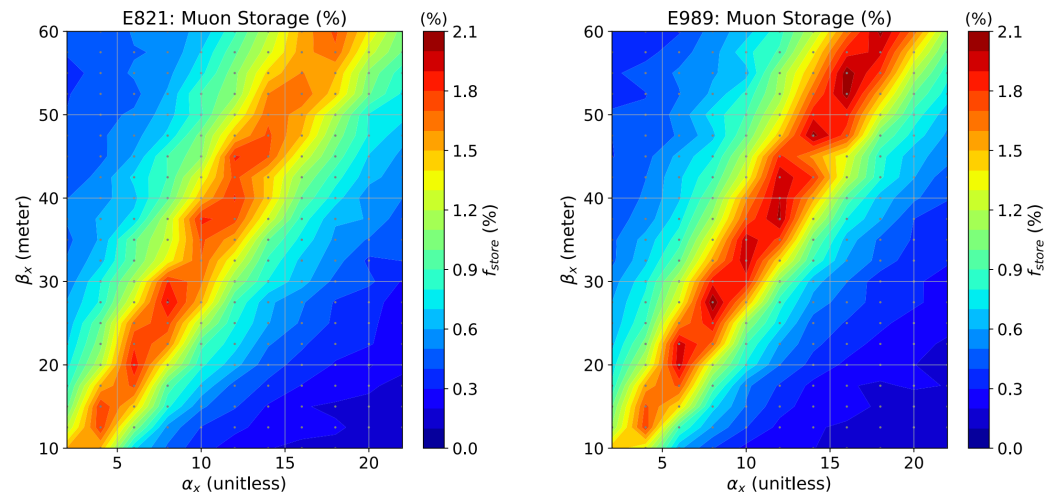
Example E989 vs. E821 Injection Reference Trajectories



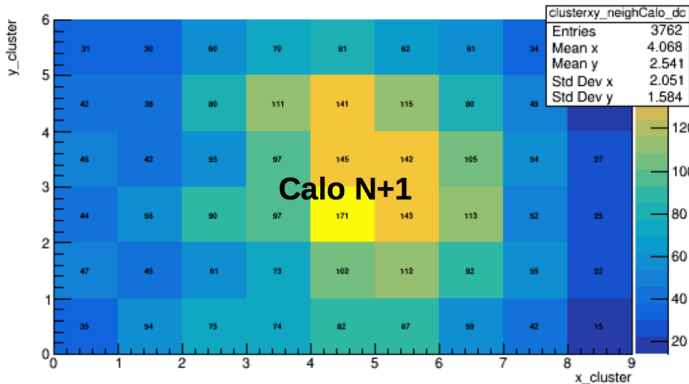
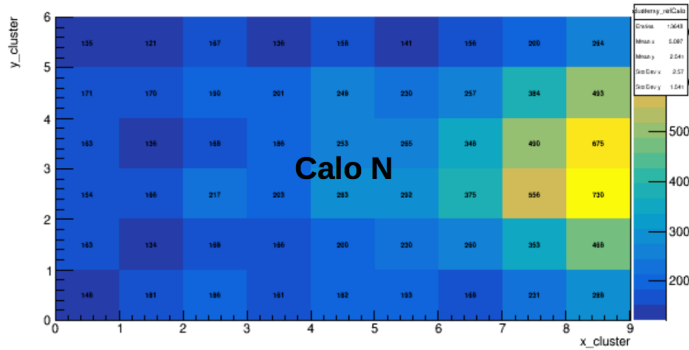
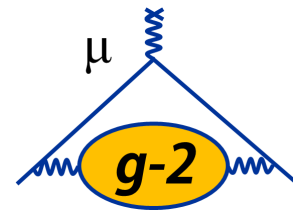
- g-2 used the original E821 inflector during the commissioning run. In parallel a new, lower mass, inflector was being designed
- The beam gun was used to study muon trajectories and storage fraction rates as a function of inflector design.

- Also used tune inflector, kicker and quad fields and optimize muon storage for commissioning run.

E989 vs. E821 INFLECTOR (PRELIMINARY)



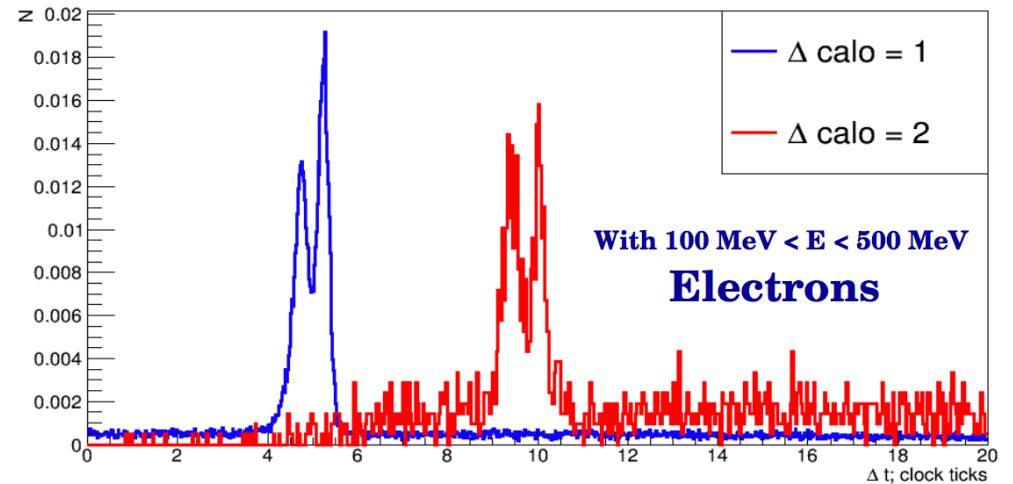
# GM2RINGSIM : Lost Muon Signal



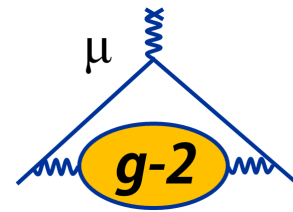
Muons that exit the storage ring before decaying distort the  $\omega_a$  extraction.

Use beamGun to study double (triple) coincidences in calorimeters.

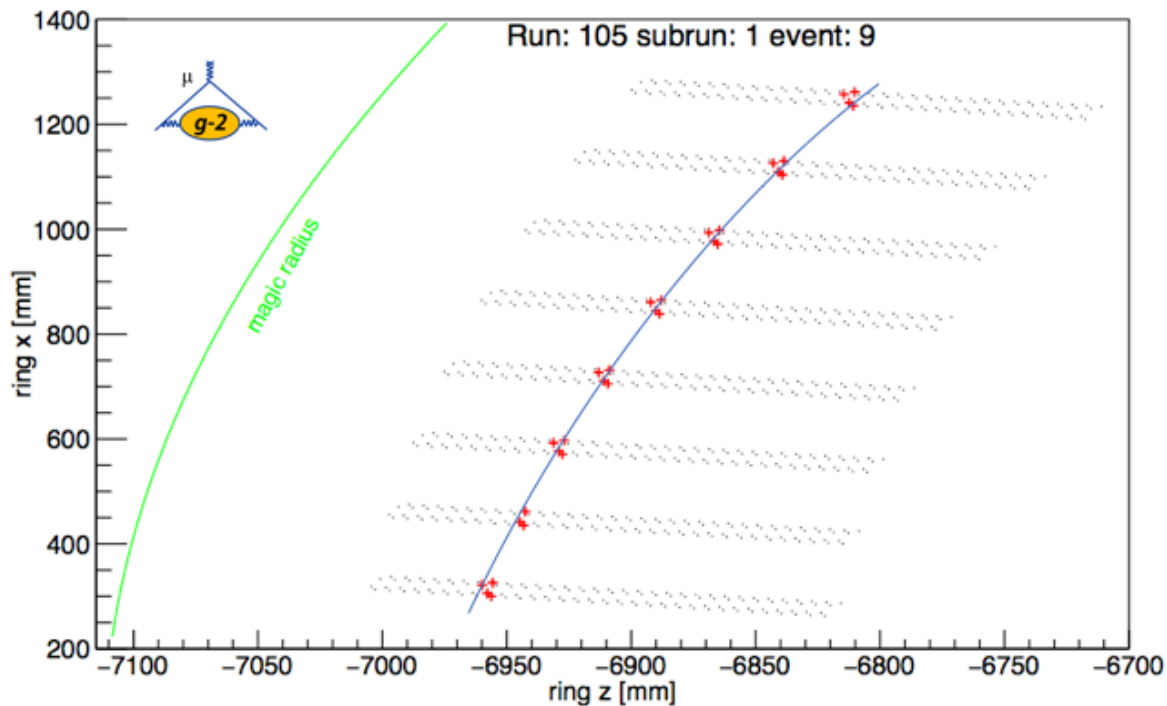
Use gasGun to study backgrounds to the lost muon signal.



# GM2RINGSIM : Track Reconstruction

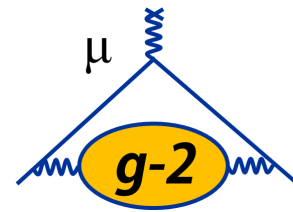


Integral part of track reconstruction in the strawtrackers.



- Geometry provides tracker module and straw positions
- The magnetic field is used to predict the path of the track through the fringe field.
- Simulation provides the energy loss in chamber walls and straws
- All of these effects are combined to extrapolate track to the decay tangential point

# Computing Resources and Contributors



## MARS

*Initial studies run at RACF @ BNL.  
Future studies will be run @ FNAL.*

- Voloyda Tishchenko
- Bill Morse
- J.F. Ostiguy
- Jim Morgan
- D. Still
- Mike Syphers

## BMAD

*Running @ CORNELL and FNAL*

- Dave Rubin
- SeungCheon Kim
- Joe Bradley

## G4BEAMLIN

*Initial studies run on Cori @ NERSC.  
If resources at NERSC become limited  
will run @ FNAL instead.*

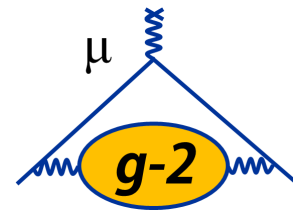
- Diktys Stratakis

## COSY

*Currently running on cluster at  
Michigan State. Exploring possibility  
of running on FermiGRID.*

- *David Tarazona*
- *Martin Berz*

# Computing Resources and Contributors



## GM2RINGSIM

*Production currently runs on FERMIGrid and will utilize OSG in future.*

- Production of truth level hits requires **0.6-6 sec/event**. Reconstruction runs x10 faster .
- Combined footprint of truth + reconstruction is **~1TB per 4M events**.
- If the collaboration requires a gm2ringsim simulation sample that replicates the expected data sample of  $1 \times 10^{11}$  we would need **10 PB** of disk space.
- The collaboration is embarking on a campaign to reduce both the running time and the total storage footprint of the gm2ringsim simulation productions.

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Jimin George\*  
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Bingzhi Li  
Adam Lyon  
James Stapleton\*  
David Sweigart  
Leah Welty-Rieger\*  
*\*current simulation team*