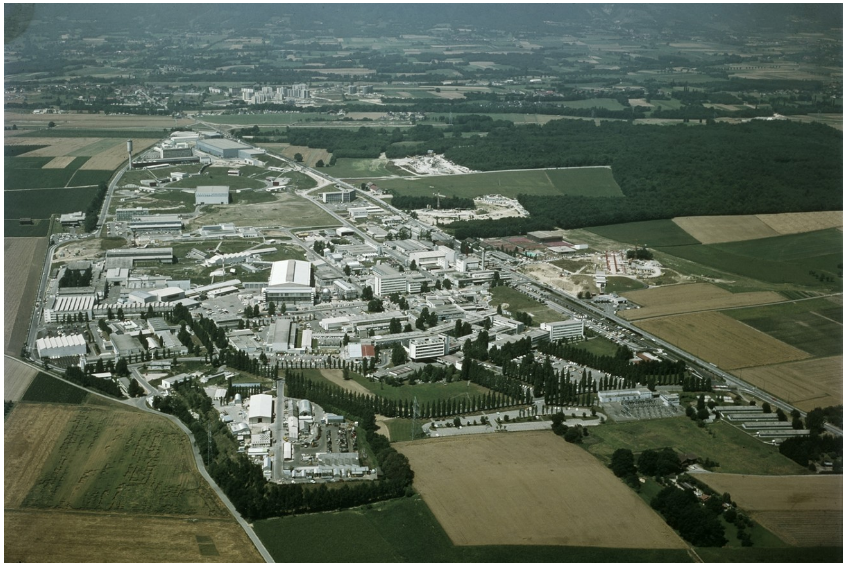
Updates on REDTOP

***R**are **E**ta **D**ecays with a **T**PC for **O**ptical **P**hotons*



R. Carosi, *INFN Pisa*

Physics Beyond Colliders Working Group Meeting

CERN, 5-6 Nov. 2019

For the REDTOP Collaboration

Fermilab

INFN

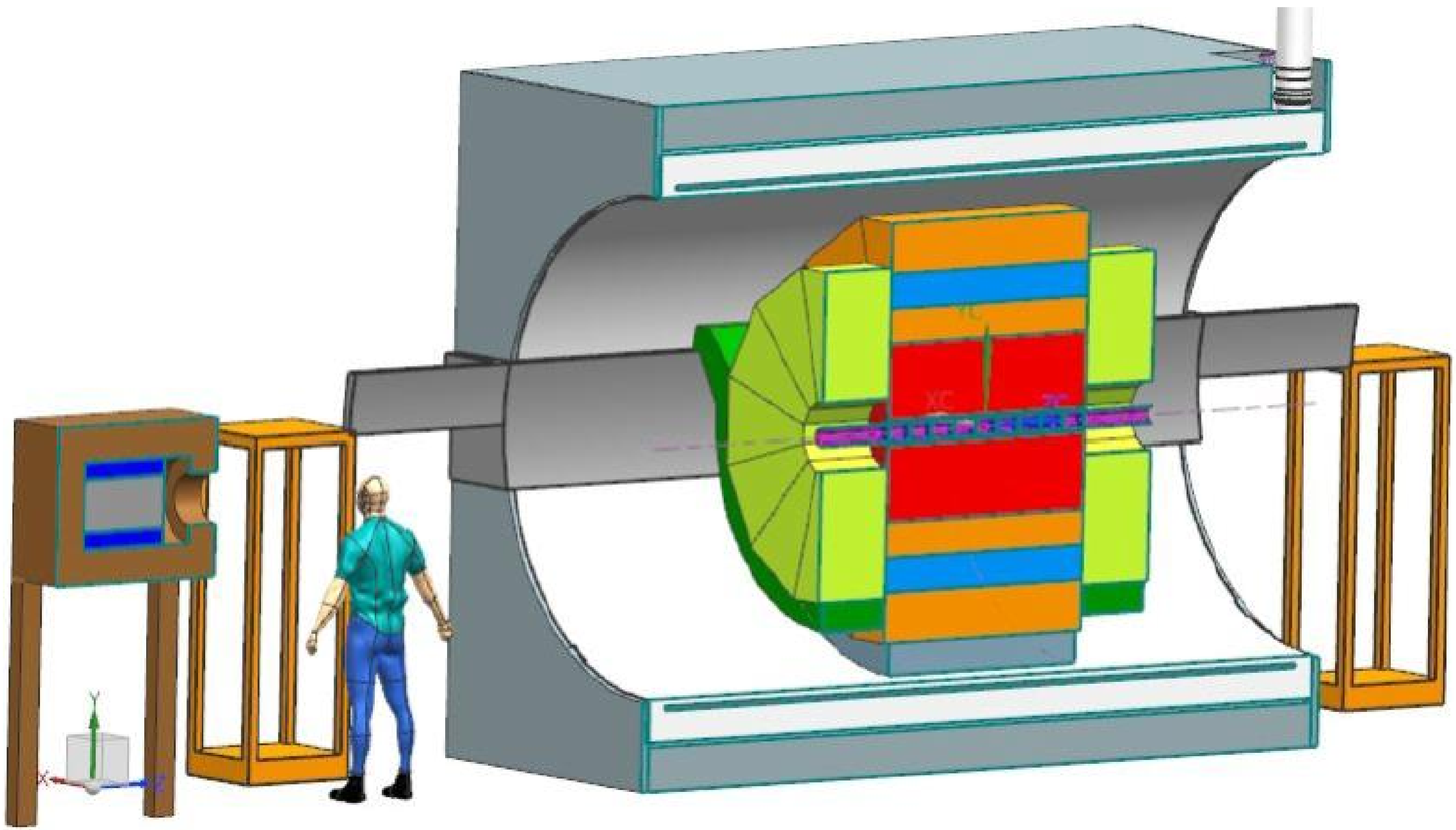
Updates on REDTOP

- Short reminder of the REDTOP main points
  - (physics, beam, detector,…)
- ***New sensitivities using better simulation***
- ***Two additional models for BC4 (Dark scalar)***
  - ***Hadrophilic Scalar Mediator***
  - ***Spontaneous Flavor Violation***
- Status and plan

REDTOP in One Slide

- **Why the η?**
  - Eigenstate of C,P,CP,G; Goldstone boson
    - Strong and EM decays forbidden in lowest order
    - Contributions from higher order are enhanced by a factor 100,000
    - Decays with leptons in the final state have very small SM background
    - Internal loops and lepton pairs can probe new physics
- **REDTOP Physics**
  - >20 interesting channels
  - 3(5) are “golden” (will be described in details in the proposal)
  - 4 benchmark channels are studied in details for the PBC (2 of them are golden)
- **REDTOP beam**
  - 8×10^{12} η/yr for 10^{17} POT/yr, 1.8 GeV protons
  - 8×10^{10} η'/yr for 10^{17} POT/yr, 3.5 GeV protons (phase II)
- **REDTOP detector**
  - Optical TPC: use Cherenkov effect for tracking charged particles
  - ADRIANO2 (Dual readout calorimeter): for reconstructing EM showers and particle ID
  - Fiber Tracker for vertexing
- `http://redtop.fnal.gov`

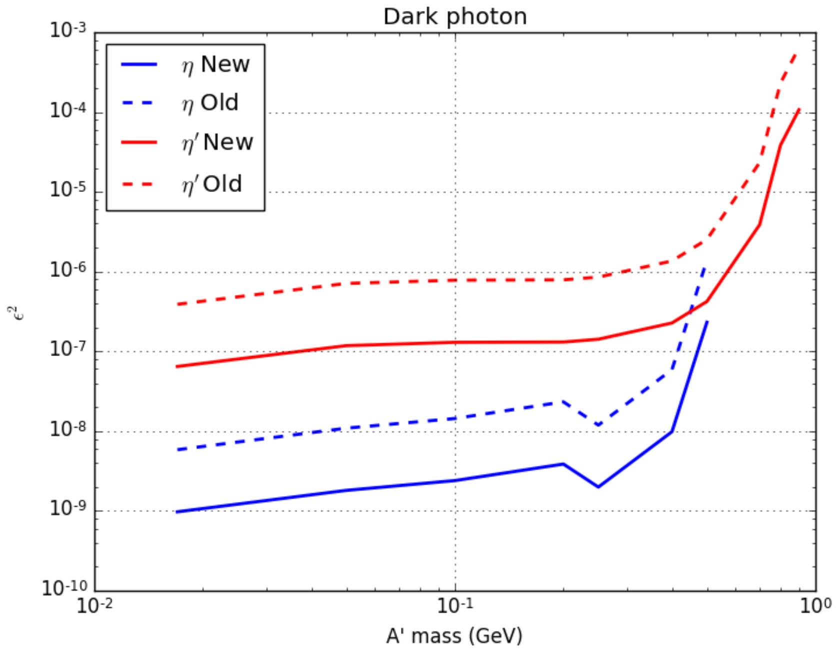
REDTOP Detector + Magnet



Simulation and PCB benchmarks

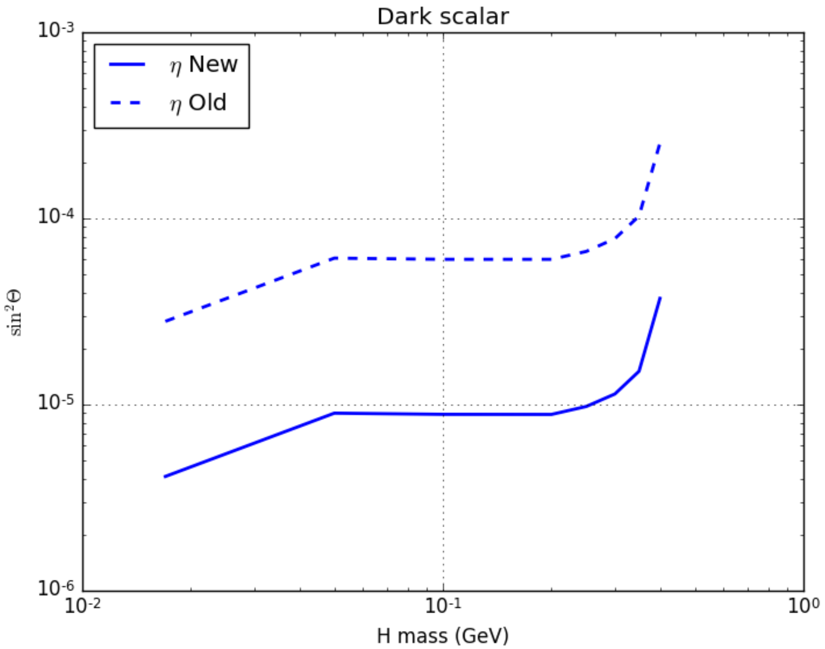
- Simulation tools ready (`slic,lcsim,ilcroot` frameworks)
  - Full simulation, including background and efficiencies
  - Only missing full reconstruction in the OTPC
- 10-15 years timescale and 10^{17} pot/year
- **Since last workshop (Jan. 2019):**
  - ***Secondary vertex recostruction (BSM particles have long lifetimes)***
  - ***Beam transverse profile: σ_y~0.5 mm (gaussian), σ_x~1 cm (uniform)***
    - ***it was 1 cm uniform both x and y;***
    - ***now: small σ for more constraints, large σ to separate multiple events***
  - ***More constraints in z using target thickness***
  - ***Background reduced by a factor 100-300, signal efficiency ~25-35%***
- Ongoing simulations for PBC benchmarks (**Visible** final states)
  - **Dark photons (BC 1) $\eta \rightarrow \gamma A' \rightarrow \ell^+\ell^-$**
  - **Dark scalars mixing with the Higgs (BC 4) $\eta \rightarrow \pi^0 H \rightarrow \ell^+\ell^-$**
  - **ALP coupled with fermions (BC 10) $\eta \rightarrow \pi\,\pi\, a \rightarrow \ell^+\ell^-$**
  - **ALP coupled with gluons (BC 11) pLi → pLi a → $\ell^+\ell^-$**

PBC benchmarks



Dark photons

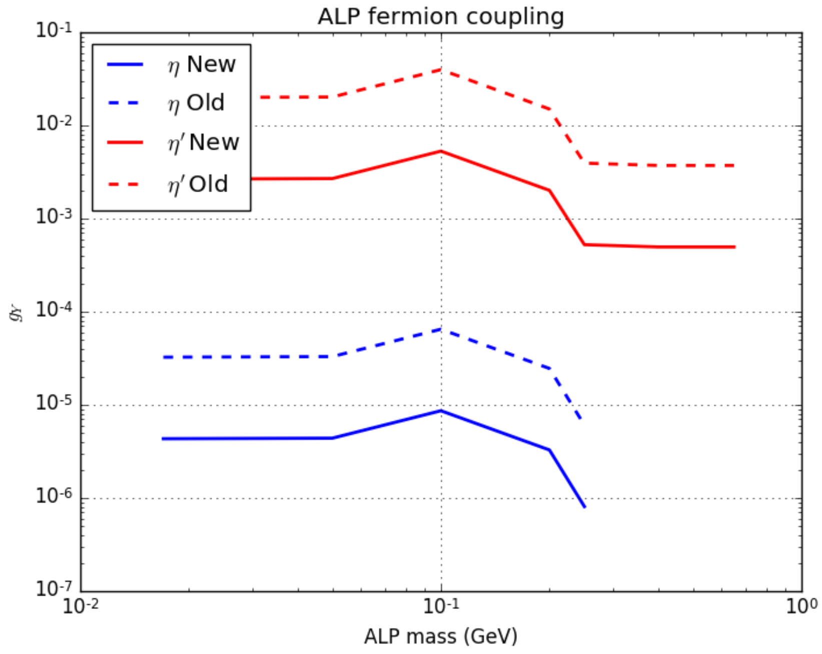
BC1

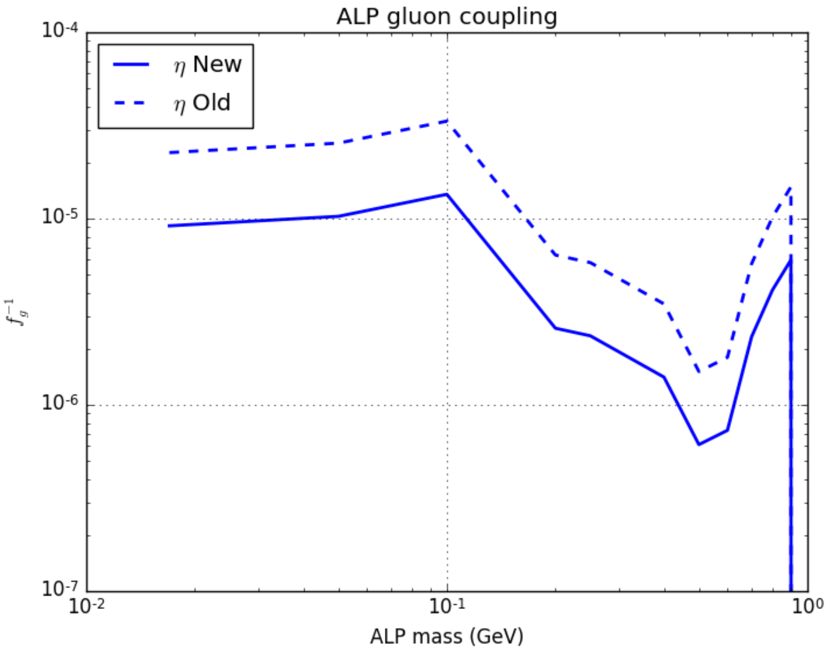


Dark scalar mixing with Higgs

BC4

PBC benchmarks





ALP with fermion coupling

BC10

ALP with gluon coupling

BC11

Light Scalar Meson $\eta \rightarrow \pi S$

$S \rightarrow ee, \mu\mu, \pi\pi$

- **Minimal SM Higgs extension**
  - Viable DM candidates coupling to Higgs portal
  - S-H mixing via mixing angle
  - It couples mostly to top quarks and gluons
  - Favorite exp. techniques: B factories (LHCb)
  - *Disfavorite at REDTOP*

- **Hadrophilic Scalar Mediator**
  - *Probing Light Dark Matter with a Hadrophilic Scalar Mediator,* B. Batell, A. Freitas, A. Ismail, D. McKeen, arXiv 1812.05103
- **Spontaneous Flavor Violation**
  - *Higgs bosons with large couplings to light quarks,* D. Egana-Ugrinovic, S. Homiller, P. Meade, arXiv 1908.11376 (2019)
  - *Aligned and Spontaneous Flavor Violation,* D. Egana-Ugrinovic, S. Homiller, P. Meade, arXiv 1811.00017; PRL 123, 031802 (2019)
  - Much less constrained by cosmological and EDM bounds
  - It couples mostly to u,d quarks
  - ***Favorite exp. Techniques: η/η' factories***
  - Disfavorite at LHCb, Belle
  - Moderate discovery potential with K

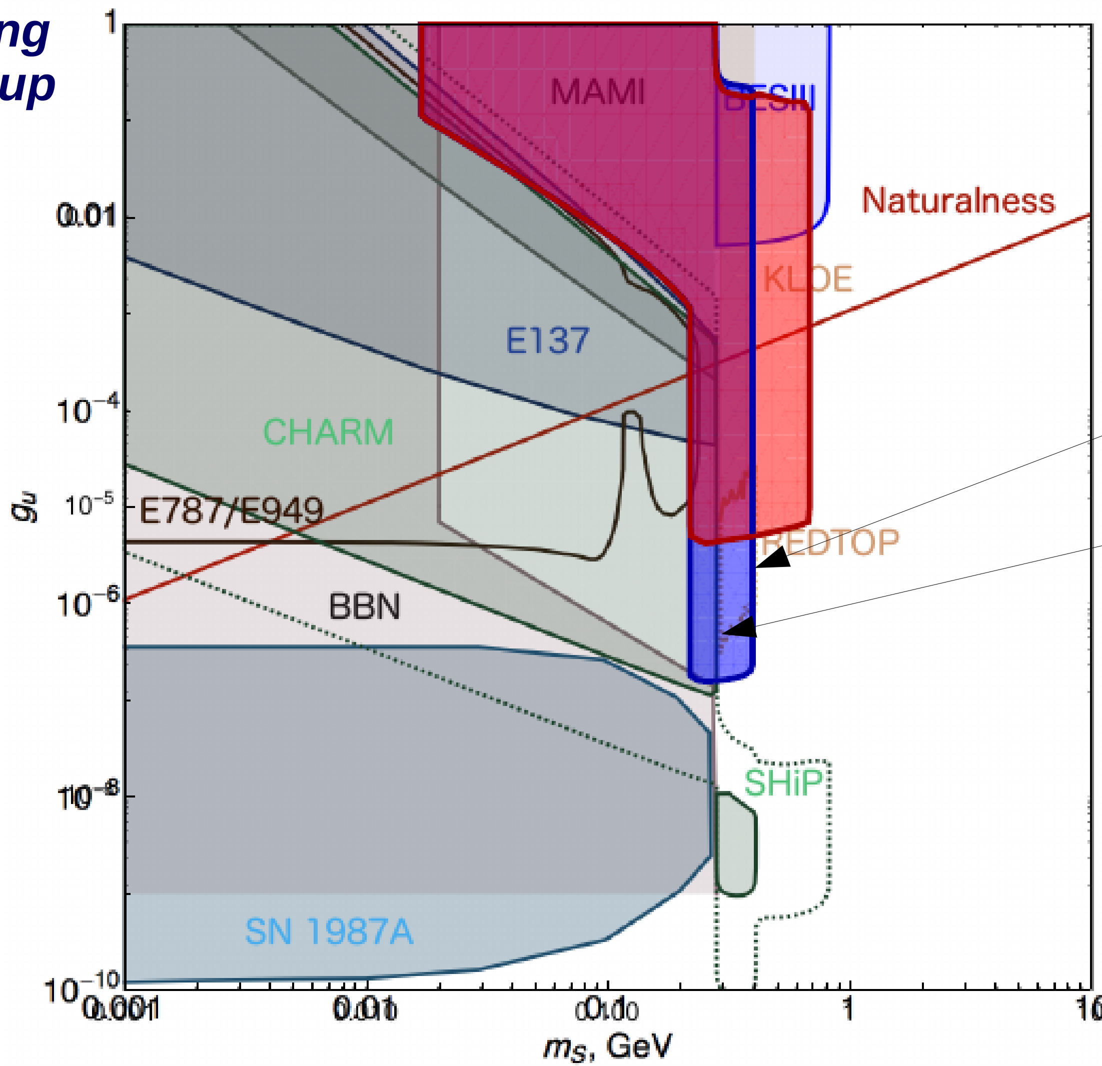
REDTOP

The η/η′ factory

P. Meade (SUNY)
"Higgs Physics at Future Colliders"
Cern, 15 Oct. 2019

Compare with BC4

Dark scalar coupling Exclusively to the up quark g_u

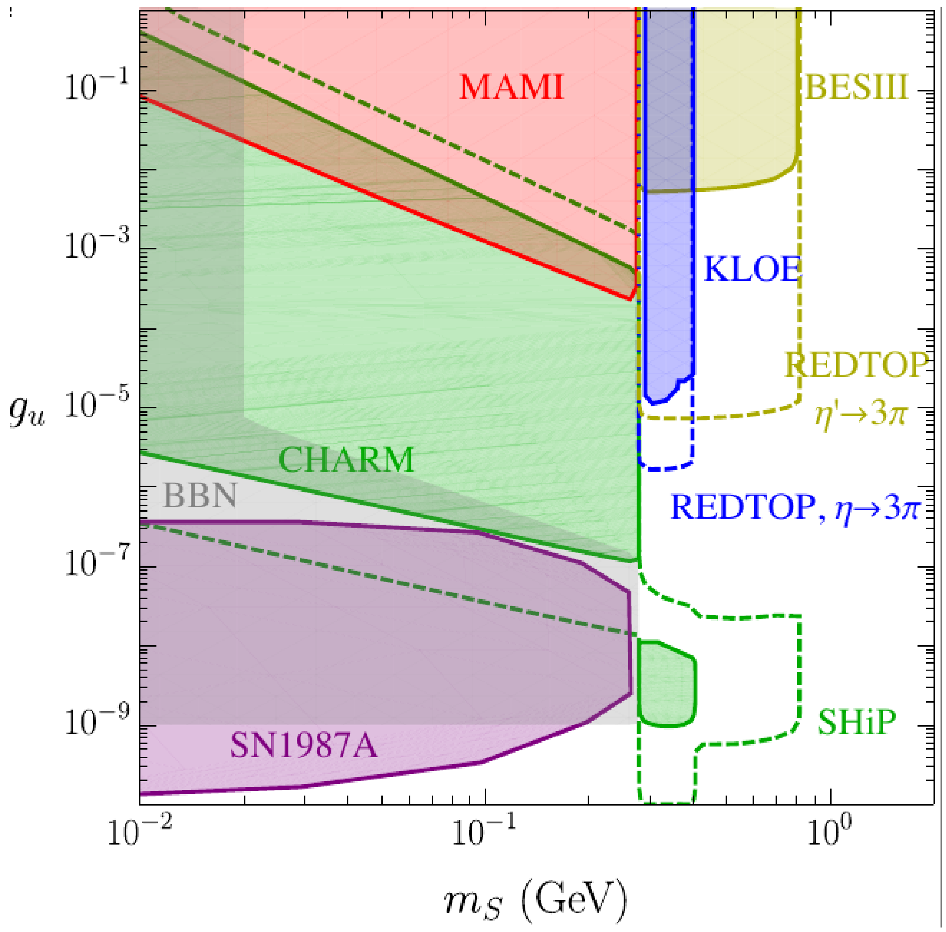


REDTOP - blue (!)
Old vtxing

SFV

HSM

KOTO signal:
$K_L \rightarrow \pi^0 \nu\nu$
What if *$K_L \rightarrow \pi^0 S$* ?



"off-shell" sensitivity (2π decay)

Status and Plan

- Cost: ~ 50 M$ (including 50 % contingence)
- Beam: requires further study (PS, 10^{17} p/yr)
- Detector
  - ADRIANO2 new prototype; funded by NIU, INFN
  - Fiber Tracker (LHCb like)
  - OTPC not started
- Detector/Simulation plan:
  - Triple readout: disentangle neutron component using time history
    - (contributions after 50 ns from are neutrons only)
  - Full reconstruction for OTPC
    - (improves vertexing and background rejection)
- Collaboration: several institutions joined during the last year; still growing
- Proposal to SPSC after ESPP process

Summary

- The η/η' meson is an excellent laboratory for studying rare processes
- Existing world samples not sufficient for studying decays violating conservations laws
- REDTOP goal is to produce ~10^{13} η mesons/year in phase I and ~ 10^{11} η'/year in phase II
- Very rich physics program, including "golden" processes:
  - CP violation via Dalitz plot mirror asymmetry
  - Dark photons
  - Scalar meson searches
  - Axion-like particles
- New generation, super-fast detector techniques
- An exciting phase of detector R&D ahead
- Full proposal in preparation
- **`http://redtop.fnal.gov`**

Thank you!

Backup slides

$$\eta :\approx \frac{u\bar{u}+dd-2s\bar{s}}{\sqrt{6}}$$

$$\eta' :\approx \frac{u\bar{u}+d\bar{d}+s\bar{s}}{\sqrt{3}}$$

η

$I^G(J^{PC}) = 0^+(0^{-+})$

Mass $m = 547.862 \pm 0.017$ MeV
Full width $\Gamma = 1.31 \pm 0.05$ keV

C-nonconserving decay parameters

$\pi^+\pi^-\pi^0$ left-right asymmetry $= (0.09^{+0.11}_{-0.12}) \times 10^{-2}$
$\pi^+\pi^-\pi^0$ sextant asymmetry $= (0.12^{+0.10}_{-0.11}) \times 10^{-2}$
$\pi^+\pi^-\pi^0$ quadrant asymmetry $= (-0.09 \pm 0.09) \times 10^{-2}$
$\pi^+\pi^-\gamma$ left-right asymmetry $= (0.9 \pm 0.4) \times 10^{-2}$
$\pi^+\pi^-\gamma$ β (D-wave) $= -0.02 \pm 0.07$ (S = 1.3)

CP-nonconserving decay parameters

$\pi^+\pi^- e^+ e^-$ decay-plane asymmetry $A_\phi = (-0.6 \pm 3.1) \times 10^{-2}$

Dalitz plot parameter

$\pi^0\pi^0\pi^0$ $\alpha = -0.0318 \pm 0.0015$
PARAMETER Λ IN $\eta \to \mu^+\mu^-\gamma$ DECAY $= 0.719 \pm 0.014$ GeV/c^2

η DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
Neutral modes			
neutral modes	(72.12 ± 0.34) %	S=1.2	–
2γ	(39.41 ± 0.20) %	S=1.1	274
$3\pi^0$	(32.68 ± 0.23) %	S=1.1	179
$\pi^0 2\gamma$	$(2.56\pm0.22)\times10^{-4}$		257
$2\pi^0 2\gamma$	$<1.2\times10^{-3}$	CL=90%	238
4γ	$<2.8\times10^{-4}$	CL=90%	274
invisible	$<1.0\times10^{-4}$	CL=90%	–
Charged modes			
charged modes	(28.10 ± 0.34) %	S=1.2	–
$\pi^+\pi^-\pi^0$	(22.92 ± 0.28) %	S=1.2	174
$\pi^+\pi^-\gamma$	(4.22 ± 0.08) %	S=1.1	236
$e^+e^-\gamma$	$(6.9\pm0.4)\times10^{-3}$	S=1.3	274
$\mu^+\mu^-\gamma$	$(3.1\pm0.4)\times10^{-4}$		253
e^+e^-	$<2.3\times10^{-6}$	CL=90%	274
$\mu^+\mu^-$	$(5.8\pm0.8)\times10^{-6}$		253
$2e^+2e^-$	$(2.40\pm0.22)\times10^{-5}$		274
$\pi^+\pi^-e^+e^-(\gamma)$	$(2.68\pm0.11)\times10^{-4}$		235
$e^+e^-\mu^+\mu^-$	$<1.6\times10^{-4}$	CL=90%	253
$2\mu^+2\mu^-$	$<3.6\times10^{-4}$	CL=90%	161
$\mu^+\mu^-\pi^+\pi^-$	$<3.6\times10^{-4}$	CL=90%	113
$\pi^+e^-\overline{\nu}_e+$ c.c.	$<1.7\times10^{-4}$	CL=90%	256
$\pi^+\pi^-2\gamma$	$<2.1\times10^{-3}$		236
$\pi^+\pi^-\pi^0\gamma$	$<5\times10^{-4}$	CL=90%	174
$\pi^0\mu^+\mu^-\gamma$	$<3\times10^{-6}$	CL=90%	210

Charge conjugation (C), Parity (P), Charge conjugation × Parity (CP), or Lepton Family number (LF) violating modes

$\pi^0\gamma$	C		$<9\times10^{-5}$	CL=90%	257
$\pi^+\pi^-$	P,CP		$<1.3\times10^{-5}$	CL=90%	236
$2\pi^0$	P,CP		$<3.5\times10^{-4}$	CL=90%	238
$2\pi^0\gamma$	C		$<5\times10^{-4}$	CL=90%	238
$3\pi^0\gamma$	C		$<6\times10^{-5}$	CL=90%	179
3γ	C		$<1.6\times10^{-5}$	CL=90%	274
$4\pi^0$	P,CP		$<6.9\times10^{-7}$	CL=90%	40
$\pi^0e^+e^-$	C	[f]	$<4\times10^{-5}$	CL=90%	257
$\pi^0\mu^+\mu^-$	C	[f]	$<5\times10^{-6}$	CL=90%	210
$\mu^+e^-+\mu^-e^+$	LF		$<6\times10^{-6}$	CL=90%	264

BSM Physics Program (η and η' factory)

C, T, CP-violation

- *CP Violation via Dalitz plot mirror asymmetry:* $\eta \rightarrow \pi^o \pi^+ \pi$
- *CP Violation (Type I – P and T odd , C even):* $\eta \rightarrow 4\pi^o \rightarrow 8\gamma$
- *CP Violation (Type II - C and T odd , P even):* $\eta \rightarrow \pi^o l^+ l$ ***and*** $\eta \rightarrow 3\gamma$
- *Test of CP invariance via* μ *longitudinal polarization:* $\eta \rightarrow \mu^+ \mu^-$
- *Test of CP invariance via* γ^* *polarization studies:* $\eta \rightarrow \pi^+ \pi^- e^+ e^-$ *and* $\eta \rightarrow \pi^+ \pi^- \mu^+ \mu^-$
- *Test of CP invariance in angular correlation studies:* $\eta \rightarrow \mu^+ \mu^- e^+ e^-$
- *Test of T invariance via* μ *transverse polarization:* $\eta \rightarrow \pi^o \mu^+ \mu^-$ *and* $\eta \rightarrow \gamma \mu^+ \mu^-$
- *CPT violation:* μ *polariz. in* $\eta \rightarrow \pi^+ \mu^- \nu$ *vs* $\eta \rightarrow \pi \mu^+ \nu$ *and* γ *polarization in* $\eta \rightarrow \gamma \gamma$

Other discrete symmetry violations

- *Lepton Flavor Violation:* $\eta \rightarrow \mu^+ e^- + c.c.$
- *Double lepton Flavor Violation:* $\eta \rightarrow \mu^+ \mu^+ e^- e^- + c.c.$

BSM Physics Program (η and η' factory)

New particles and forces searches

- *Scalar meson searches (charged channel):* $\eta \to \pi^o H$ *with* $H \to e^+e^-$ *and* $H \to \mu^+\mu^-$
- *Dark photon searches:* $\eta \to \gamma A'$ *with* $A' \to l^+l^-$
- *Protophobic fifth force searches :* $\eta \to \gamma X_{17}$ *with* $X_{17} \to e^+e^-$
- *New leptophobic baryonic force searches :* $\eta \to \gamma B$ *with* $B \to e^+e^-$ *or* $B \to \gamma\pi^o$
- *Indirect searches for dark photons new gauge bosons and leptoquark:* $\eta \to \mu^+\mu^-$ *and* $\eta \to e^+e^-$
- *Search for true muonium:* $\eta \to \gamma(\mu^+\mu^-)|_{2M_\mu} \to \gamma e^+e^-$

Other Precision Physics measurements

- *Proton radius anomaly:* $\eta \to \gamma\mu^+\mu^-$ *vs* $\eta \to \gamma e^+e^-$
- *All unseen leptonic decay mode of* η / η ‘ *(SM predicts* 10^{-6} *-*10^{-9}*)*

BSM Physics Program (η and η' factory)

Non-η/η' based BSM Physics

- *Dark photon and ALP searches in Drell-Yan processes:* *qqbar* $\rightarrow A'/a \rightarrow l^+l^-$
- *ALP's searches in Primakoff processes:* $p\,Z \rightarrow p\,Z\,a \rightarrow l^+l^-$ *(F. Kahlhoefer)*
- *Charged pion and kaon decays:* $\pi^+ \rightarrow \mu^+\nu A' \rightarrow \mu^+\nu e^+e^-$ *and* $K^+ \rightarrow \mu^+\nu A' \rightarrow \mu^+\nu e^+e^-$
- *Neutral pion decay:* $\pi^0 \rightarrow \gamma A' \rightarrow \gamma e^+e^-$

Non-BSM Physics Program (η and η' factory)

High precision studies on low energy physics

- *Nuclear models*
- *Chiral perturbation theory*
- *Non-perturbative QCD*
- *Isospin breaking due to the u-d quark mass difference*

- *Octet-singlet mixing angle*
- *ππ interactions*
- *Electromagnetic transition form-factors (important input for g-2)*
- *Lots of other bread&butter physics*

η Samples – Present and future

	Technique	Total η
CB @AGS	$\pi p \rightarrow \eta n$	10^7
CB @MAMI-B	$\gamma p \rightarrow \eta p$	$2x10^7$
CB @MAMI-C	$\gamma p \rightarrow \eta p$	$6x10^7$
KLOE @DAFNE	$e^+e^- \rightarrow \Phi \rightarrow \eta\gamma$	$5x10^7$
WASA @COSY	$pp \rightarrow \eta pp$ $pD \rightarrow \eta\ {}^3He$	$>10^9$ (unt.) $3x10^7$ (tagged)
CB @MAMI 10 wk *(proposed 2014)*	$\gamma p \rightarrow \eta p$	$3x10^8$
Phenix @RHIC	$d\ Au \rightarrow \eta X$	$5x10^9$
Hades @GSI	$pp \rightarrow \eta pp$ $p\ Au \rightarrow \eta X$	$4.5x10^8$
Near future samples:		
GlueX @JLAB *(just started)*	$\gamma p \rightarrow \eta p \rightarrow$ neutrals	$4.5x10^7$/year
JEF @JLAB *(recently approved)*	$\gamma p \rightarrow \eta X \rightarrow$ neutrals	$3.9x10^5$/day
REDTOP @FNAL ***(proposing)***	**$p\ Be \rightarrow \eta X$**	**$2.5x10^{13}$/year**

REDTOP – Golden Channel I

CP violation from Dalitz plot mirror asymmetry in $\eta \to \pi^+\pi^-\pi^0$

- *J.Bijnens and K.Ghorbani, jhep11200730(2007), arXiv:0709.0230[hep-ph]; S.Gardner and J.Tandean, Phys. Rev. D69:034011, 2004, arXiv:hep-ph/0308228; S. Gardner and J. Shi, arXiv:1903.11617[hep-ph]*
- It is an Isopin-violating decay
- EM contributions are known to be strongly suppressed
- It can occur via Strong Interactions due to the mass difference m_u-m_d
- Any mirror-asymmetry in the Dalitz plot is an indication of **CP and C** violation
- Good for testing the Chiral Perturbation Theory
- Current PDG limits consistent with no asymmetry
- Largest data samples: WASA 2014 (1.2×10^7), KLOE2 2016 (4.7×10^6)
- REDTOP expected sample: 10^9 analyzed events.
- Test of CP invariance via γ^* polarization studies, as in $\eta \to \pi^+\pi^- \gamma^*$; $\gamma^* \to l^+l^-$ (golden channel)

REDTOP – Golden Channel II

Dark photon searches:

$$\eta \rightarrow \gamma A' \; ; \qquad A' \rightarrow \gamma\, l^+ l^-$$

- Motivations:
  - Possible cosmic ray excesses from dark matter annihilation
  - Structures anomalies in dwarf galaxies (*Pospelov and Ritz, 2008; Arkani-Hamed et al., 2008*)
  - The muon g-2 anomaly.
- Most accredited model has A' mass is the MeV-GeV range, coupling to to SM charged particles with a strength ~10^{-3}-10^{-4} of that of the photon
- REDTOP could complement the new experiments at JLAB and Frascati with γ and e^- beams.
- REDTOP can also make a clear statement on similar searches ($\gamma e^+ e^-$) of the proposed 17 MeV super-weak gauge boson (*S.Gardner at al., 2016, arXiv:1608.03591*) – [Golden channel Iia].
  - $\eta \rightarrow \gamma X_{17}$; $X_{17} \rightarrow e^+ e^-$
  - Below WASA sensitivity.

REDTOP – Golden Channel III

Search for light scalar mesons

$$\eta \to \pi^0 H \, ; \qquad H \to l^+ l^-$$

- Potentially viable DM candidate, *Pospelov et al., Phys. Rev. D78, 115012, 2008.*
- Existence of this light scalar particle can significantly enhance this BR compared to the SM value ($\sim 10^{-9}$)
- REDTOP expected sensitivity is better than 10^{-10}
  - Current limits are $\sim 10^{-5} – 10^{-6}$
- Implications for the R_p anomaly. [Golden channel IIIa]
  - $\eta \rightarrow \gamma\, l^+ l^-$
  - Conventional methods (levels of muonic atoms and elastic scattering experiments) find a discrepancy of about 7σ.

REDTOP – Search for Axion Like Particles

- ALP's with fermion couplings
  - **$\eta \rightarrow \pi\pi$ a ; a → l^+l^-**
- ALP's with gluon couplings
  - Not associated with η/η' decays
  - Drell-Yan processes: **qqbar → a→ l^+l^-**
  - Proton bremsstrahlung: **pN → pN a ; a → l^+l^-**
  - Primakoff processes: **pZ → pZ a ; a → l^+l^-**

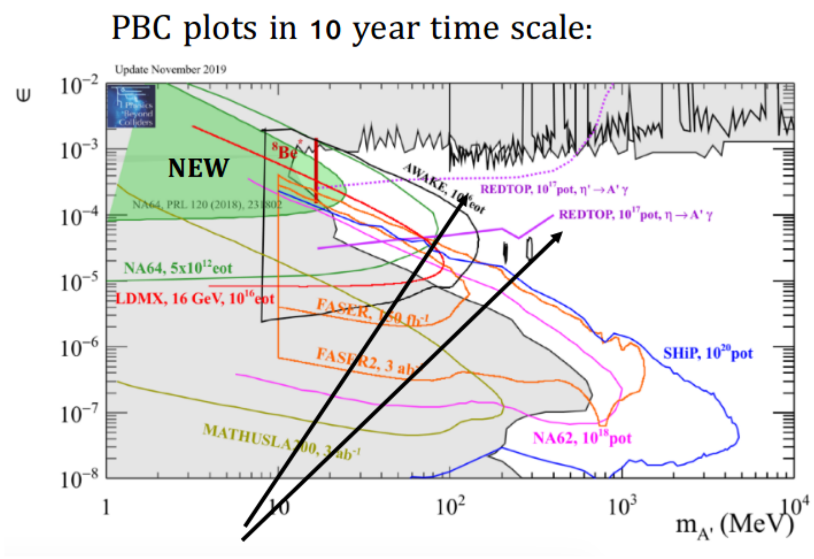
Effects of new simulation

(secondary vertexes, beam profile, z-target, optimized cuts)

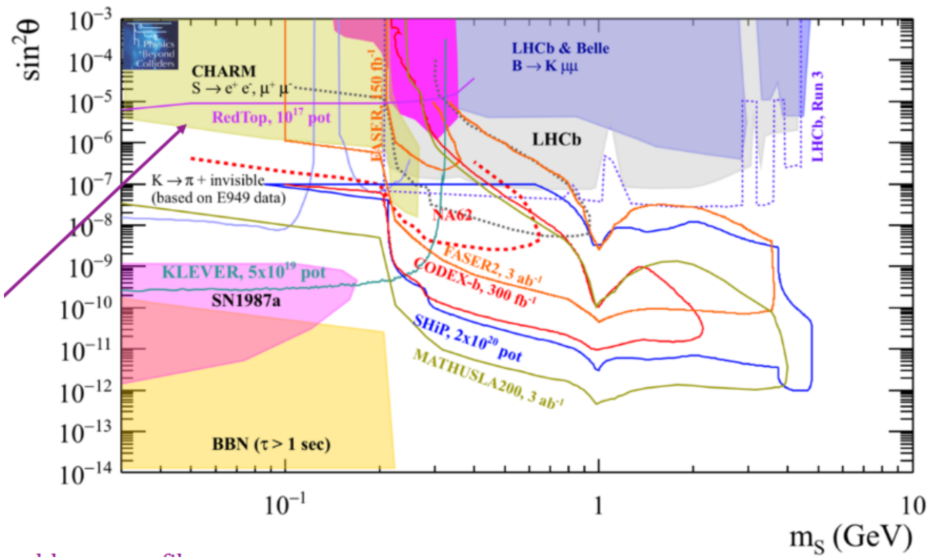
Benchmark channel	Signal efficiency (%)	Background efficiency (%)	Largest background
Dark photon (BC1)	34	0.3	$\eta \rightarrow \gamma e^+e^-$
Dark scalar (BC4)	30	0.2	$\eta \rightarrow \gamma e^+e^-$
ALP “fermion dominance” (BC10)	35	0.2	$\eta \rightarrow \pi^+\pi^- e^+e^-$
ALP “gluon dominance” (BC11)	24	0.9	

PBC benchmarks

(PBC, Cern 5-6 Nov. 2019)



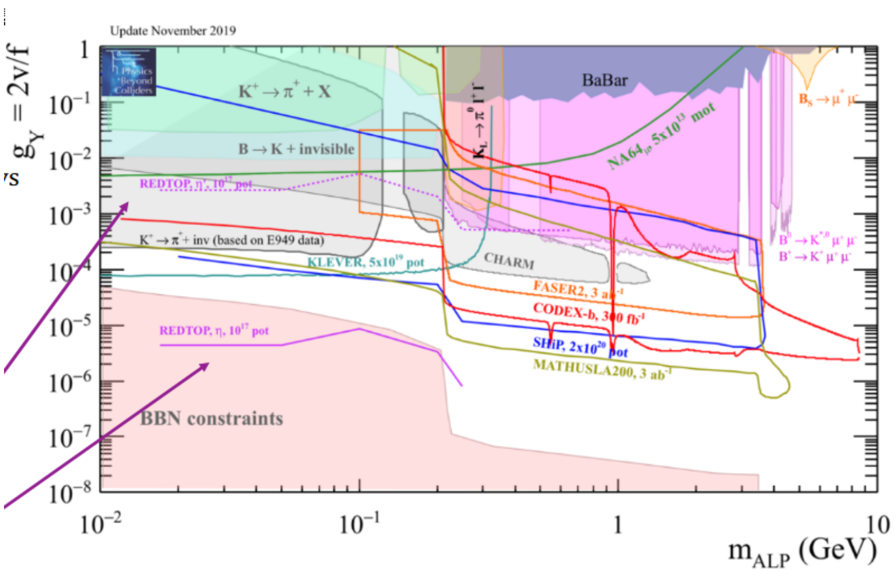
Dark photons



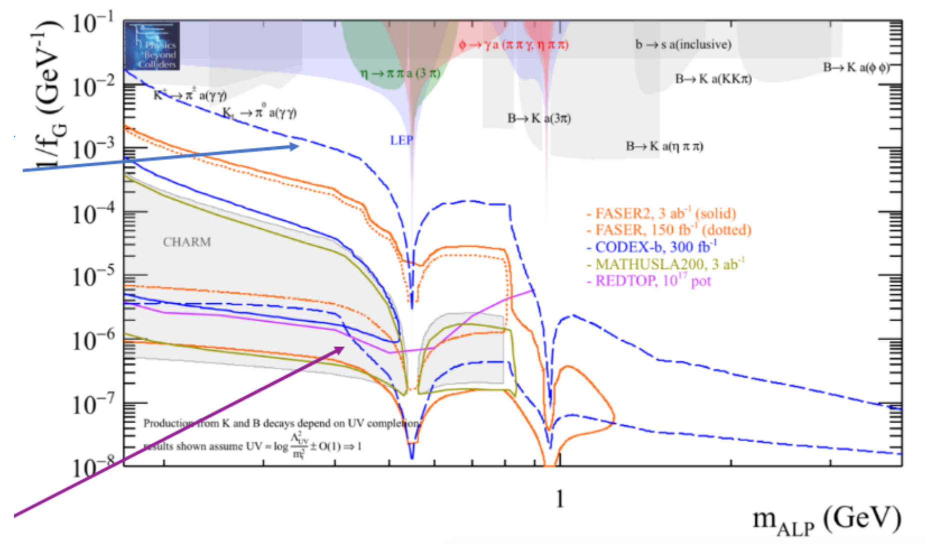
Dark scalar mixing with Higgs

PBC benchmarks

(PBC, Cern 5-6 Nov. 2019)

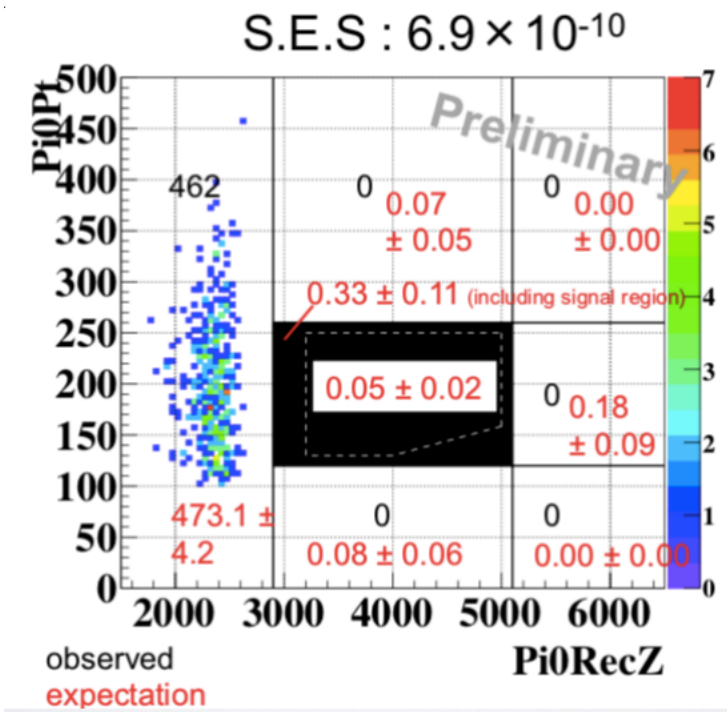


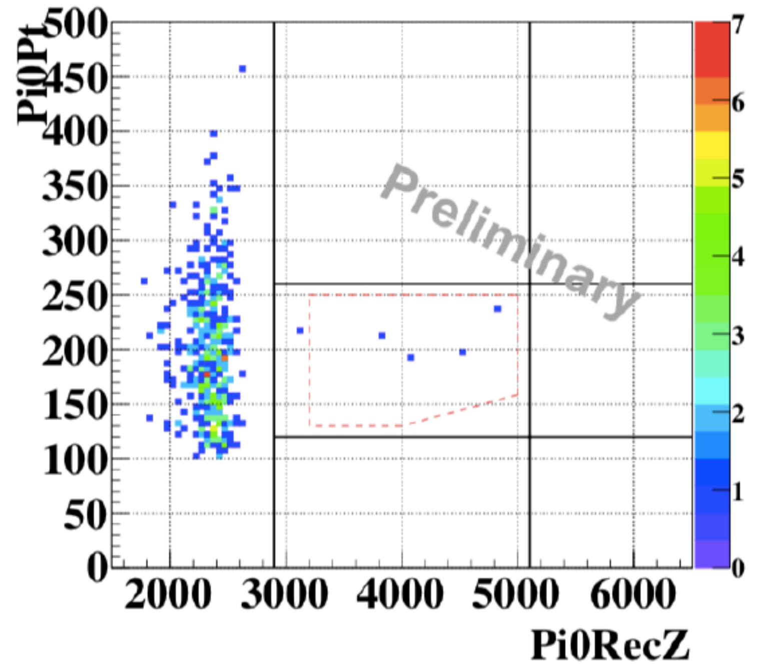
ALP with fermion coupling



ALP with gluon coupling

KOTO results



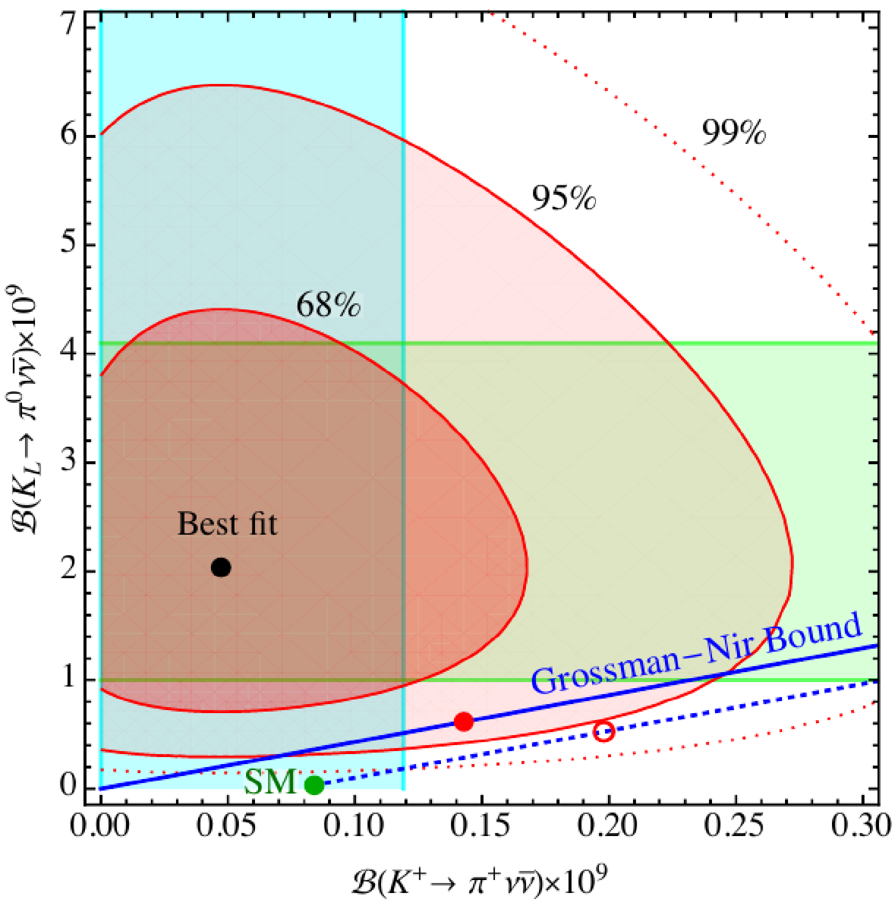


unblinded in the end of Aug. 2019

4 events, ***$BR(K_L \rightarrow \pi\nu\nu) \sim 2x10^{-9}$,*** ***$BR(K_L \rightarrow \pi\nu\nu)_{SM}$=(3.4+-0.6)x$10^{-11}$***

$K_L \rightarrow \pi^0$ S ??

KOTO/NA62 results



From arXiv 1909.11111: Kitahara, Okui, Perez, Sorez, Tobioka

New physics implications of recent search for $K_L \to \pi\nu\nu$ at KOTO

REDTOP Running Phases

(original plan)

- Intermediate phases (during detector R&D, OTPC only)
  - p $^{7}Li \rightarrow {}^{8}Be \rightarrow e^{+}e^{-}X$
  - p $^{2}H \rightarrow {}^{3}He\ e^{+}e^{-}$ (M.Viviani et al.)
  - Confirm 17 MeV bump in Hungary exp. (*J.Feng at al., arXiv:1604.07411; A.Krasznahorkay at al., Phys. Rev. Lett. 116, 042501, 2016*)
  - More possible beams (p/μ/e)
- Phase I: η factory
- Phase II: η' factory
- Phase III: Dark photons radiating from muons
- Phase IV: Muon Scattering Experiment (optional)
- Phase V: Tagged REDTOP (at PIP-II)
- Phase VI: Rare Kaon Decays: $K^{+} \rightarrow \pi^{+} \nu\nu$ (depending on NA62, JPARC)

Why the η ?

- Decays are flavor conserving
- Eigenstate of C, P, CP and G: $I^G J^{PC} = 0^+ 0^{-+}$
  - *can be used to test C and CP invariances*
- *Very narrow state (1.3 keV) – overconstraints events → low background*
- Strong decays forbidden in lowest order by C, P, CP, G, and Isospin invariance
- EM decays forbidden in lowest order by C and angular momentum conservation
  - *contributions from higher orders are enhanced by a factor of ~100,000*
  - *η decays with leptons in the final state have very small SM backgrounds*
  - *Internal loops and lepton pairs can probe new physics*
- **η is an excellent laboratory to search for physics Beyond Standard Model**

REDTOP Key Points

- Yield of **$8x10^{12}$ η** mesons/year for 10^{17} POT
  - Possibly ~$8x10^{10}$ η' mesons/years in a second phase
- 3 (5) "golden" channels (will be described in details in the proposal)
  - ***But at least ~20 interesting channels (simmetry violations, new particles and forces searches, precision measurements)***
  - 4 benchmark channels are studied in details for the PBC (2 of them are golden)
- Innovative detector techniques
  - Dual readout calorimeter
  - Optical TPC
  - Detector blind to protons and slow pions
  - 4π detector coverage (almost)
- Significant improvement (10^6 in some cases) to the current limits.
- **`http://redtop.fnal.gov`**

Beam and η yield

- Incident proton energy ~1.8 GeV (3.5 for η')
- Continuous beam, 10^{17} POT/yr
  - At Fermilab: ~10^{18} p/yr
- Target system: 10x0.5 mm Li or 10x0.33 mm Be spaced 10 cm apart
  - Low Z (primary hadrons multiplicity ~$A^{1/3}$)
- Large beam spot size (~1 cm) with small divergence (<1^0)
- p-inelastic production (event rate): 2×10^8 evts/sec
- Eta production: 8×10^{12} η/year
  - At Fermilab: 8×10^{13} η/year
- Possible second phase (η'): 8×10^{10} η'/year
  - At Fermilab: 8×10^{11} η'/year

Detection Techniques

Charged Tracks Detection

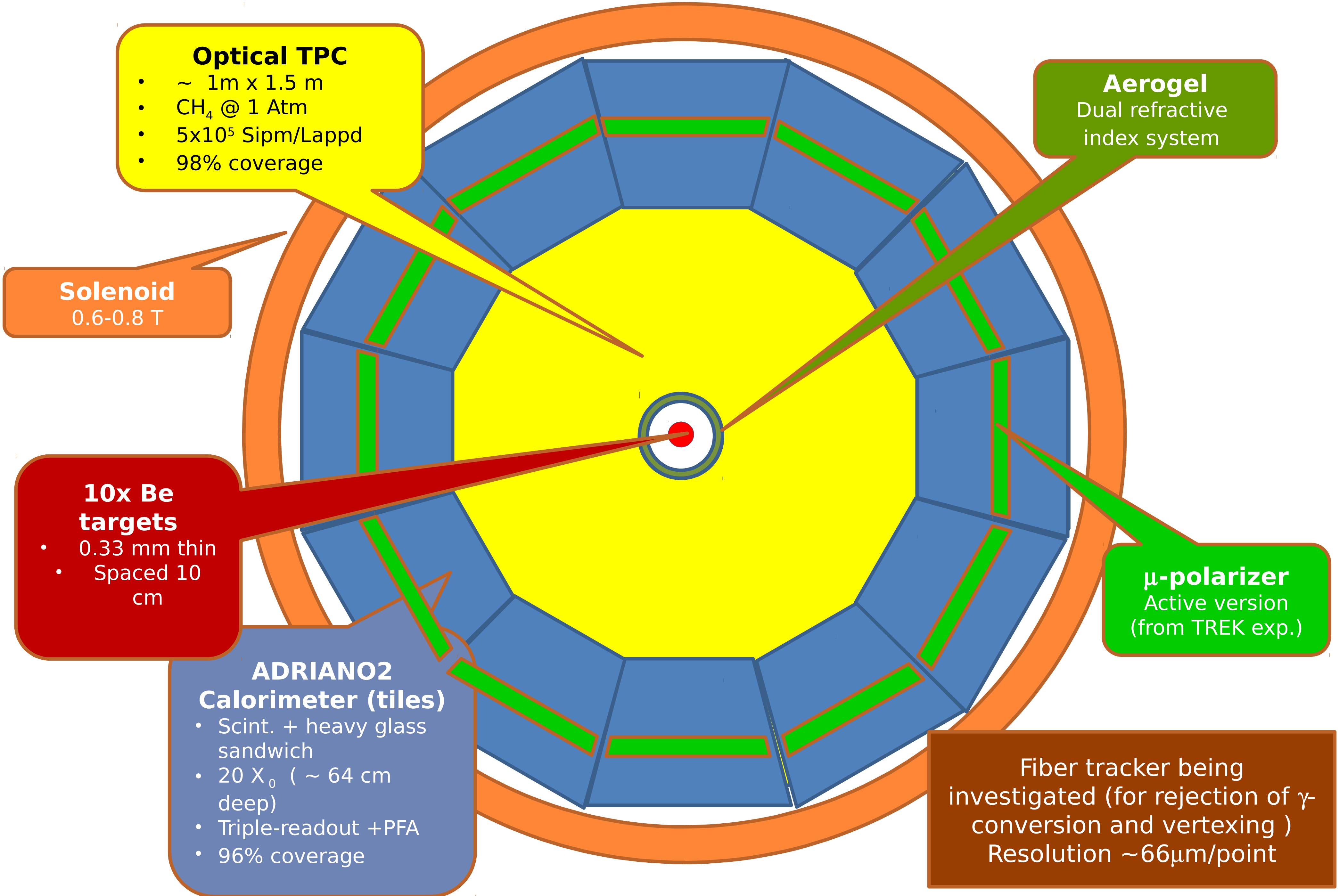
- Use Cherenkov effect in an Optical-TPC for tracking charged particles
- Baryons and most pions are below Cherenkov threshold
- Electrons and most muons are detected and reconstructed
- Fiber-tracker for vertexing and rejection of gamma conversion (being investigated)

Gamma Detection

- Use ADRIANO2 calorimeter for reconstructing EM showers
- Resolution <5%/sqrt(E)
- PID from dual-readout to disentangle showers from γ/μ/hadrons
- 96.5% coverage
- High granularity
- Good time resolution (<100 psec) for high rate DAQ

ADRIANO: **A** **D**ual-**R**eadout **I**ntegrally **A**ctive **N**on-segmented **O**ption

The REDTOP Detector



Disclaimers

- *The contents in this text are subject to change without a notice*
- *Reading this presentation impairs your ability to drive a car or operate a machinery*
- *If infection, rash, or irritation develops, discontinue use and consult a physician*
- *This presentation has been found to cause drowsiness in laboratory animals*
- *Caution: FLAMMABLE – Do not read while smoking or near a fire*
- *Warning: for external use only. Use only as directed. Intentional misuse by deliberately concentrating contents can be harmful or fatal. Keep out of reach of children*
- *In the unlikely event of a water landing do not use this presentation as a flotation device*
- *The material in this text is fiction; any resemblance to real persons, living or dead, is purely coincidental*
- *The surgeon general has determined that excessive reading of this presentation is detrimental to your health*