Giornate di Studio sul Piano Triennale INFN 2015-2017, Trento, 7-8 Novembre, 2014

WHAT NEXT

Antonio Masiero

dove saremo fra 3-4 anni

- **LHC → 14 TeV 300 fb^{-1}**
- **DM → 1 ton 10^{-11} pb per WIMP di m = 50-100 GeV**
- **$\beta\beta_{0\nu}$ → staremo per entrare nella regione di "ordinamento inverso" delle masse dei neutrini**
- **Flavour → NA62, MEG upgrade, LHCb, Belle II**
- **Onde gravitaz. → forse scoperta, comunque ~ GR**
- **CMB → risultati finali Planck, polarizzazione**
- **Sorprese???**

E se nel 2018 avremo solo miglioramento di limiti,
cioe' tutto OK col il Modello Standard?

2018: se SM OK, che si fa?
FISICA BALISTICA post-2018

- **LHC → HL 3000 fb^{-1}**

- **DM → n-ton exps. (n=7-10) 10^{-13} – 10^{-14} pb (limite background neutrinico)**

- **$\beta\beta_{0\nu}$ → 1 ton copertura della regione di gerarchia inversa**
- **….**

FISICA NON BALISTICA
Le 3 gambe di WHAT NEXT

- **Nuove proposte “non main stream” in filoni di ricerca in cui gia’ operiamo:**
  i) alta energia; ii) alta intensita’; iii) fisica nucleare;
  iv) fisica astroparticellare;

- **Nuove proposte in filoni di ricerca in cui NON stiamo operando: es. cosmologia osservativa (CMB, DE, etc.); materia condensata-ottica quantistica (atomi freddi) …**

- **Nuove proposte (elaborazione propria INFN) di prospettive di cui si discute nella comunita’ scientifica: es. nuovi acceleratori (HE –LHC, ILC linear collider, FCC – future circular collider, LHeC – Large Hadron electron Collider al CERN), nuove tecniche rivelazione DM WIMP – rivelatori direzionali, nuovi esperimenti di rivelazione modulazione DM, nuove tecniche per $\beta\beta_{0\nu}$ > 1ton, etc.)**

What the SM does not account for…

- neutrino masses
- dark matter
- baryogenesis
- inflation

→ OBSERVATIONAL REASONS

- $M_{HIGGS} / M_{PLANCK} \sim 10^{-16}$
- $E_{VACUUM} (DE) / M_{HIGGS} \sim 10^{-14}$
- $\Theta_{\text{CPV in STRONG INTERAC.}} < 10^{-9}$

→ THEOR. REASONS

Cosa e come fare agli accelerator oltre HL-LHC:
ILC, FCC, LHeC, muon collider …

- **MISURE DI PRECISIONE SM**
  Conveners: Andrea DAINESE, Stefano FORTE, Aleandro NISATI, Giampiero PASSARINO, Roberto TENCHINI
- **FLAVOUR**
  Conveners: Concezio BOZZI, Guglielmo DE NARDO, Paola GIANOTTI, Gino ISIDORI, Luca SILVESTRINI
- **BEYOND SM**
  Conveners: Giacomo POLESELLO, Shahram RAHATLOU, Andrea ROMANINO, Andrea WULZER

Gli interrogativi ancora aperti nella rottura della simmetria elettrodebole

- Bosone di Higgs: elementare o composto? E' uno pseudo-bosone di Goldstone?
- Gil accoppiamenti con la materia sono quelli previsti dal SM?
- Ci sono altri "bosoni di Higgs" nelle vicinanze?
- La massa del bosone di Higgs (scala di energia a cui avviene la rottura della simmetria elettrodebole) e' "protetta" da un completamento dello spettro di particelle SM, cioe' esistono nuove particelle/interazioni alla scala elettrodebole?
- Se si' quali evidenze dirette (produzione-osservazione) o indirette (deviazioni da SM in misure di precisione) cercare?
- ....

e quale il valore aggiunto di farlo in What Next

- Sinergia teorici –sperimentali, sinergia tra I tre WG e tra I WG e la piattaforma Nuove Tecnologie (quest'ultima per ora potenziale...)
- Domande rivolte alla "nostra"comunita': come questa vede il post HL-LHC negli acceleratori

Alcune nuove idee in fase di elaborazione

FRANCO BEDESCHI

- PADME at LNF
- SHIP at SPS
- NA62 extensions at SPS
- Extreme flavor experiment(s) at LHC
- High intensity evolution of Mu2e with PIP-2

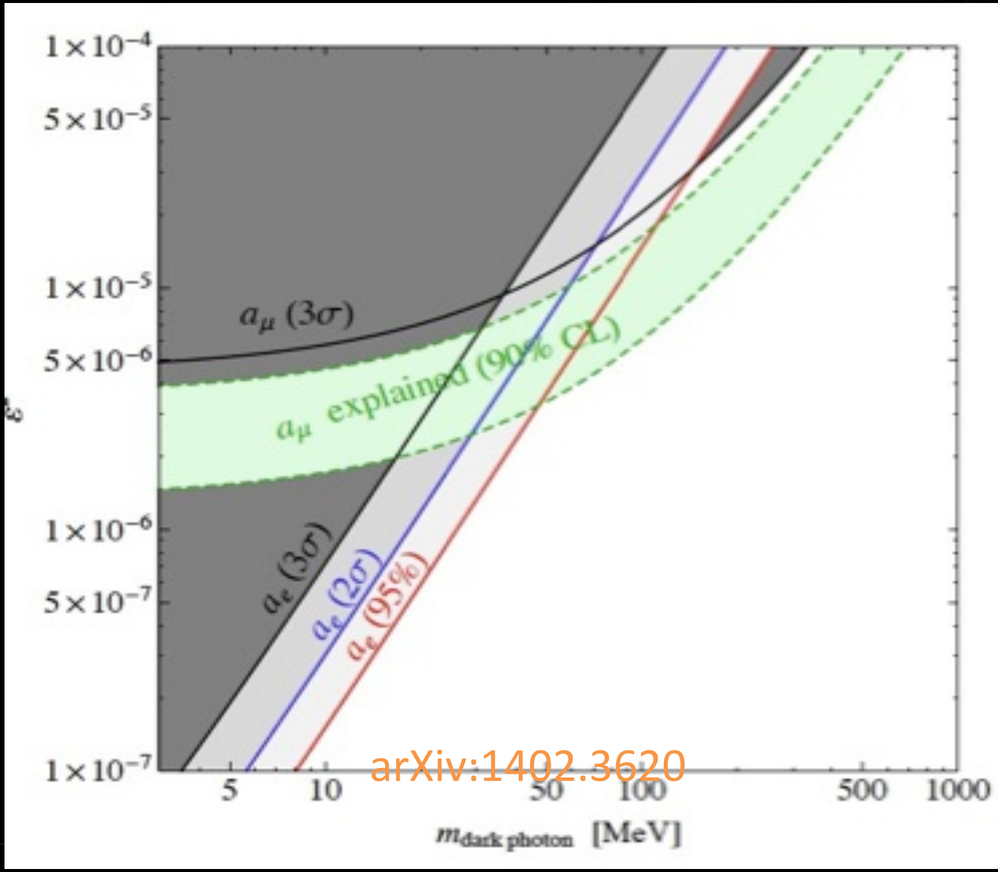
- workshop di Maggio scorso all'Elba
  - https://agenda.infn.it/conferenceOtherViews.py?view=standard&confId=7567
  - Le slides che seguono sono prese dalle presentazioni di Valente, Punzi e Miscetti

PADME at Frascati

PADME aims to detect U boson produced in e^+e^- annihilation and decaying into invisibles

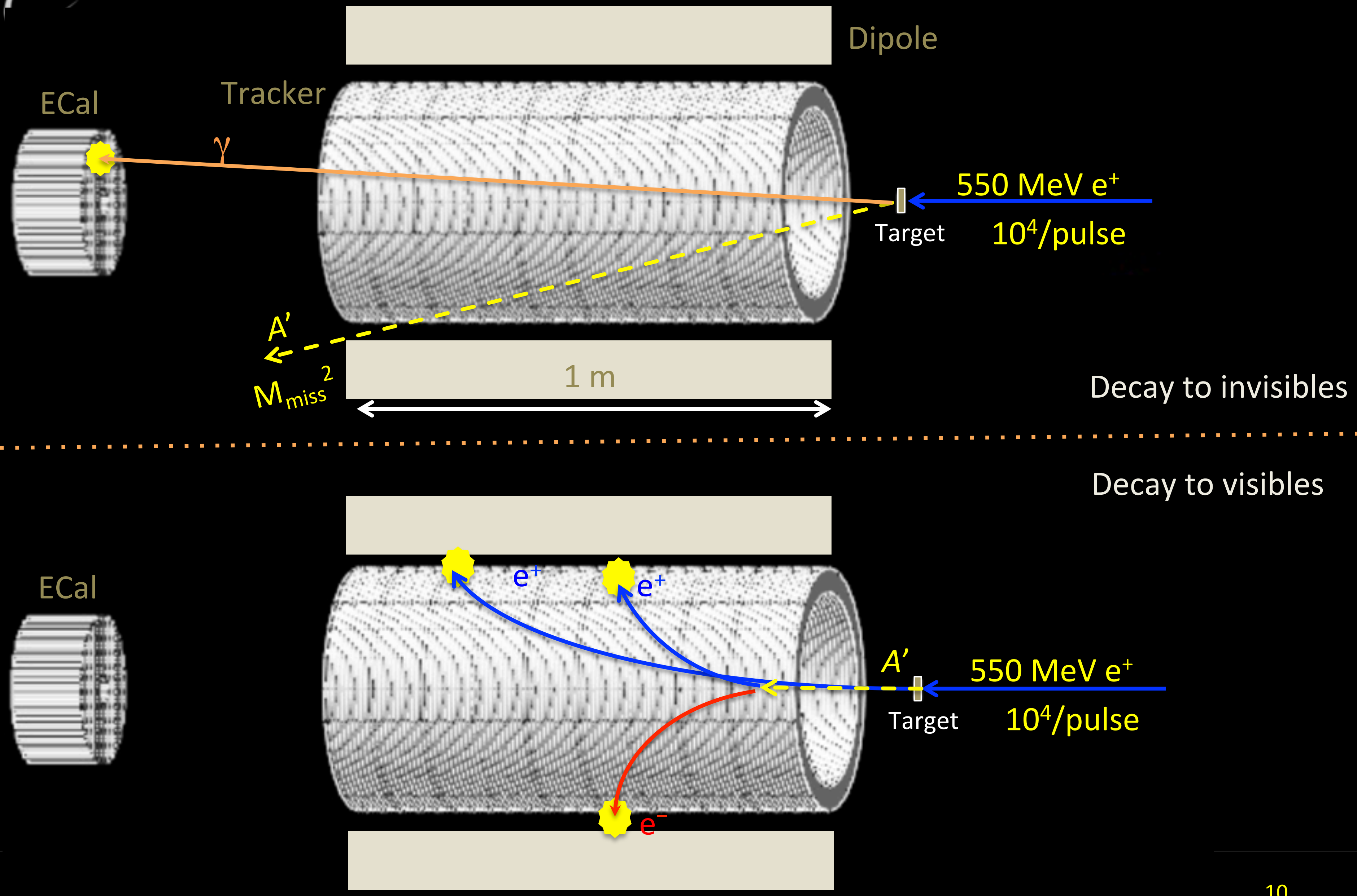
- No assumption on the U decays products and coupling to quarks
- Only minimal assumption: U bosons couples to leptons

No experimental results yet with this approach (VEPP3 planned experiment)

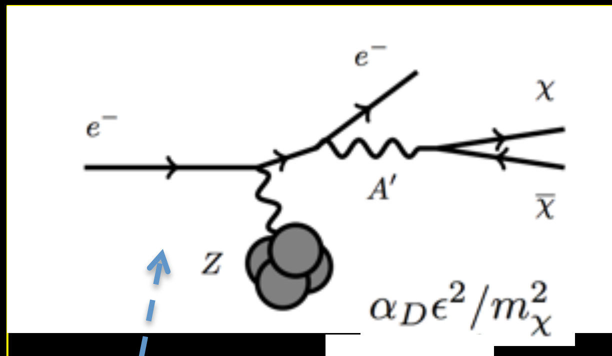


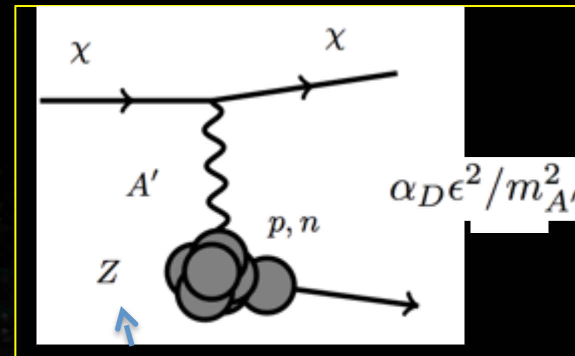
arXiv:1402.3620

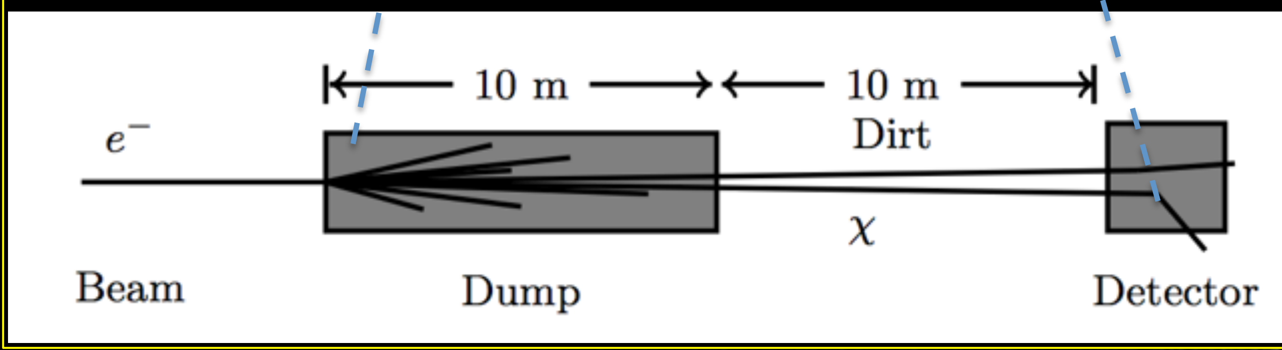
PADME at Frascati



New ideas for dump experiment: BDX at JLAB







$\sim \frac{\alpha_D^2 \epsilon^4}{m_\chi^2 m_{A'}^2}$ $m_{A'} < 2m_\chi$

$\sim \frac{\alpha_D \epsilon^4}{m_{A'}^4}$ $m_{A'} > 2m_\chi$

Scintillator 1 m^3
1 MeV/10 MeV e^+e^- detection threshold

Backgrounds:

- Neutrino production
- Cosmogenic muons and neutrons

LOI presented to PAC

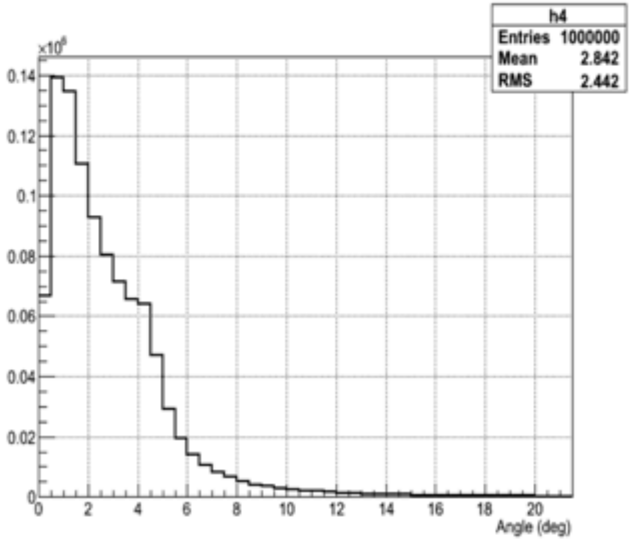
BDX at Frascati?

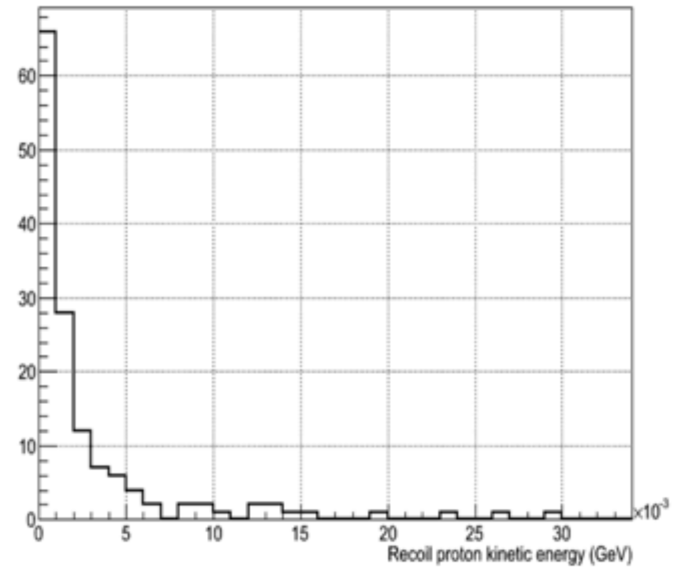
χ production and detection

- 1.5 GeV electron beam
- 7 10^{19} EOT/year
- 1 year run (50% efficiency)
- Repetition rate: 50 Hz, (0.7A in 10 ns bunch)
- **Negligible cosmogenic BG with timing cut**
- Expected ~20 counts in 1m^3 plastic scintillator detector (1 MeVee threshold)
- **Significant sensitivity to low mass (A'/χ) region**

Parameters:

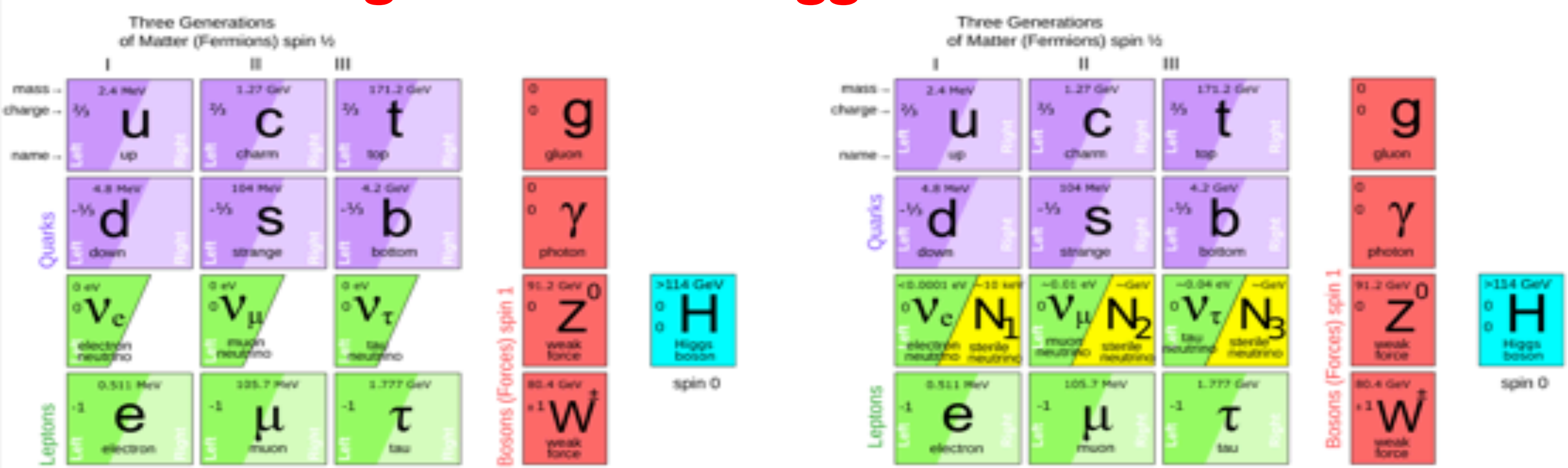
M_A' = 50 MeV
M_Chi = 10 MeV
Alpha_dark = 0.1
Epsilon = 10^-3





Very preliminary study. Results look very promising and should be investigated further.

quale **minima estensione del SM** posso fare per "curare" le sue tre malattie "osservative": **dar massa ai neutrini, avere materia oscura e produrre una asimmetria materia-antimateria** **Modello di Shaposhnikov et al. con 3 neutrini right-handed "leggeri"**



Role of N_1 with mass in keV region: dark matter

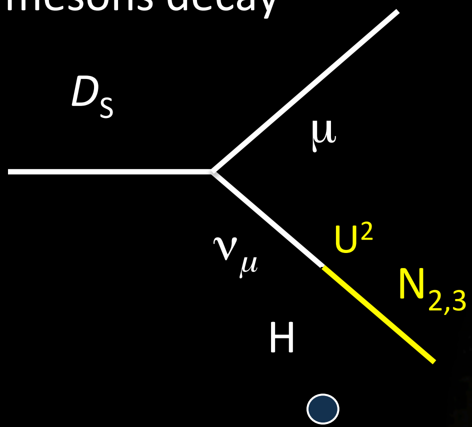
Role of N_2, N_3 with mass in 100 MeV – GeV region: "give" masses to neutrinos and produce baryon asymmetry of the Universe

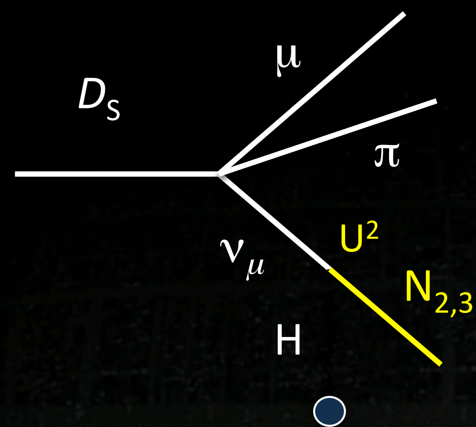
Role of the Higgs: give masses to quarks, leptons, Z and W and inflate the Universe.

Role of scale invariance and unimodular gravity: dilaton gives mass to the Higgs and $N_{1,2,3}$ and provides dynamical dark energy

SHiP at CERN SPS

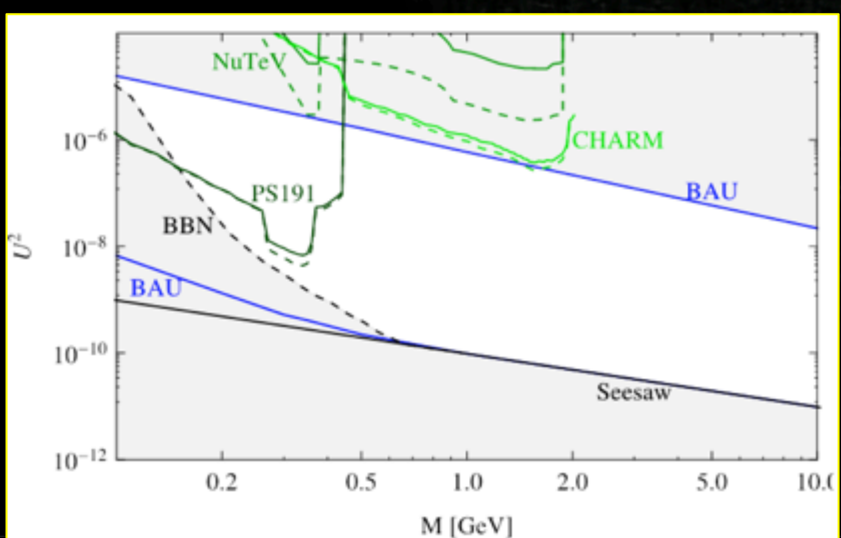
Look for HNL through the only possible interaction (Yukawa coupling to the Higgs) in the D mesons decay





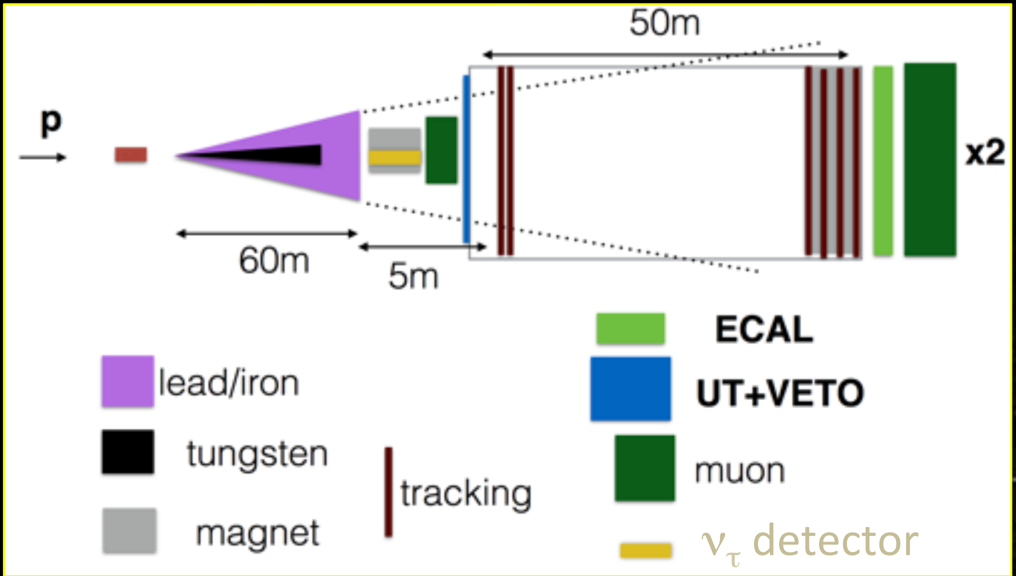
- Small couplings, long decay length (km!)
- Decay channels in μ/e π, μ/e ρ, ν μ e

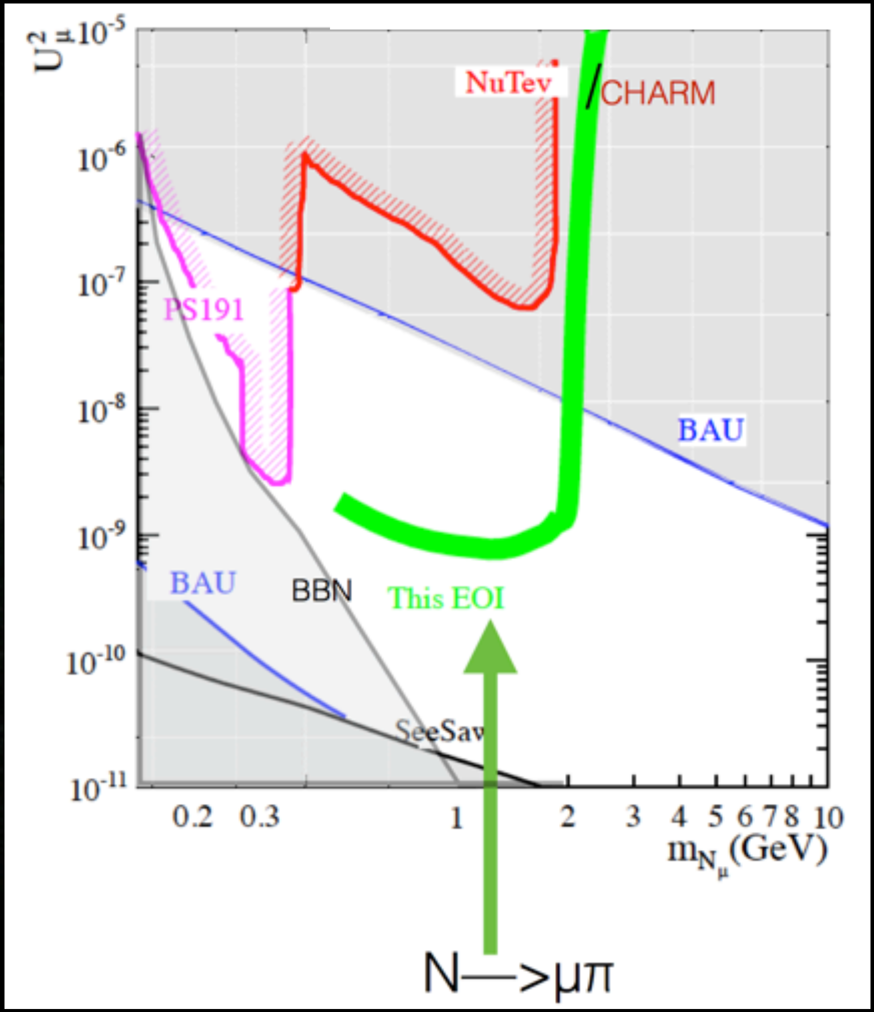
Coupling



Mass

SHiP at CERN SPS



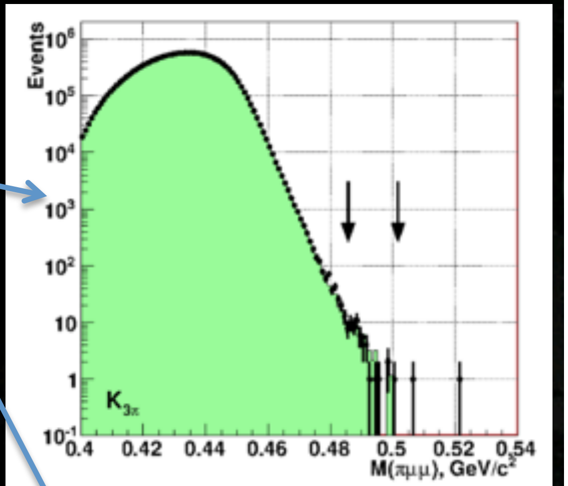


2×10^{20} pot
Zero background

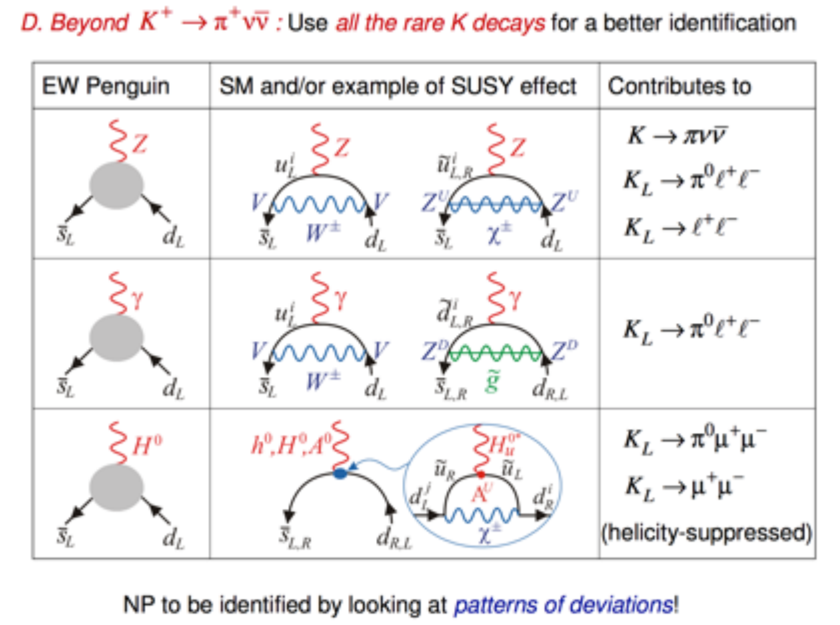
NA62

- Of course NA62 main goal is already searching for BSM effects
- What can be done with 10^{13} *K* decay and $2.5\cdot 10^{12}$ π^0 decays?

- Search for LFV modes
- Dark photon
- Majorana neutrino
- Right-handed neutrino



$$B(\pi^0 \to \nu\nu) \sim 3\cdot 10^{-8} k \left(\frac{m_\nu}{m_\pi}\right)^2 \sqrt{1-4\left(\frac{m_\nu}{m_\pi}\right)^2}$$



D. Beyond $K^+ \to \pi^+ \nu\bar{\nu}$: Use *all the rare K decays* for a better identification

EW Penguin	SM and/or example of SUSY effect	Contributes to
		$K \to \pi\nu\bar{\nu}$ $K_L \to \pi^0 \ell^+\ell^-$ $K_L \to \ell^+\ell^-$
		$K_L \to \pi^0 \ell^+\ell^-$
		$K_L \to \pi^0 \mu^+\mu^-$ $K_L \to \mu^+\mu^-$ (helicity-suppressed)

NP to be identified by looking at *patterns of deviations*!

Current landscape at hadron colliders

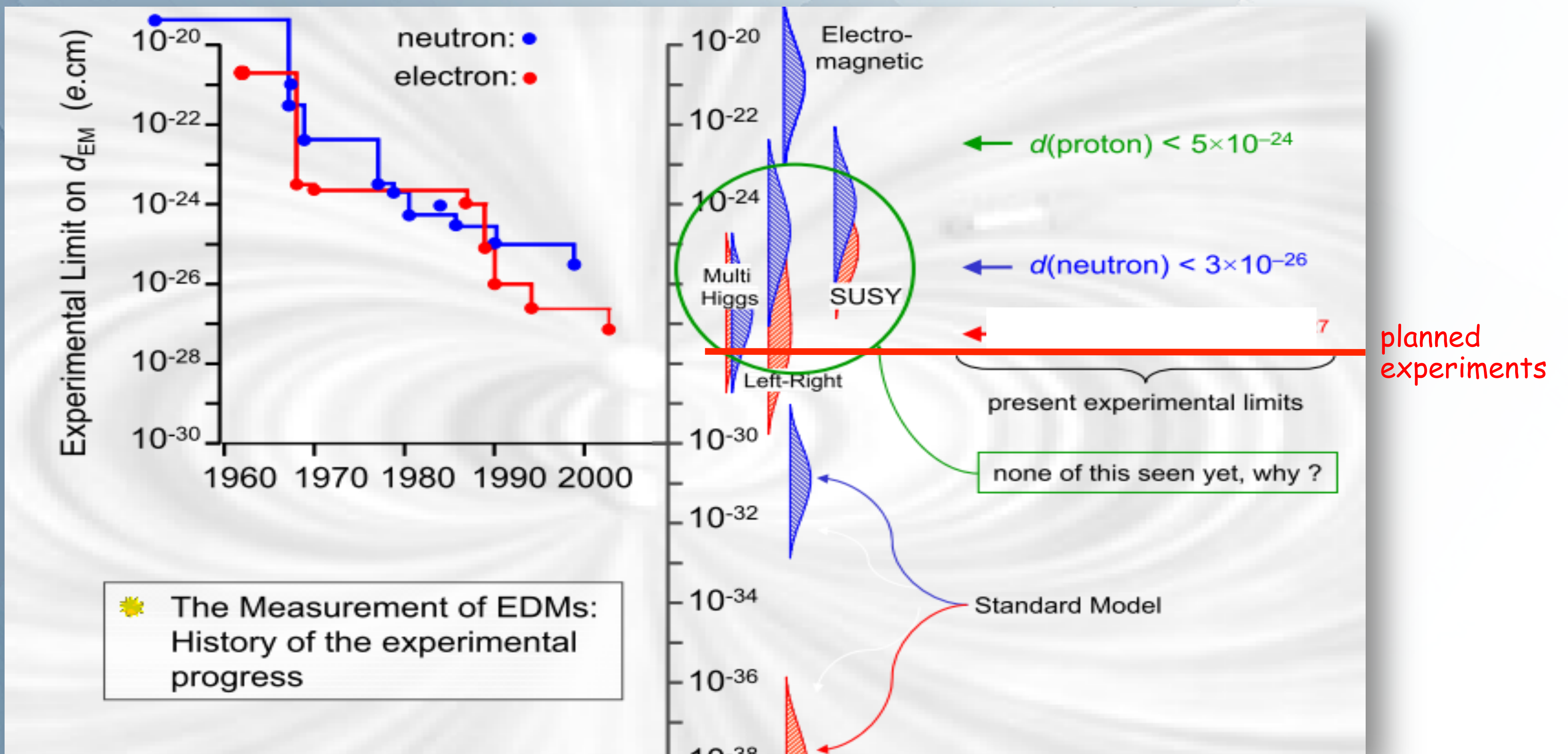
- LHC and HL-LHC are an immense source of Heavy Quarks
- Current/foreseen experiments only exploit a fraction of this enormous production
  - ATLAS/CMS:
    - Full LHC lum: 3000 fb-1
    - But limited efficiency: lepton / hi-pt requirements
  - LHCb:
    - High efficiency also on hadronic/charm events
    - But limited luminosity: projected 50fb-1 vs 3000 fb-1

- *"Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine"* [EU strategy document]
- What if we could fully exploit the production of $\sim 10^{14}$ b-quarks and $\sim 10^{15}$ c-quarks per year ?

AN "EXTREME" FLAVOUR EXP.

- Idea: exploit the full luminosity of hadron colliders for flavour physics.
- Reference sample: 100x LHCb upgrade lumi.
- Goal: improve dramatically accuracy on LHCb measurements & add new measurements using low-efficiency, high-purity methods
- Exploration of full physics potential under way, several items already studied

I Momenti di Dipolo Elettrico (neutrone, elettrone, protone?): splendido terreno per sondare nuove sorgenti di CPV e presenza di nuove particelle/ interazioni

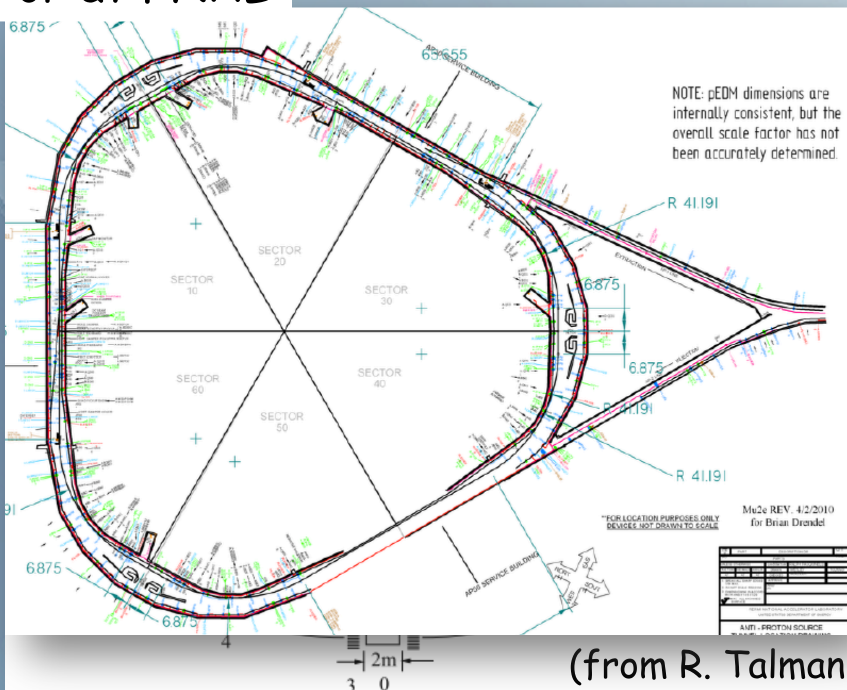


No Standard Model Background!

J.M. Pendlebury: „nEDM has killed more theories than any other single expt."

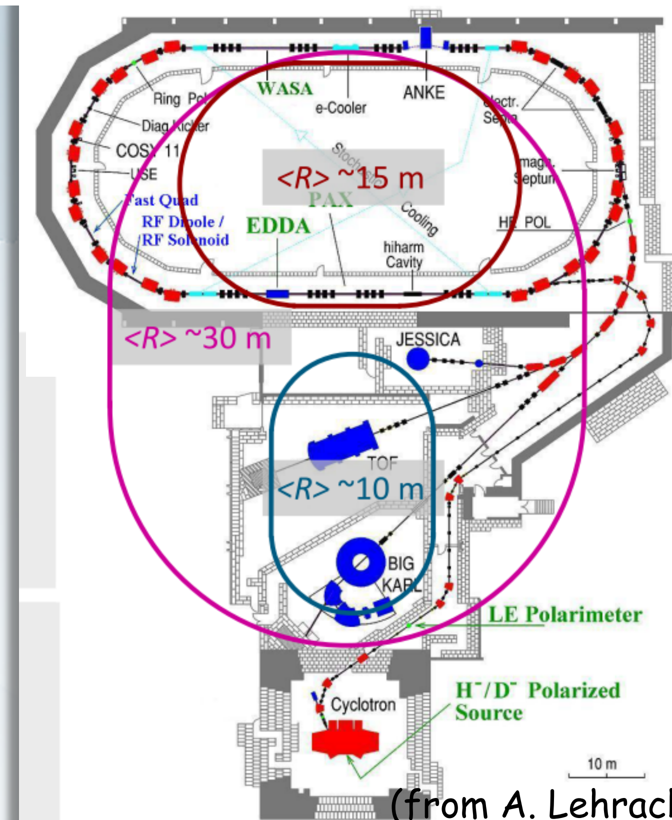
Storage ring projects

pEDM in all electric ring at BNL or at FNAL



(from R. Talman)

Jülich, focus on deuterons, or a combined machine



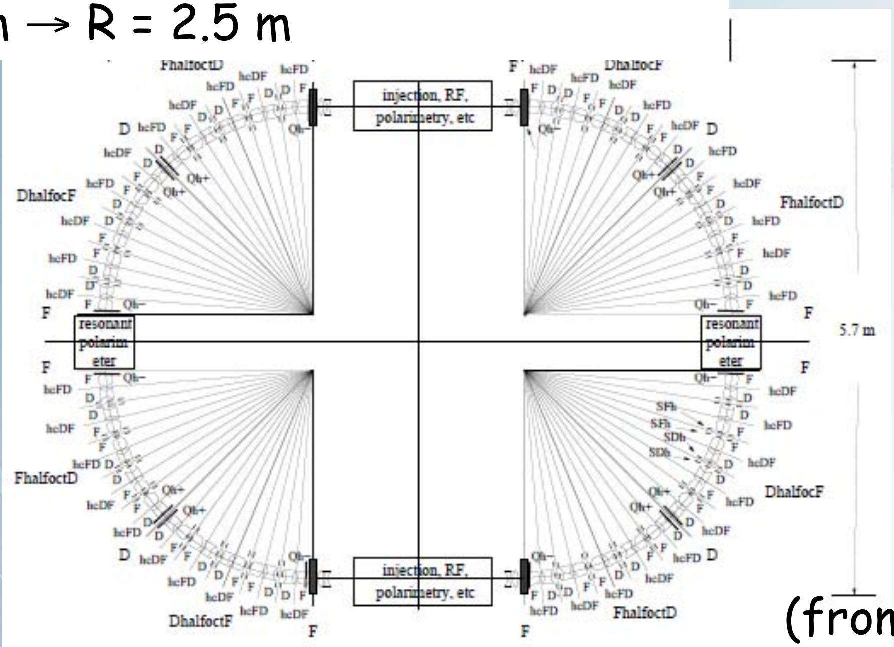
(from A. Lehrach)

CW and CCW propagating beams

Two projects: **US** (BNL or FNAL) and **Europe** (FZJ)

An option for LNF: all electric electron-EDM storage ring

- Magic energy for electron: 14.5 MeV (γ=29.4)
- E = 6 MeV/m → R = 2.5 m



(from R. Talman)

Note:

- Electron→ μ_e = 5.788 x 10^{-5} eV/T G_e=0.001159 → =1.020 x$10^8 s^{-1}$/T
- Proton → μ_p = 3.152 x 10^{-8} eV/T G_p=1.792 → =0.859 x$10^8 s^{-1}$/T

Almost same precession frequency in magnetic field

Issue: polarimetry?

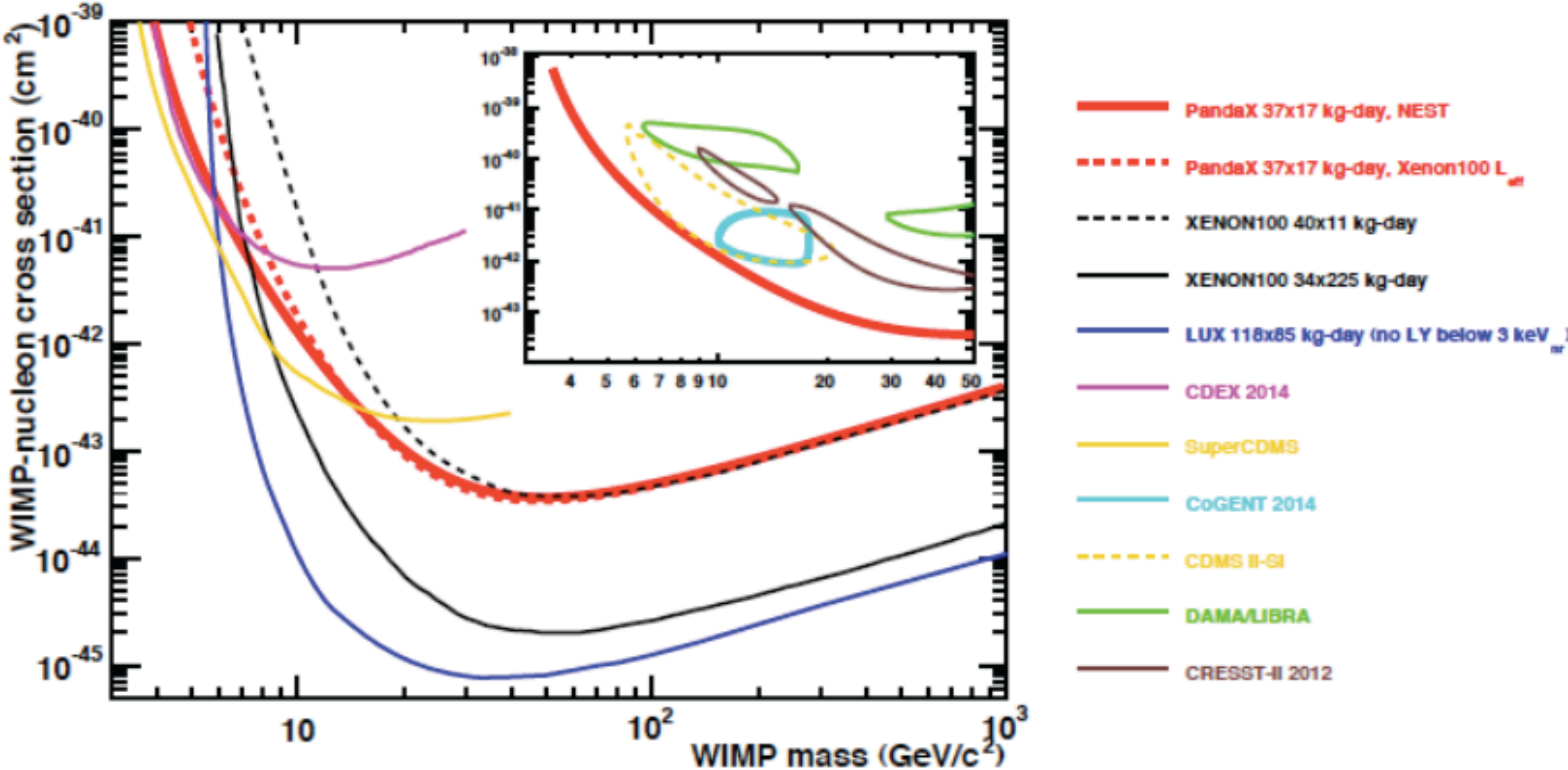
What next nella caccia alla materia oscura

- **WIMP di massa > 10 GeV: battere il limite del bckg. di neutrini con rivelatori DIREZIONALI**
- **WIMP di massa <10 GeV: come migliorare la nostra sensibilita'**
- **Segnale "modulato" di DM: nuovi esperimenti DAMA-like**
- **DM non-WIMP**: assioni, ALPs, come cercarli in modo nuovo (su quello usuale di fotoni che cambiano frequenza interagendo in una cavita' con assioni, gli americani sono ormai troppo avanti), altri candidati, es. dark photon…

WG DM – Conveners: Marco BATTAGLIERI, Nicolao FORNENGO, Aldo IANNI, Mario N. MAZZIOTTA, Giacomo POLESELLO, Piero ULLIO
In collaborazione per alcuni aspetti con il WG di Fisica Fondamentale – Conveners: Tommaso CALARCO, Giovanni CARUGNO, Saverio PASCAZIO, Gemma TESTERA

Dark Matter Direct Detection: Updates at Low Mass I

arXiv: 1408. 5114



Stawell Gold Mine In Victoria

credits Matteo Volpi and COEPP group University of Melbourne

1600m maximum depth. Caverns at many different depths (including one interesting site at 1025m depth). Many caverns have concrete sprayed surfaces.

Decline mine: accessible via cars/trucks. The access road supports mining vehicle traffic.

The mine is “dry”, has power, compressed air and fibres.

Surrounding rock is basalt:density 2.86 t/m^3

C. TOMEI

THE DETECTOR

C. TOMEI, WHAT NEXT LNGS

Crucial point is the radio purity of NaI(Tl) crystals and background control

SABRE (Sodium Iodine with Active Background REjection) proposed at LNGS scientific committee addresses both points:
https://agenda.infn.it/getFile.py/access?contribId=6&resId=0&materialId=slides&confId=7861

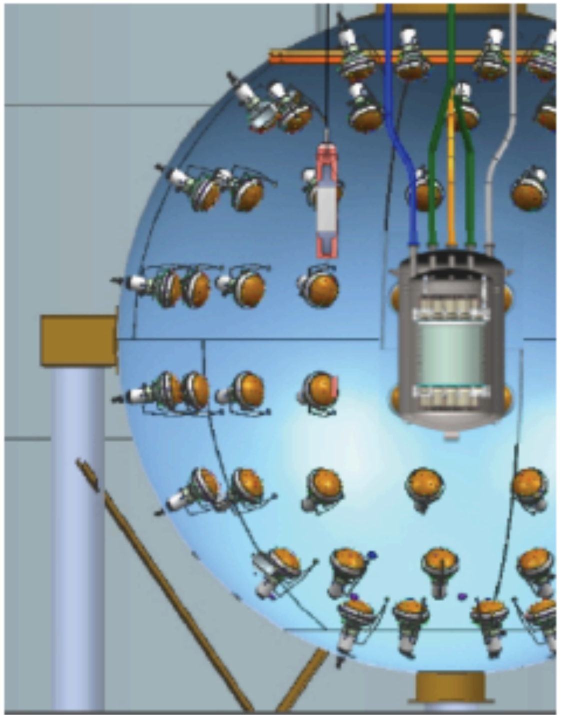
SABRE test on prototype crystals at LNGS in the near future

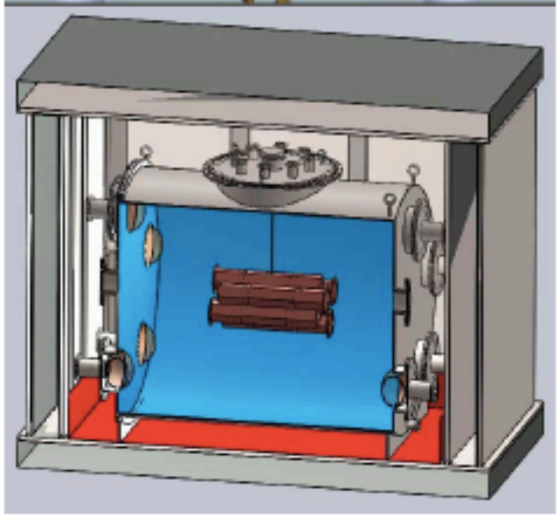
R&D at SICCAS for the production of high purity NaI powder

Italian groups interested so far: MI, LNGS, NA , RM1

Australian universities already interested in the project: Melbourne, Adelaide

International collaboration to be built

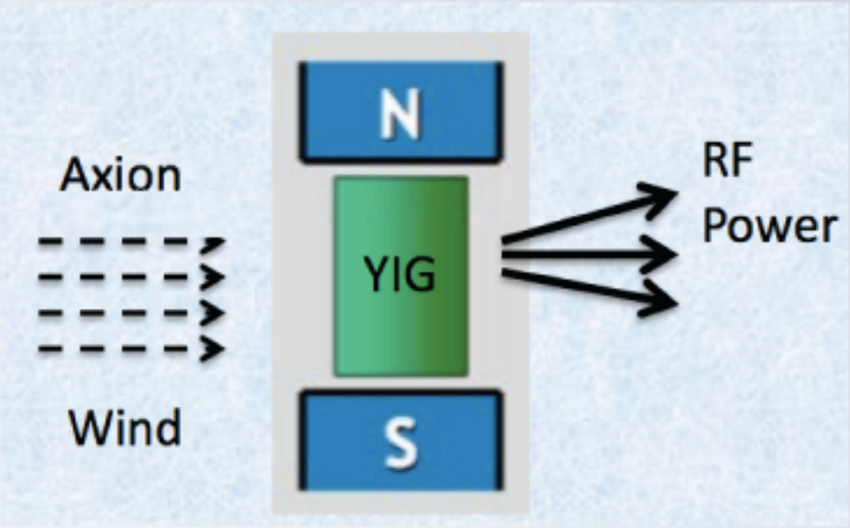




What Next

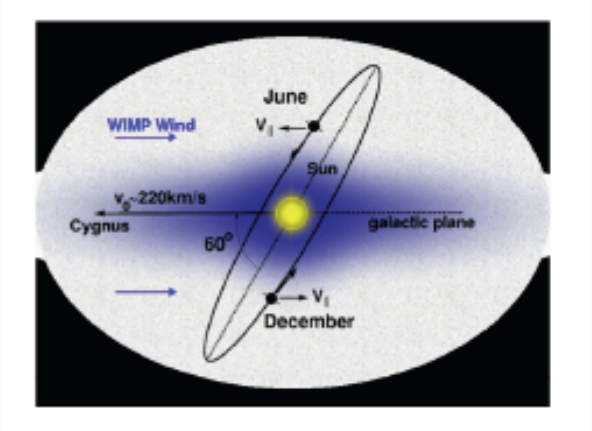
QUAX: SEARCH FOR AXIONS

- Main idea:
  - Use axion spin coupling
  - The axion field may act as an effective magnetic field on electron spin
  - It may induce ferromagnetic transitions in magnetised sample and emit μ-waves



- The idea is under investigation
  - Noise budget unknown
  - An R&D phase approved for 2015 to establish it
  - Collaboration with INRIM
  - Magnet uniformity and stability: a challenge
  - Group: PD, LNL, TO

Resp.: Gianni CARUGNO



Directionality between axion wind and spin

What Next – GdL Neutrini

Conveners:

Chiara Brofferio
Carlo Giunti
Eligio Lisi
Maurizio Spurio
Francesco Terranova

Attività del GdL →

2.1 Fisica nucleare e doppio decadimento beta (27 marzo)

- DBD, struttura nucleare ed elementi di matrice
- Reazioni con doppio scambio di carica (NUMEN)

2.2 Neutrini di bassissima energia (2 aprile)

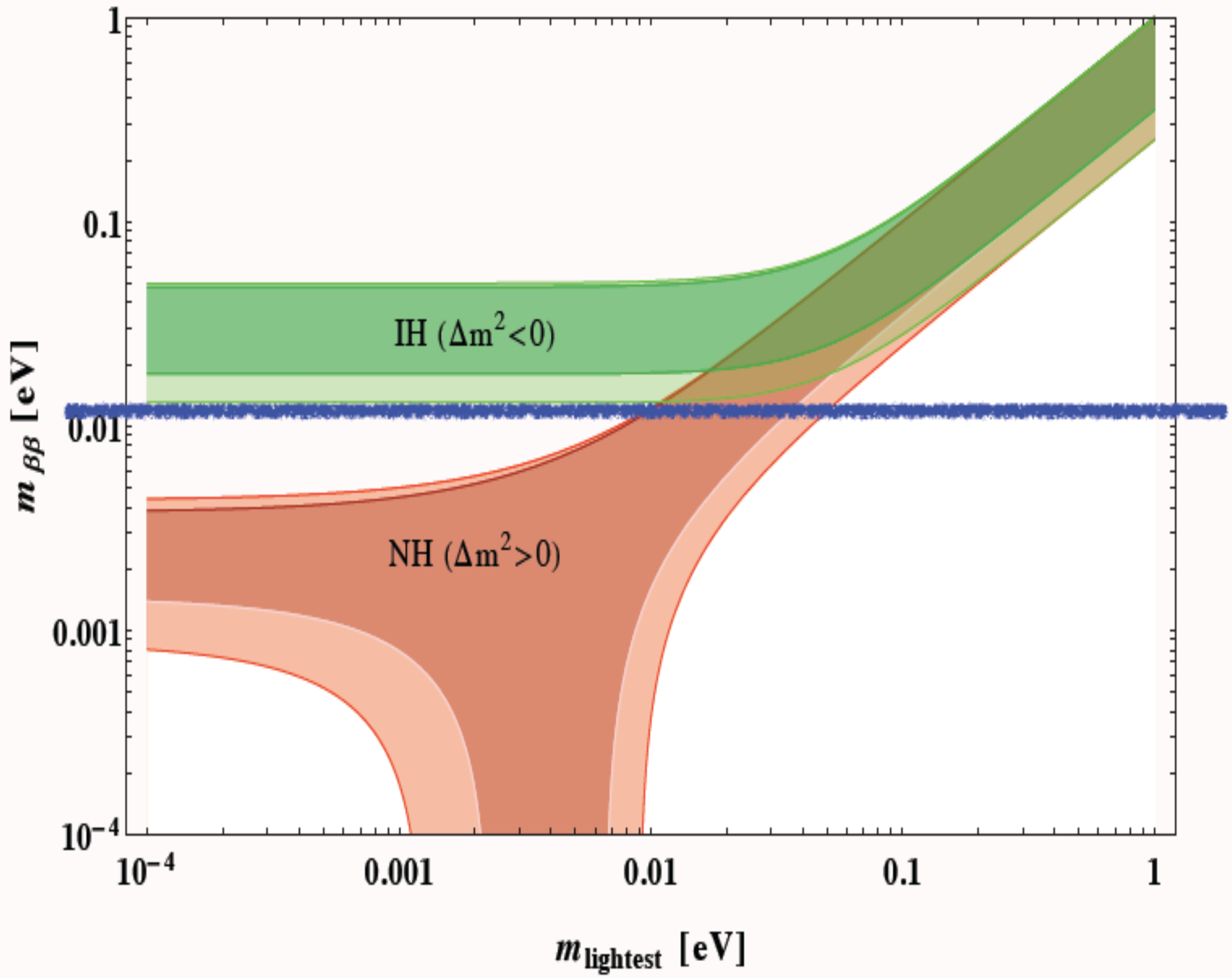
- Rivelazione di neutrini "relic" (Ptolemy)
- Decadimento beta e neutrini sterili (KATRIN, MARE)
- Neutrini Mossbauer

2.3 Gerarchia di massa dei neutrini (13 giugno)

- Con acceleratori (T2K, NovA, HK, LBNE, LBNO)
- Con neutrini atmosferici (ORCA)
- Con reattori (JUNO)
- \+ neutrini sterili ai reattori (SIR proposal TESEO)

LA SFIDA DEL DOPPIO BETA: DOVE VOGLIAMO ARRIVARE CON LA PROSSIMA GENERAZIONE DI ESPERIMENTI

Dell'Oro, Marcocci e Vissani, Phys. Rev. D 90, 033005 (2014)



Main open issues

Enrichment

Price/ton [M$]

Isotope	Abundance	Price per kg, k$
^{76}Ge	7.61	~ 80
^{82}Se	8.73	~ ~~120~~ 80
^{100}Mo	9.63	~ 80
^{116}Cd	7.49	~ 180
^{130}Te	34.08	~ 20
^{136}Xe	8.87	~ 5-10
^{150}Nd (?)	5.6	> 200

A. Barabash, arXiv:1109.6423v2

^{136}Xe → Low cost, but global year production is 40 tons

Theory

$$1/\tau \propto g_A^{\,4}$$

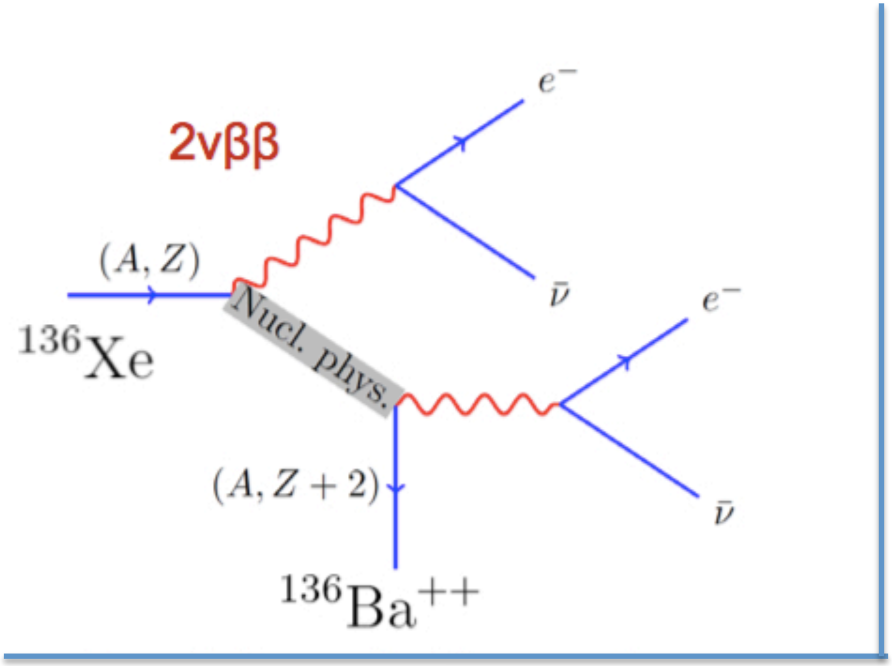
- → = 1.26 (free nucleon)
- → ~ 1 (accounting for quenching)
- → ~ 0.7-0.8 (recent fits)

Strong implications (but controversial)

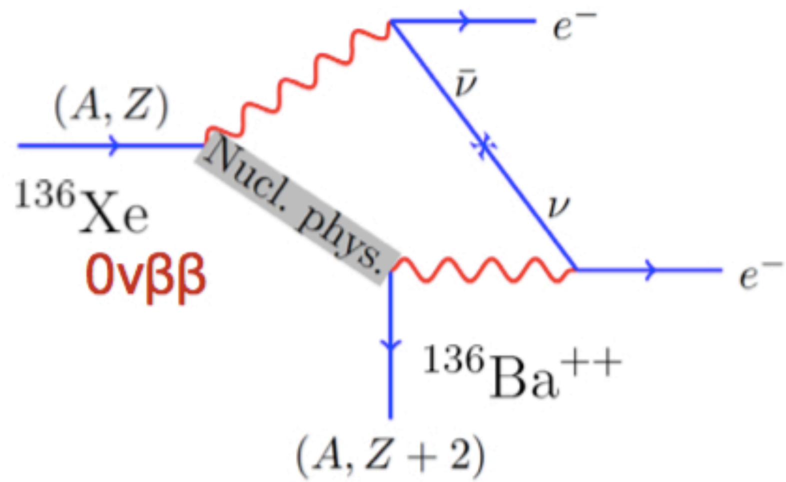
I prossimi anni devono servire ad identificare le tecniche e gli isotopi percorribili per gli esperimenti di prossima generazione

C. BUCCI, WHAT NEXT LNGS, ottobre 2014

Double β-decay



(simple 0νββ mechanism)



$$1/T_{1/2}^{0\nu}(0^+ \to 0^+) = G_{01}\left|M^{\beta\beta 0\nu}\right|^2 \left|\frac{\langle m_\nu \rangle}{m_e}\right|^2$$

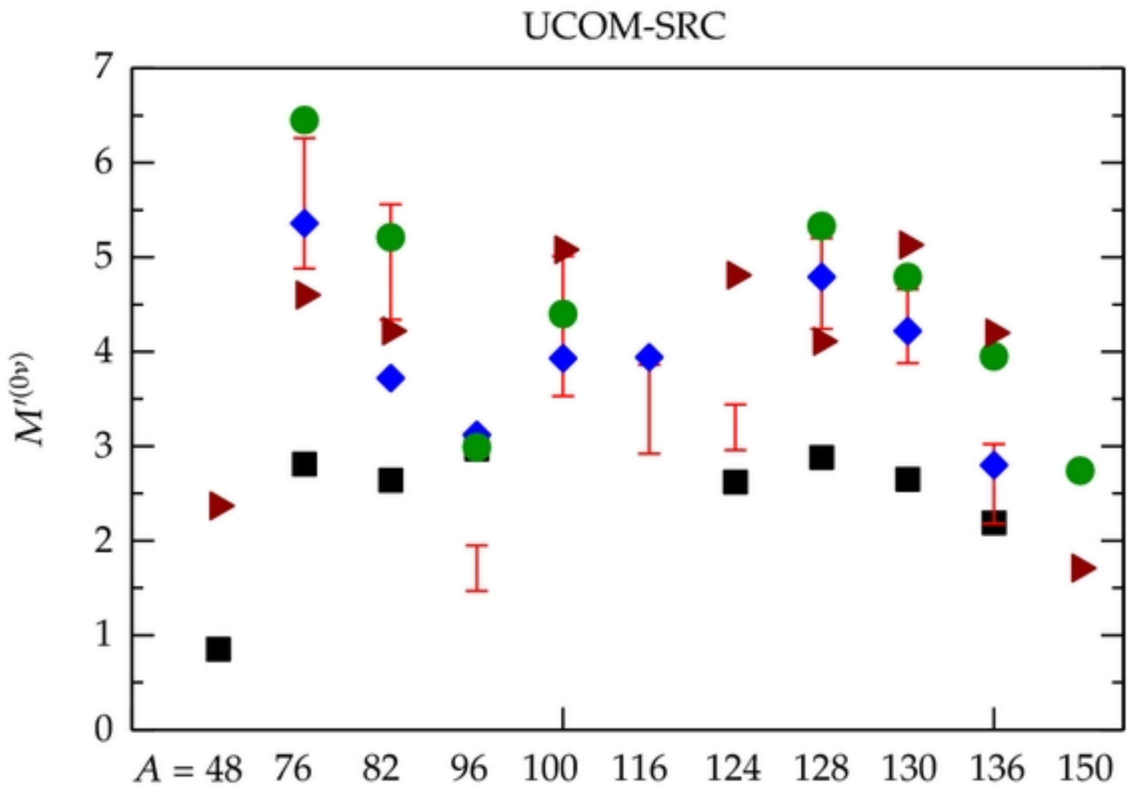
Great new physics inside

$$\langle m_\nu \rangle = \sum_i \left|U_{ei}\right|^2 m_i e^{i\alpha_i}$$

but one should know **Nuclear Matrix Element**

$$\left|M_\varepsilon^{\beta\beta 0\nu}\right|^2 = \left|\left\langle \Psi_f \left| \hat{O}_\varepsilon^{\beta\beta 0\nu} \right| \Psi_i \right\rangle\right|^2$$

State of the art NME calculations

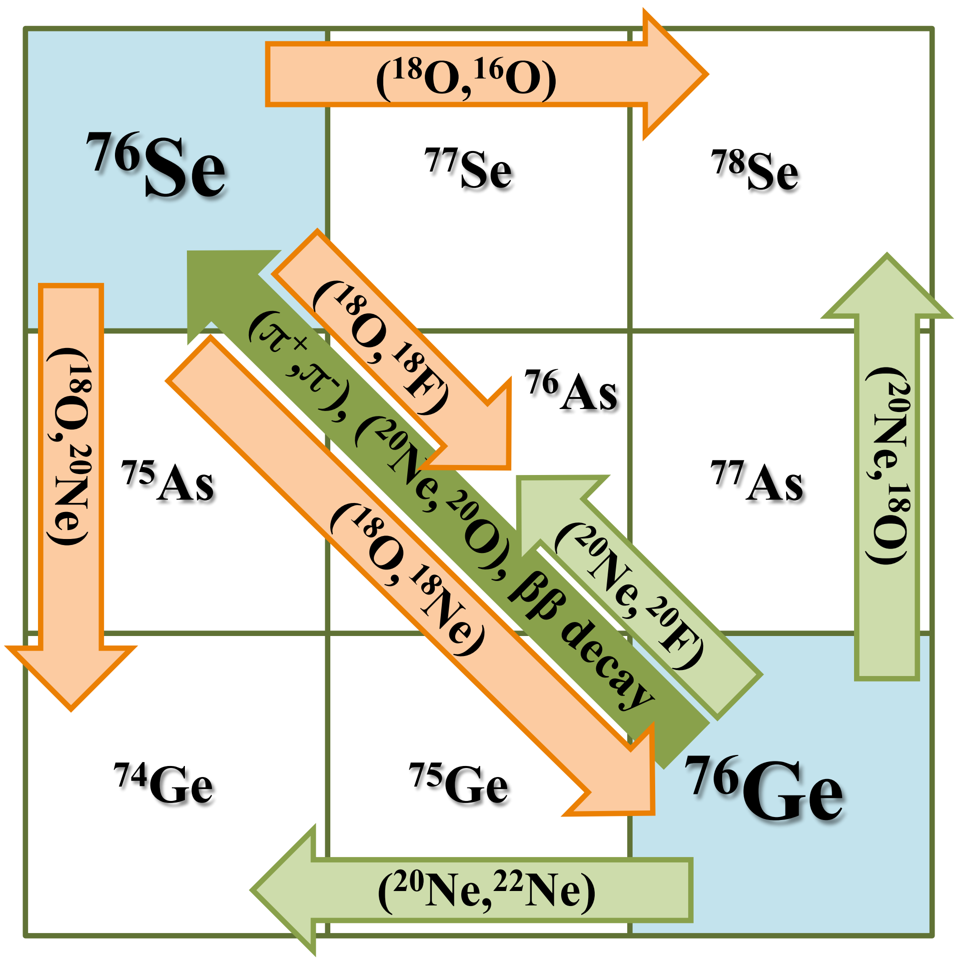


The neutrinoless double-beta decay; "state-of-the-art" NMEs: QRPA [30] (red bars) and [21, 22] (diamonds), ISM [31] (squares), IBM [25] (circles), and GCM [26] (triangles).

From A. Giuliani and A. Poves Adv. in High En. Phys. 2012 (2012) 857016

Double charge exchange reactions

Determining the Nuclear Matrix Elements of Neutrinoless Double Beta Decays by Heavy-Ion Double Charge Exchange Reactions



The NUMEN project

Proponents: C. Agodi, M. Bondì, V. Branchina, L. Calabretta, F. Cappuzzello, D. Carbone, M. Cavallaro, M. Colonna, A. Cunsolo, G. Cuttone, A. Foti, P. Finocchiaro, V. Greco, L. Pandola, D. Rifuggiato, S. Tudisco

Spokespersons: F. Cappuzzello (cappuzzello@lns.infn.it) and C. Agodi (agodi@lns.infn.it)

- $^{18}O^{7+}$ beam from Cyclotron at **270 MeV (10 pnA, 330 μC in 10 days)**
- ^{40}**Ca** solid target 300 μg/cm^2
- Ejectiles detected by the MAGNEX spectrometer
- Unique angular setting: -2° < θ_{lab} < 10° corresponding to a momentum transfer range **from 0.17 fm^{-1} to about 2.2 fm^{-1}**

- **The CS accelerator current upgrade (from 100 W to 5-10 kW);**
- **The MAGNEX focal plane detector will be upgraded from 1 khz to 100 khz**
- **The MAGNEX maximum magnetic rigidity will be increased**
- **An array of detectors for γ-rays measurement in coincidence with MAGNEX will be built**
- **The beam transport line transmission efficiency will be upgraded from about 70% to nearly 100%**
- **The target technology for intense heavy-ion beams will be developed**

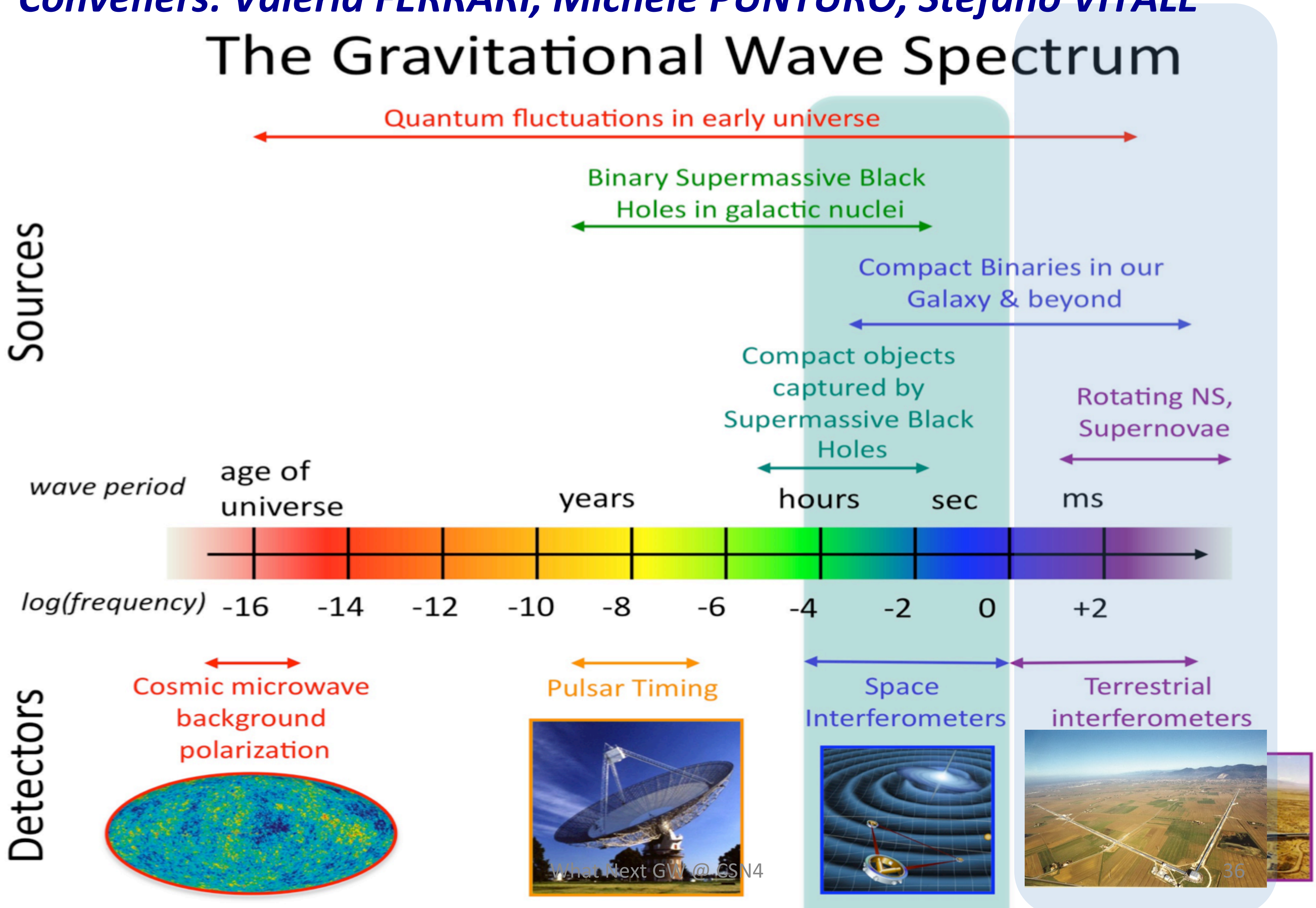
RADIAZIONE COSMICA

Conveners: Roberto ALOISIO, Bruna BERTUCCI, Maurizio BUSSO, Alessandro DE ANGELIS, Piera SAPIENZA, Francesco VISSANI

- Cosmic rays (charged particles) (Aloisio, Bertucci)
- Gamma rays (De Angelis, Busso)
- Neutrinos (<100 MeV, 1-100 GeV, > 100 GeV) (Sapienza, Vissani)
- Multimessenger &Particle Physics (Lipari, De Angelis) → questo e' a mio avviso il maggiore valuto aggiunto di avere la CR in What Next: interagiscono insieme tre comunita', quella dei cosmici (a terra e nello spazio), quella dalla gamma astronomia (a terra e nello spazio), quella dei neutrini di alta' energia (telescopi marini etc.)

L'altro messaggero cosmico: ONDE GRAVITAZIONALI

Conveners: Valeria FERRARI, Michele PUNTURO, Stefano VITALE



Plausible LIGO-Virgo Observing

Aasi et al. 1304.0670

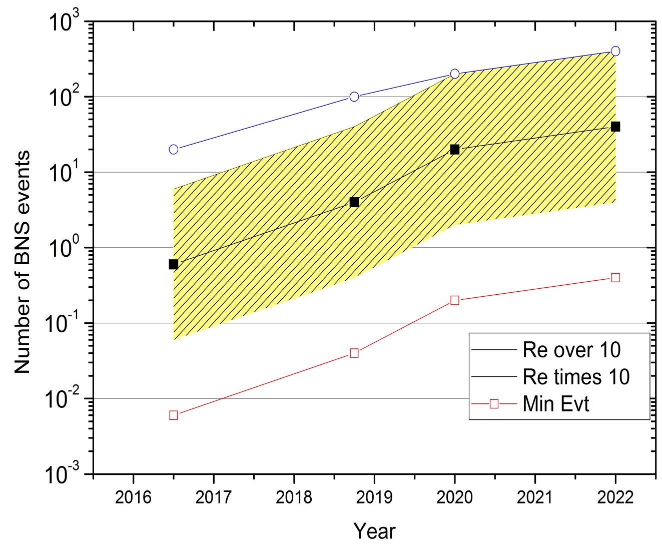
Epoch	Estimated Run Duration	BNS Range (Mpc)		Number of BNS Detections
		LIGO	Virgo	
2015	3 months	40 – 80	–	0.0004 – 3
2016–17	6 months	80 – 120	20 – 60	0.006 – 20
2017–18	9 months	120 – 170	60 – 85	0.04 – 100
2019+	(per year)	200	65 – 130	0.2 – 200
2022+ (India)	(per year)	200	130	0.4 – 400

Assumes NS-NS rate between 10^{-8} Mpc^{-3} y^{-1} and 10^{-5} Mpc^{-3}y^{-1}.
Ranges double for 1.4 $M_{\odot}$ – 10 $M_{\odot}$ NS-BH binary.

P. Sutton, APPEC SAC meeting , Nov. 4, 2014

Evoluzioni

- I detector GW stanno per raggiungere sensibilità scientificamente interessanti
  - Collaborazione con gruppi di relatività numerica per produzione templati di BNS
  - Sinergia fra osservatori e.m. e GW detectors
    - EM follow up



Advanced Virgo

E.M. follow up program

Virgo members of the e.m. follow-up committee:
M. Branchesi (INFN Firenze/Urbino univ.)
E. Chassande-Mottin (APC)
M. Boer (Obs. de Nice)
P. Groot (Radboud Univ. – Nijmegen)

IDENTIFICATION AND FOLLOW UP OF ELECTROMAGNETIC COUNTERPARTS OF GRAVITATIONAL WAVE CANDIDATE EVENTS

The LIGO Scientific Collaboration (LSC) and the Virgo Collaboration currently plan to start taking data in 2015, and we expect the sensitivity of the network to improve over time. Gravitational-wave transient candidates will be identified promptly upon acquisition of the data; we aim for distributing information with an initial latency of a few tens of minutes initially, possibly improving later. The LSC and the Virgo Collaboration (LVC) wish to enable multi-messenger observations of astrophysical events by GW detectors along with a wide range of telescopes and instruments of mainstream astronomy.

In 2012, the LVC approved a statement (LSC, Virgo) that broadly outlines LVC policy on releasing GW triggers (partially-validated event candidates). Initially, triggers will be shared promptly only with astronomy partners who have signed an Memorandum of Understanding (MoU) with LVC involving an agreement on deliverables, publication policies, confidentiality, and reporting. After four GW events have been published, further event candidates with high confidence will be shared immediately with the entire astronomy community (and the public), while lower-significance candidates will continue to be shared promptly only with partners who have signed a MoU.

From June to October 2013, we organized rounds of consultations with groups of astronomers that have expressed interest in the GW-EM follow-up program. Thanks to these consultations, we could define the framework and guiding rules for this program that are collected into a standard MoU template.

OPEN CALLS FOR PARTICIPATION TO GW-EM FOLLOW-UP PROGRAM.

An open call for proposals to sign standard MoU with LVC was issued on December 16, 2013 with deadline February 16, 2014. This call was open to all professional astronomers with demonstrated experience, and required a partner to bring some useful observing resource(s), not just astronomy expertise, to participate. All qualified applicants have been contacted and MoUs are currently being signed. GW triggers will be sent to these groups in the course of next science runs circa 2015-2017 (arXiv:1304.0670, LIGO-P1200087, VIR-0288A-12). A second open call is expected to be issued in fall 2014.

We welcome comments on this process sent to lsc-spokesperson@ligo.org (Gabriela González), and to virgo-spokesperson@ego-gw.it (Jean-Yves Vinet).

64 requests of application received from the international astronomical community from 19 countries

Interferometria atomica?

- La componente non-balistica che si sta affacciando è il mondo degli interferometri atomici
- Tecnologia interessante, performante per costruire gravimetri, ma il loro utilizzo per realizzare in GW detectors è tutto da dimostrare
- Design Study proposal in H2020
  - Componente italiana assente
- Inseriti in EGWII
  - Framework opportuno per la definizione del loro potenziale ruolo in GW

WHAT NEXT verso nuove (per l'INFN) strade

- **COSMOLOGIA OSSERVATIVA:**

  CMB, ENERGIA OSCURA

WG New Directions: Conveners: Nicola BARTOLO, Paolo DE BERNARDIS, Alessandro MELCHIORRI

- **SIMULAZIONE DI CAMPI QUANTISTICI MEDIANTE ATOMI FREDDI DISPOSTI SU RETICOLI OTTICI**

Nell'ambito del **WG di Fisica Fodamentale**

Conveners: Tommaso CALARCO, Giovanni CARUGNO, Saverio PASCAZIO, Gemma TESTERA

Quantum simulation?

L. FALLANI, CSN2, Ferrara, sett..2014

FISħ

Quantum simulator:

a *dedicated* quantum computer which can solve open problems of quantum physics by *imitating* the physics of the target system / model

It's not a Turing machine, but a machine of a different kind. If we disregard the continuity of space and make it discrete, and so on, as an approximation (the same way as we allowed ourselves in the classical case), it does seem to be true that all the various field theories have the same *kind* of behavior, and can be simulated in every way, apparently, with little latticeworks of spins and other things. It's been noted time and time again that the phenomena of field theory (if the world is made in a discrete lattice) are well imitated by many phenomena in solid state theory (which is simply the analysis of a latticework of crystal atoms, and in the case of the kind of solid state I mean each atom is just a point which has numbers associated with it, with quantum-mechanical rules).

I therefore believe it's true that with a suitable class of quantum machines you could imitate any quantum system, including the physical world.

And I'm not happy with all the analyses that go with just the classical theory, because nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical, and by golly it's a wonderful problem, because it doesn't look so easy.

R. P. Feynman, International Journal of Theoretical Physics **21**, 467 (1982)

What do we need? a quantum system that can be "engineered" and detected

Experiment goal

Scientific goal of the FISh experiment:

engineer the interactions in ultracold quantum gases in order to realize quantum simulators for some aspects of high-energy physics, connected to the colour symmetry and to the quark confinement in QCD

- **strong interconnections between HEP and atomic physics**
- **highly-innovative project**
- **ambitious goal, with a lot of interesting physics at hand on the way**

Disclaimer:

We don't (and cannot!) promise to perform a full quantum simulation of QCD

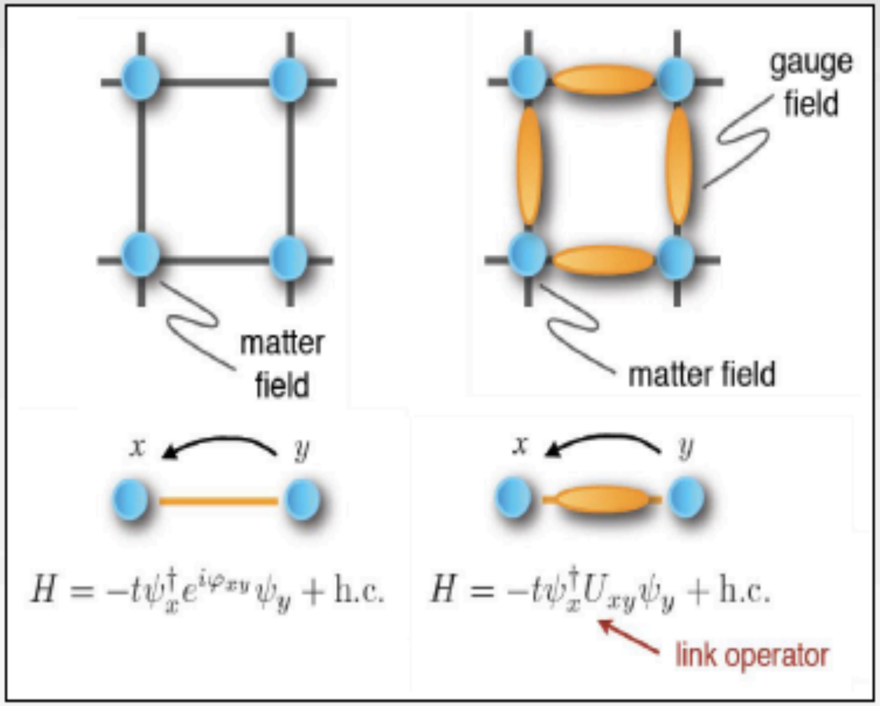
We plan to realize certain simplified models to make cold atoms behave as quark matter, to learn something new about basic phenomenology of QCD.

Quantum simulation of fermionic matter coupled to gauge fields

Recent proposals for the implementation of gauge fields and gauge theories in Yb atoms with laser-assisted tunnelling and/or structured optical lattices

- Realization of abelian and non-abelian gauge fields with ultracold atoms

- Dynamical gauge fields (simple instances of lattice gauge theories)

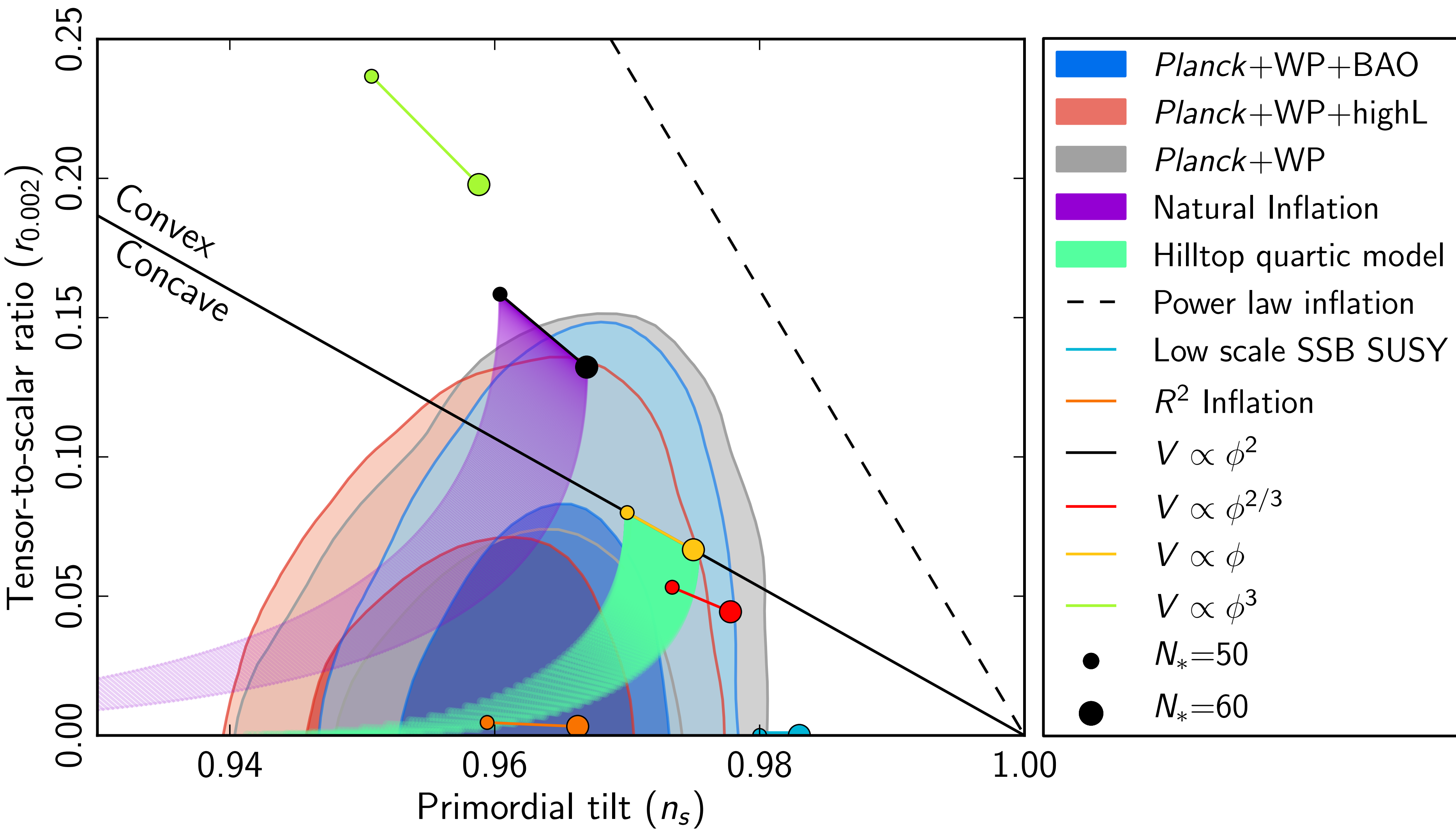


Theory collaboration: P. Zoller (Innsbruck)

Artificial gauge potentials for neutral atoms
J. Dalibard et al., Rev. Mod. Phys. **83**, 1523 (2011).

Atomic Quantum Simulation of U(N) and SU(N) Non-Abelian Lattice Gauge Theories
D. Banerjee et al., PRL **110**, 125303 (2013)

Misura della polarizzazione della CMB ci fornisce l'impronta lasciata dall'inflazione primordiale → possibilita' di discriminare tra I modelli di inflazione



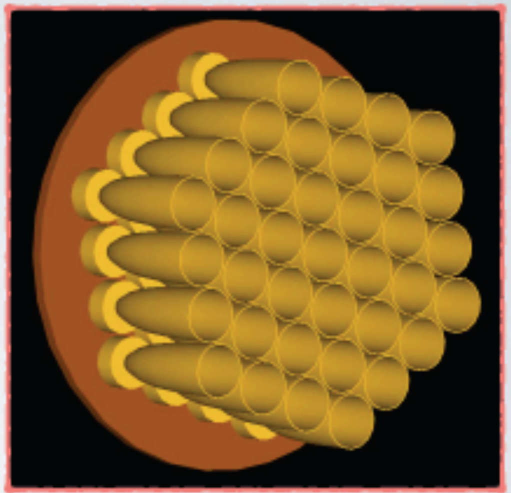
What Next

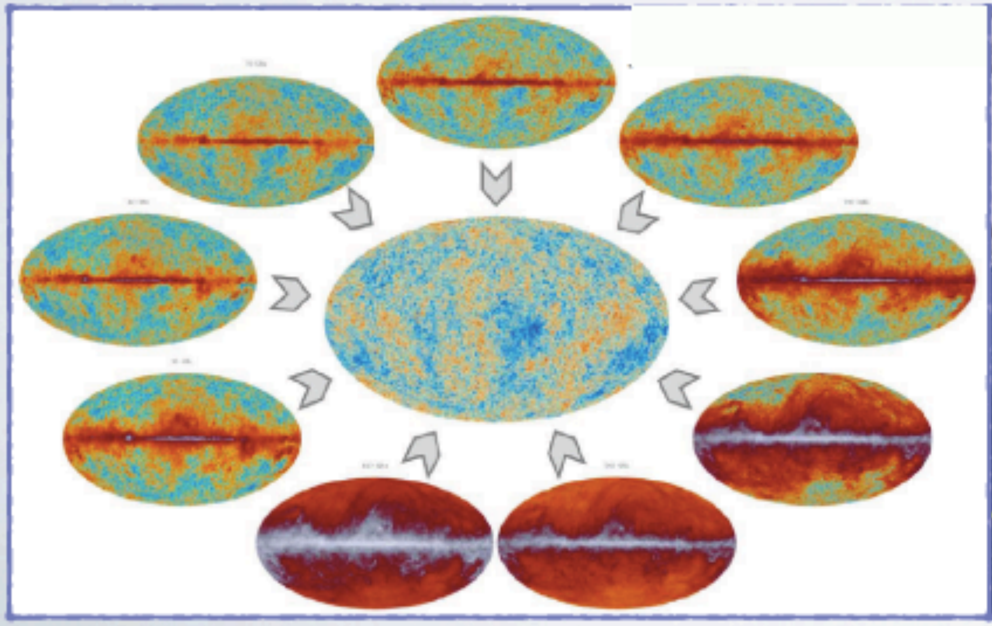
LSPE: SEARCH FOR COSMIC INFLATION

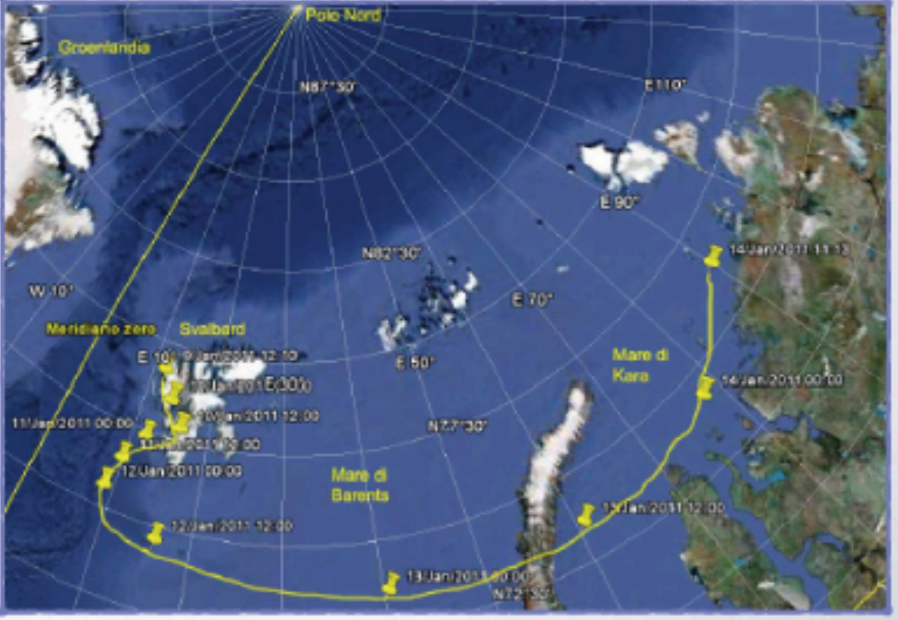
- **LSPE: Large Scale Polarisation Explorer**
  - Balloon mission for polarised CMB photons
  - Search for B-modes in a multi-wavelength approach
  - Re-use of technology R&D for neutrino mass measurement (µ-bolometers) + TES + KIDs
    - 5 channels (40 - 250 GHz) on spinning payload
    - Angular resol. 1.5°-2.3° Sky coverage: 20-25%
    - Sensitivity: about 10 µK

Pallavicini CSN2

P. De Bernardis
A. Baldini, F. Gatti







Dark Energy Studies

R. Miquel, APPEC SAC, nov. 4, 2014

- What is causing the acceleration of the expansion of the universe?
  - Einstein's cosmological constant Λ?
  - Some new dynamical field ("quintessence," Higgs-like)?
  - Modifications to General Relativity?

  } "Dark Energy"

- Dark energy effects can be studied in two main cosmological observables:
  - The history of the expansion rate of the universe: supernovae, weak lensing, baryon acoustic oscillations (BAO), cluster counting, etc.
  - The history of the rate of the growth of structure in the universe: weak lensing, large-scale structure, cluster counting, redshift-space distortions, etc.
- For all probes other than SNe, **large galaxy surveys are needed**:
  - **Spectroscopic**: 3D (redshift), medium depth, low density, selection effects
  - **Photometric**: "2.5D" (photo-z), deeper, higher density, no selection effects

Euclid Science Reach

	Modified Gravity	Dark Matter	Initial Conditions	Dark Energy		
Parameter	γ	m_ν/eV	f_{NL}	w_p	w_a	*FoM*
Euclid Primary	0.010	0.027	5.5	0.015	0.150	430
Euclid All	0.009	0.020	2.0	0.013	0.048	1540
Euclid+Planck	0.007	0.019	2.0	0.007	0.035	4020
Current	0.200	0.580	100	0.100	1.500	~10
Improvement Factor	**30**	**30**	**50**	**>10**	**>50**	**>300**

Euclid Science Reach

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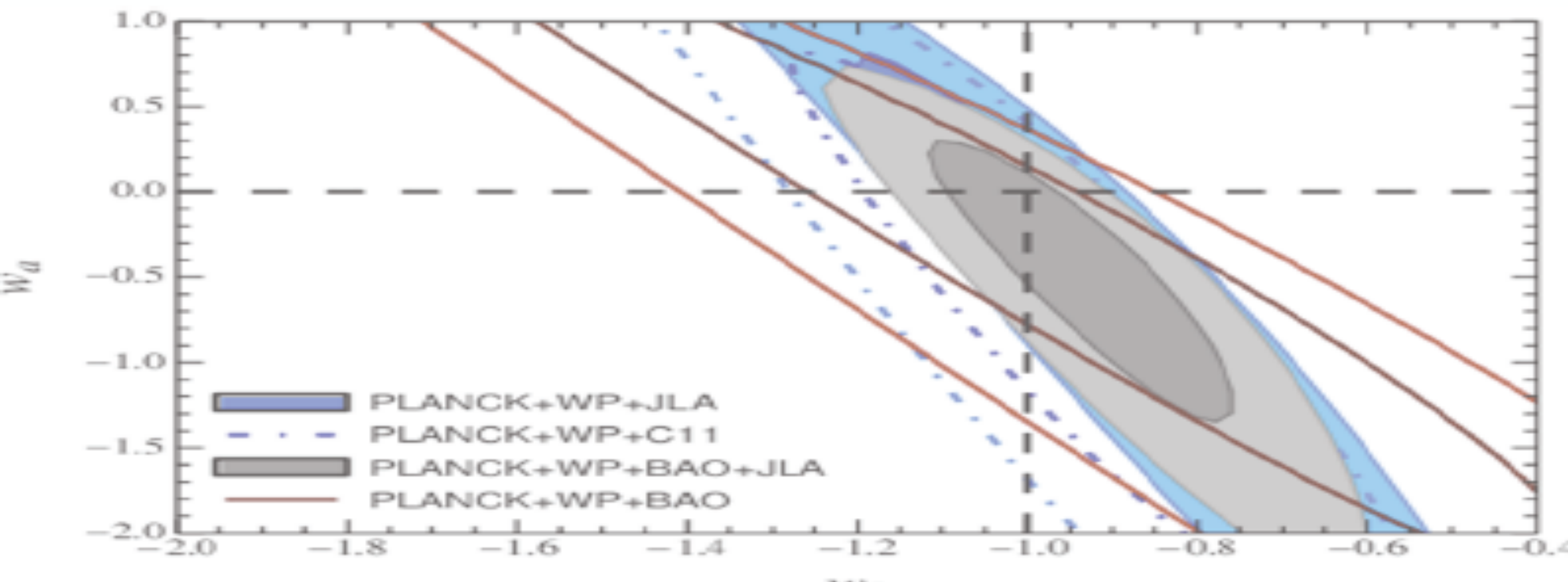
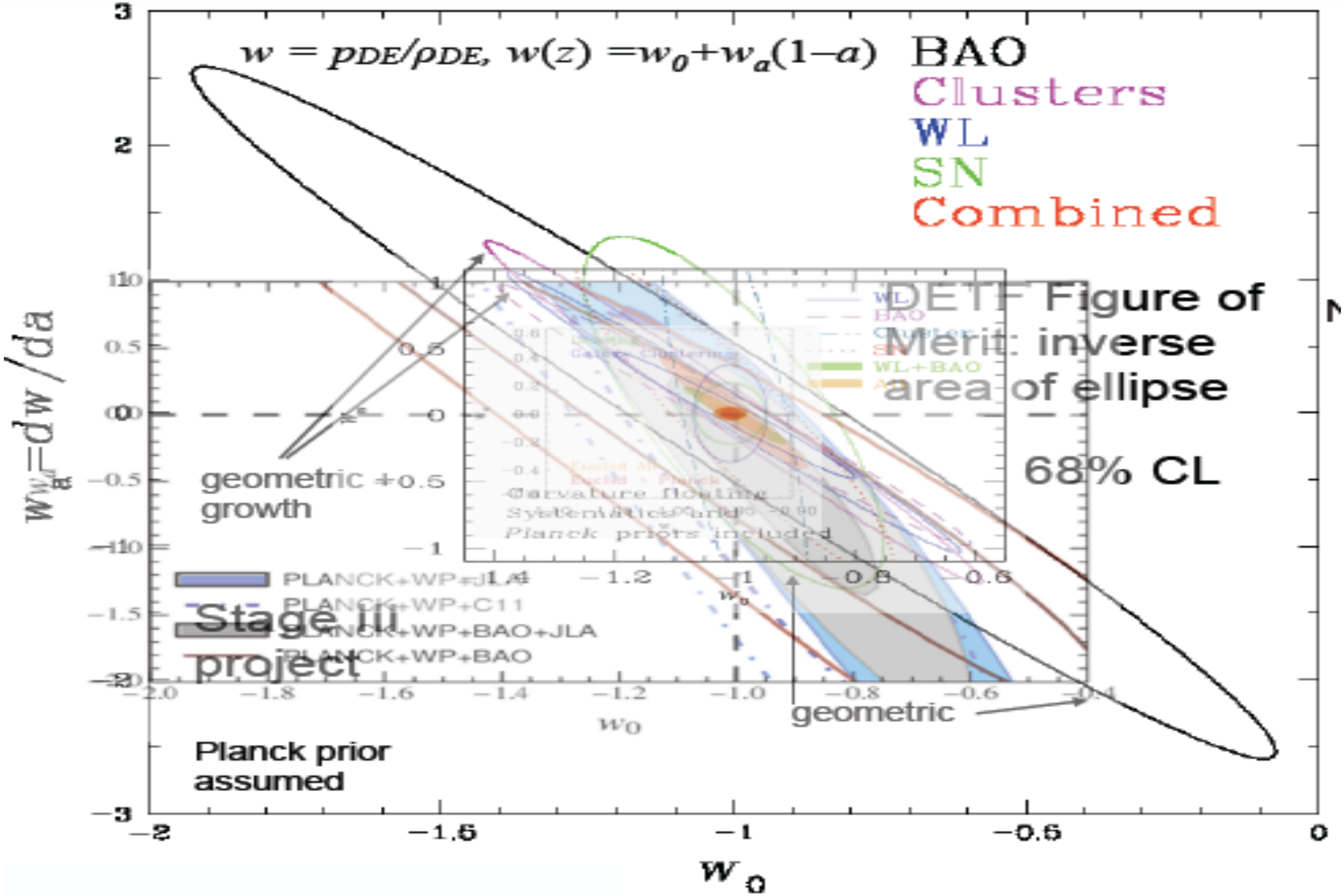
Improvement Factor	**30**	**30**	**50**	**>10**	**>50**	**>300**



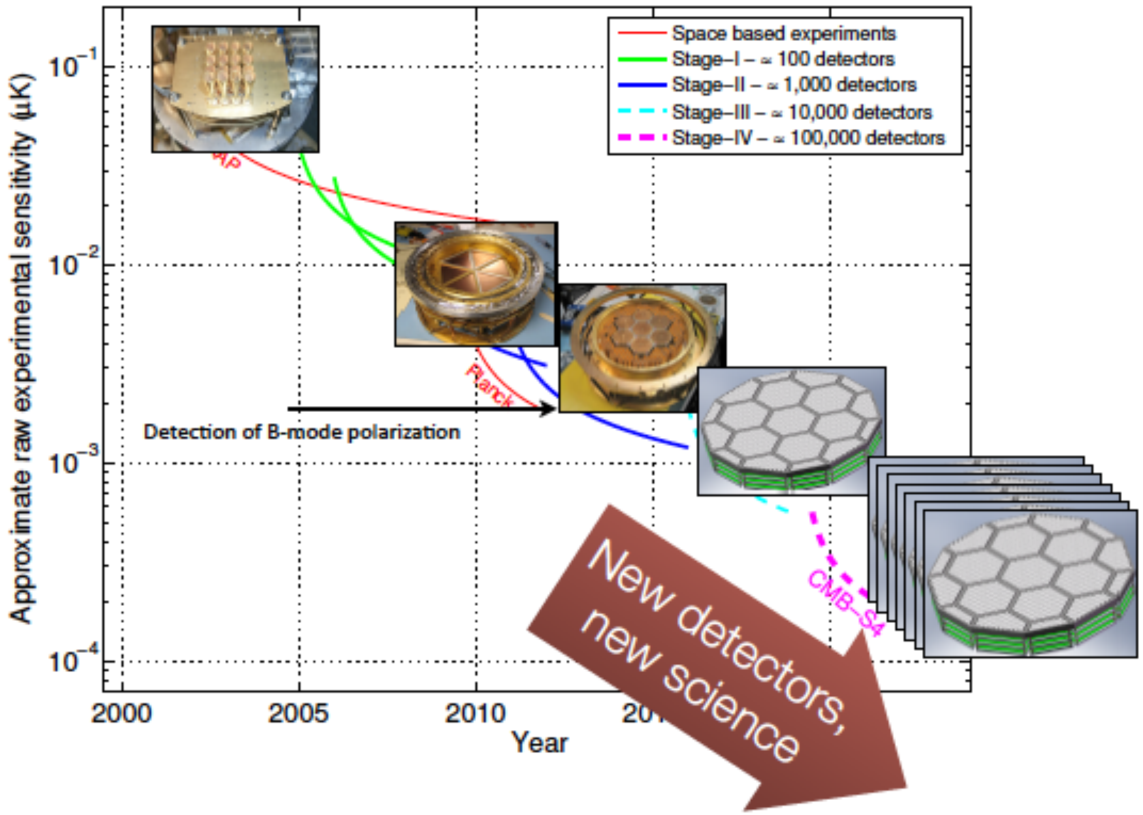
e dove arriveremo con EUCLID



Finita la fase esploratoria per entrare in EUCLID: partiamo con un gruppetto PD, BO con spokesperson Laura Patrizi

The importance of Technology

Development of TES and KIDS technology



LA SFIDA DEI RIVELATORI DI LUCE: SiPM come risposta? …………

WHAT NEXT LNGS – Ambrosi et al

Area tematica
NUOVE TECNOLOGIE

- **Task Force: Luciano CALABRETTA, Alberto FACCO, Massimo FERRARIO, Francesco FORTI, Gaetano MARON, Marco PAGANONI, Ezio PREVITALI, Marco RIPANI**
- **Task force → Working Group** se qualche WG interagisce con loro su specifici temi da studiare/sviluppare/inventare !!!

WHAT NEXT

tocca tutte queste domande...

neutrino masses
dark matter
baryogenesis
inflation

→ OBSERVATIONAL REASONS

$M_{HIGGS} / M_{PLANCK} \sim 10^{-16}$
$E_{VACUUM} (DE) / M_{HIGGS} \sim 10^{-14}$
$\Theta_{CPV\ in\ STRONG\ INTERAC.} < 10^{-9}$

→ THEOR. REASONS

risposte all'Angelicum tra ~un anno