Title: Quantum Gravity Phenomenologyâ€¦ Done carefully

Date: Dec 06, 2017 04:00 PM

URL: http://pirsa.org/17120013

Abstract: <p>In this talk I will discuss issues and possibilities to outline Quantum Gravity Phenomenology using cosmological and astrophysical data. After a brief review on some formal aspect of the problem I will focus on the analysis of in-vacuo dispersion features for GRB (gamma-ray-burst) neutrinos of energy in the range of 100 TeV, and for GRB photons with energy in the range of 10 GeV. I will introduce a strategy of data analysis which has the advantage of being applicable to several alternative possibilities for the laws of propagation of neutrinos and other particles in a quantum spacetime. Far from being conclusive, the results to be shown should nonetheless motivate a vigorous program of investigation following the methodology of multi-messenger astronomy.</p>

QUANTUM GRAVITY PHENOMENOLOGY ...DONE CAREFULLY

6/12/2017
PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

LORET NICCOLÒ

BASED ON

G. Amelino-Camelia, N. Loret, G. Mandanici, F. Mercati, Int. J. Mod. Phys. D 21 (2012) 1250052
N. Loret, Phys. Rev. D 90 (2014) no.12, 124013
G. Amelino-Camelia, L. Barcaroli., G. D'Amico, N. Loret, G. Rosati, Phys. Lett. B 761 (2016) 318
I.P. Lobo, N. Loret, F. Nettel, Eur. Phys. J. C 77 (2017) no.7, 451
L. Barcaroli, L.K. Brunkhorst, G. Gubitosi, N. Loret, C. Pfeifer Phys. Rev. D 95 (2017) no.2, 024036
G. Amelino-Camelia, G. D'Amico, G. Rosati, N. Loret, Nat. Astron. 1 (2017) 0139

THEORETICAL INVESTIGATIONS

RELATIVE LOCALITY
arXiv:1102.4637
arXiv:1107.3334
arXiv:1305.5062

FINSLER GEOMETRY
arXiv:1407.8143
arXiv:1611.04995

HAMILTON GEOMETRY
arXiv:1507.00922
arXiv:1612.01390
arXiv:1703.02058

NONCOMMUTATIVE GEOMETRY
arXiv:1610.08310

RAINBOW METRICS
arXiv:1404.5093
arXiv:1610.04277

PHENOMENOLOGY

COMPACT STARS
arXiv:0906.2016
arXiv:1007.0851
arXiv:1311.1042

ACCELERATED ELECTRONS
arXiv:1111.0993

DATA ANALYSIS

ICE CUBE NEUTRINOS AND FERMI PHOTONS
arXiv:1605.00496
arXiv:1609.03982
arXiv:1612.02765

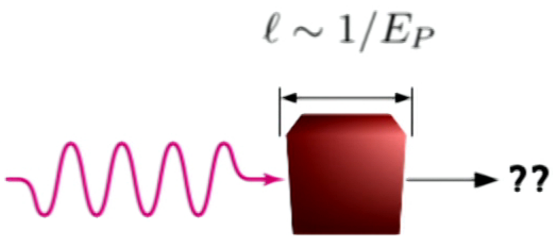
LOW ENERGY NEUTRINOS
arXiv:1109.5172

PART I

SOME THEORETICAL ASPECTS OF QUANTUM GRAVITY PHENOMENOLOGY

3/32

QUANTUM GRAVITY PHENOMENOLOGY



WE DO NOT OWN A GALAXY-SIZE COLLIDER

WE NEED A MAGNIFICATION MECHANISM

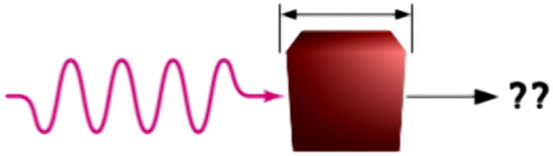
AND SOME SIMPLE GENERIC FORMULA TO TEST

$$\boxed{E^2 = p^2 + m^2 + \eta p^2 \frac{E^\alpha}{E_P^\alpha}}$$

4/32

QUANTUM GRAVITY PHENOMENOLOGY

$\ell \sim 1/E_P$



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$$\boxed{E^2 = p^2 + m^2 + \eta p^2 \frac{E^\alpha}{E_P^\alpha}}$$

COSMOLOGICAL DISTANCES

$$v = \frac{\partial E}{\partial p}$$

RAINBOW METRICS

$$ds^2 = g_{\alpha\beta} dx^\alpha dx^\beta$$

HIGH PRESSURE, LARGE NUMBER OF PARTICLES

$$E_0 = \frac{2V}{8\pi^3} \int_0^{p_F} dp\, 4\pi p^2 \left[\sqrt{p^2 + m_e^2} \left(1 + \frac{\eta}{2} \frac{p^2}{p^2 + m_e^2} \left(\frac{\sqrt{p^2 + m_e^2}}{E_p} \right) \right) - m_e \right]$$

4/32

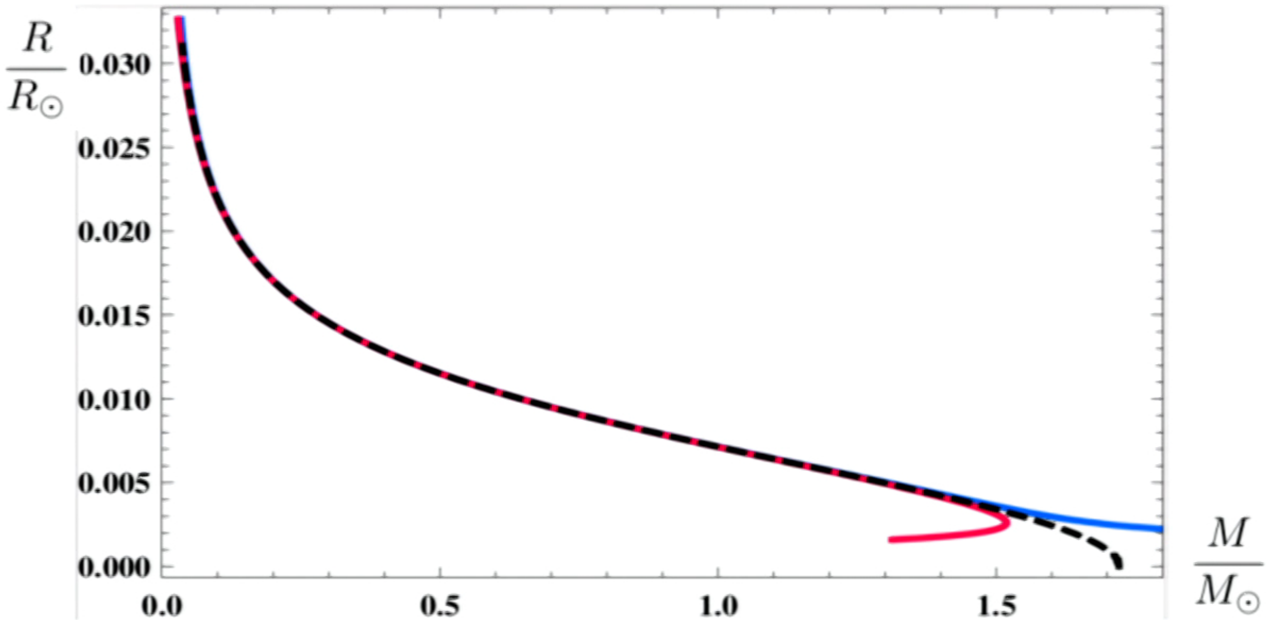
Q.G. PHENOMENOLOGY IN COMPACT STARS

CHANDRASEKHAR MODEL WITH MODIFIED DISPERSION RELATION

$$R = R_{Chan}\left(1 + \frac{2}{5}\eta\frac{m_e}{E_p}\frac{1}{(1-(\frac{M}{M_0})^{\frac{2}{3}})^{\frac{3}{2}}}\right)$$

AND NON TRIVIAL MOMENTA COMPOSITION LAWS

$$\sum_{\oplus} E_i \equiv \sum_i E_i + \sum_{i<j}\left(\frac{\beta_1}{\Lambda}E_iE_j + \frac{\beta_2}{\Lambda}\vec{p}_i\cdot\vec{p}_j\right)$$



5/32

RAINBOW METRICS

MAGUEIJO AND SMOLIN
arXiv:gr-qc/0305055

$$\boxed{m^2 = E^2 f^2\left(\frac{E}{E_P}\right) - (p\cdot p) g^2\left(\frac{E}{E_P}\right) = \tilde{g}^{\alpha\beta}(\ell, E) p_\alpha p_\beta}$$

6/32

RAINBOW METRICS

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LEWANDOWSKI
arXiv:1211.0161

$$\bar{g}_{\mu\nu} dx^\mu dx^\nu = -\bar{N}^2 dt^2 + \bar{a}^2\left(dx^2 + dy^2 + dz^2\right)$$

$$\bar{a}^2(k^2/m^2) \approx \bar{a}_o^2\left[1 + \frac{\beta}{3}\left(\frac{k/\bar{a}_o}{m}\right)^2\right]$$

FINSLER GEOMETRY
arXiv:gr-qc/0611024

$$g_{\mu\nu} = \frac{1}{2}\frac{\partial^2 \mathcal{F}^2}{\partial v^\mu \partial v^\nu} \qquad \mathcal{F}(x, v)$$

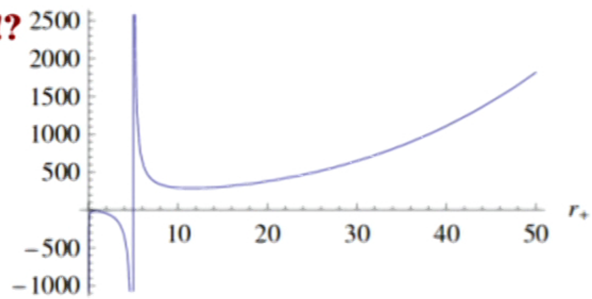
MOMENTUM-DEPENDENT METRICS FROM RG-FLOW
arXiv:gr-qc/0607030

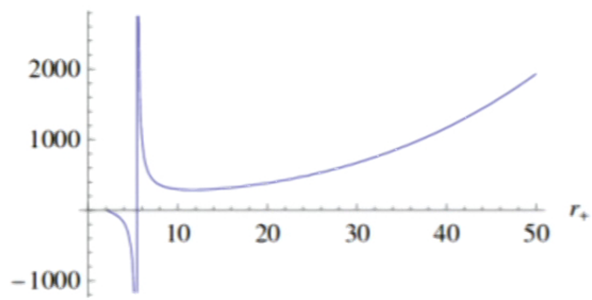
$$g^{\mu\nu}_{k_0} = \eta^{\mu\nu}$$
$$g^{\mu\nu}_{k} = \frac{\Lambda_k}{\Lambda_{k_0}}\eta^{\mu\nu}$$

RAINBOW METRIC PHENOMENOLOGY USUALLY

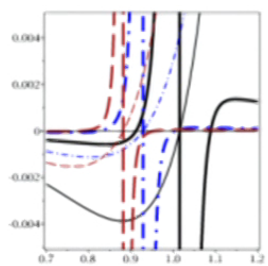
BLACK HOLE TEMPERATURE WITH RAINBOW GRAVITY AND MODIFIED UNCERTAINTY PRINCIPLE

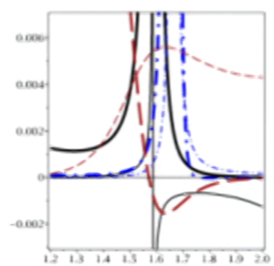
C_v !!?





CHARGED ROTATING BLACK HOLES THERMODYNAMICS WITH MASSIVE GRAVITONS AND RAINBOW METRICS





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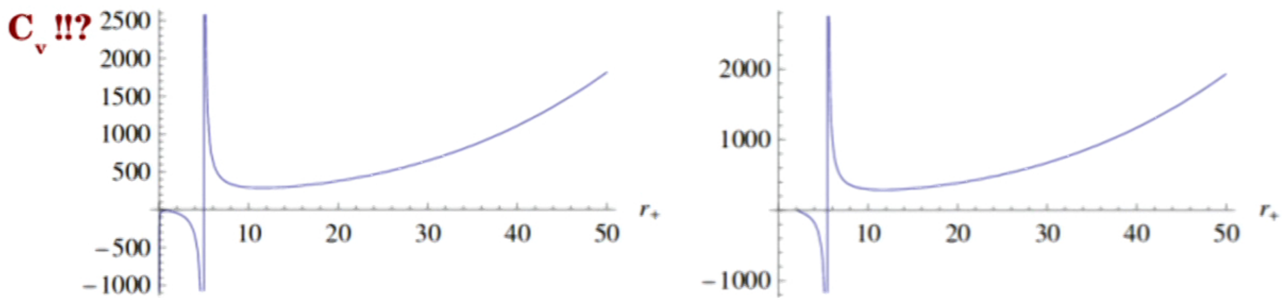

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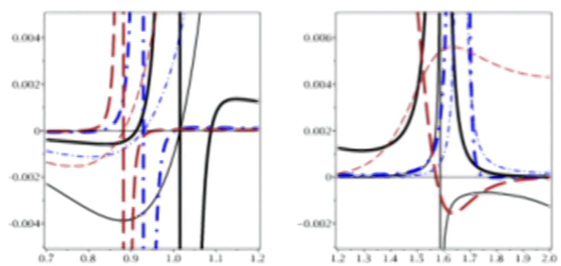


MANY HYPOTESES, MANY PARAMETERS, CAN ALL THOSE FEATURES COHABIT IN THE SAME PHYSICAL FRAMEWORK?

RELATIVE LOCALITY INTERPRETATION

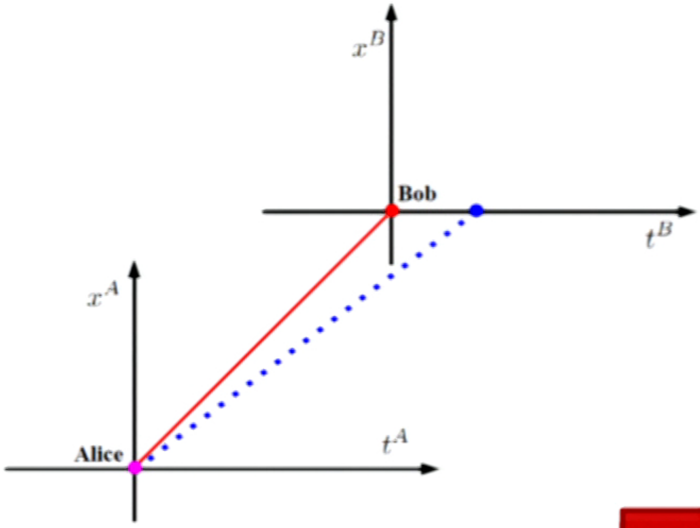
$$L_P = \sqrt{\frac{G\hbar}{c^3}} \xrightarrow[G,\hbar\to 0]{} 0 \qquad M_P = \sqrt{\frac{\hbar c}{G}} \neq 0$$

$$\boxed{[A,B] = i\hbar\{A,B\}}$$

WE STILL HAVE A DEFORMED MOMENTUM SPACE AT

$$\ell \sim \frac{1}{M_P}$$

BUT NO WEIRD PLANCK LENGTH EFFECTS RELATED TO SPACETIME QUANTIZATION



SEE arXiv:1101.0931, arXiv:1107.1724

DEFORMED LORENTZ TRANSFORMATIONS

IF WE WANT TO KEEP SPACETIME SYMMETRIES UNBROKEN

$$\frac{dp(\xi)}{d\xi} = \{N, p\} = E(\xi) + \ell E^2(\xi) + \frac{\ell}{2}p^2(\xi)$$
$$\frac{dE(\xi)}{d\xi} = \{N, E\} = p(\xi),$$

WHICH ADMIT SOLUTIONS

$$\sinh(\xi) = \frac{p}{\mu} - \ell\frac{pE}{\mu} \quad \cosh(\xi) = \frac{E}{\mu} - \frac{\ell}{2}\frac{p^2}{\mu}$$

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$$\boxed{\mathcal{H} = E^2(\xi) - |p|^2(\xi) - \ell E(\xi)p^2(\xi)}$$

RELATIVE LOCALITY'S RAINBOW METRICS

WE CAN DO THE SAME FOR SPACETIME COORDINATES

$$\Delta s^2 = \zeta_{\alpha\beta} \Delta x^\alpha \Delta x^\beta$$

WHERE

$$\boxed{\zeta_{\alpha\beta}(p) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -(1-2\ell p_0) & 0 \\ 0 & 0 & -(1-2\ell p_0) \end{pmatrix}}$$

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$$\mathcal{H} = \tilde{g}^{\mu\nu}(p) p_\mu p_\nu \qquad\qquad ds^2 \neq \tilde{g}(p)_{\mu\nu} dx^\mu dx^\nu$$

10/32

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INVARIANT MOMENTUM-SPACE LINE-ELEMENT

$$\mathcal{H}_\kappa = \int_0^1 \eta^{AB} \dot{\Pi}_A(s) \dot{\Pi}_B(s)\, ds = \int_0^1 \zeta^{\alpha\beta}(P) \dot{P}_\alpha(s) \dot{P}_\beta(s)\, ds$$

MDR IN HOMOGENEOUS AND ISOTROPIC SPACETIMES

$$\dot{p}_\alpha + \partial_\alpha \mathcal{H} = 0\ , \quad \dot{x}^\alpha - \bar{\partial}^\alpha \mathcal{H} = 0$$

REDSHIFT

$$\boxed{p_t(t) = -\frac{1}{\ell} \ln\left(1 - \frac{a(\bar{t})}{a(t)}(1 - e^{-\ell \bar{p}_t})\right) \xrightarrow[\ell \to 0]{} \bar{p}_t \frac{a(\bar{t})}{a(t)}}$$

MDR IN HOMOGENEOUS AND ISOTROPIC SPACETIMES

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WORLDLINES

$$r(t) = \frac{1}{\sqrt{k}} \sin\left(\sin^{-1}\left(\sqrt{k}\bar{r}\right) \mp \sqrt{k} \int_{\bar{t}}^{t} \frac{1}{a(\bar{t})(1 - e^{-\ell \bar{p}_t}) - a(\mathbf{t})} \, d\mathbf{t}\right)$$

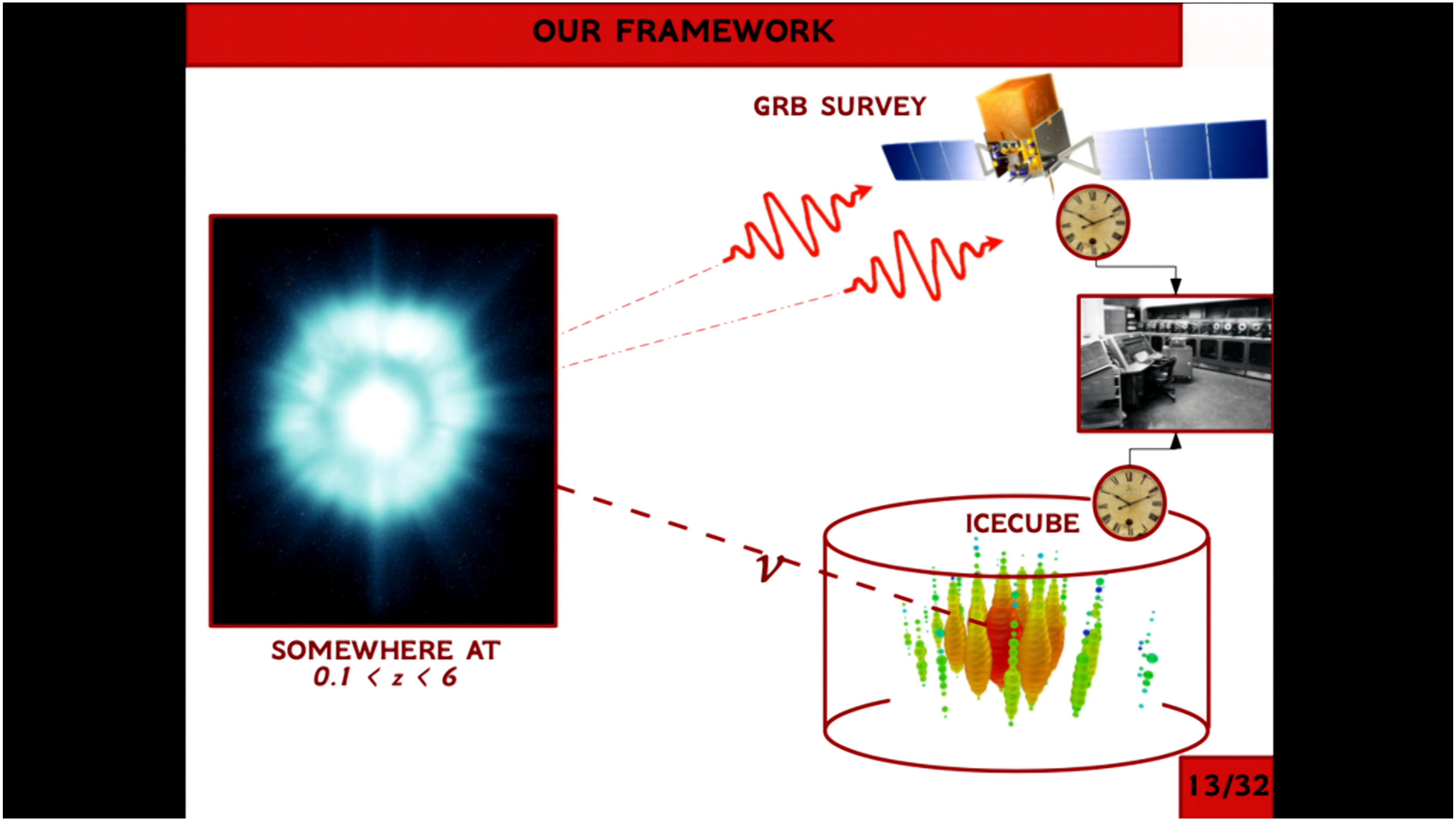
DeSITTER LIMIT

$$r(t) - \bar{r} = \mp \frac{e^{H\bar{t} + \ell \bar{p}_t}}{(e^{\ell \bar{p}_t} - 1)H} \ln\left(e^{H(t-\bar{t})}(1 - e^{\ell \bar{p}_t}) + e^{\ell \bar{p}_t}\right) \begin{cases} \xrightarrow{\ell \to 0} \mp \frac{e^{H\bar{t}} - e^{Ht}}{H} \\ \xrightarrow{H \to 0} \pm e^{\ell \bar{p}_t}(t - \bar{t}) \end{cases}$$

LATESHIFT

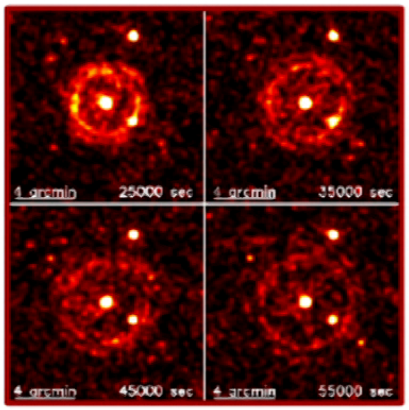
$$\boxed{\Delta t|_{k=0} = \ell p_t(t^h) \frac{(z + \frac{z^2}{2})}{H} + \mathcal{O}(\ell^2)}$$

ASTROPARTICLE DATA ANALYSIS FOR QUANTUM GRAVITY PHENOMENOLOGY


OUR FRAMEWORK
GRB SURVEY
SOMEWHERE AT
0.1 < z < 6
ν
ICECUBE
13/32

GRB AND COSMICRAYS

- COSMIC RAYS ARE MOSTLY COMPOSED BY PROTONS
- WE CAN EXPECT THEM TO BE EMITTED IN CORRELATION WITH HIGH ENERGETIC NEUTRINOS
- WHAT'S THEIR SOURCE? WHAT ABOUT GRBS?



- HIGHEST ENERGY SOURCE IN THE UNIVERSE

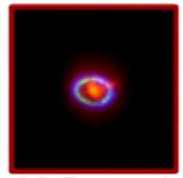
- THEY ARE HOMOGENEOUSLY DISTRIBUTED IN THE SKY

- IS THERE ANY CORRELATION BETWEEN HIGH-ENERGY NEUTRINOS AND GRBS?
astro-ph/9701231, astro-ph/0302524, arXiv:1103.3421, arXiv:1407.5671

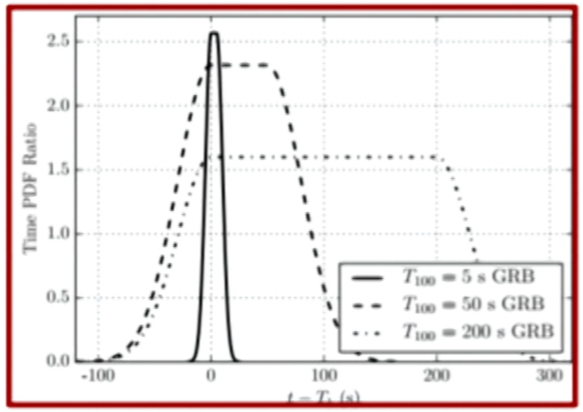
NEUTRINO IN VACUO DISPERSION

- SOME BOUNDS ON PHOTONS' DISPERSION RELATION
  SEE EXEMPLI GRATIA arXiv:0908.1832

- VERY WEAK LIMITS ON NEUTRINO DEFORMATION PARAMETERS
  (LOW ENERGY NEUTRINOS FROM SN1987A)



- NO CONCLUSIVE DETECTION OF GRB NEUTRINOS, CONTRADICTING SOME INFLUENTIAL PREDICTIONS
  ICECUBE COLLABORATION:
  arXiv:1601.06484v1



- NO TESTS ON QUANTUM GRAVITY EFFECTS ON NEUTRINO PROPAGATION !!

OUR OBSERVABLES

WE FOCUS ON THE CLASS OF SCENARIOS WHOSE PREDICTIONS FOR ENERGY (E) DEPENDENCE OF Δt CAN ALL BE DESCRIBED IN TERMS OF

SYSTEMATIC

FUZZY

$$\Delta t = \eta_X \frac{E}{M_P} D(z) \pm \delta_X \frac{E}{M_P} D(z) \qquad D(z) = \int_0^z d\zeta \frac{(1+\zeta)}{H_0\sqrt{\Omega_\Lambda + (1+\zeta)^3\Omega_m}}$$

16/32

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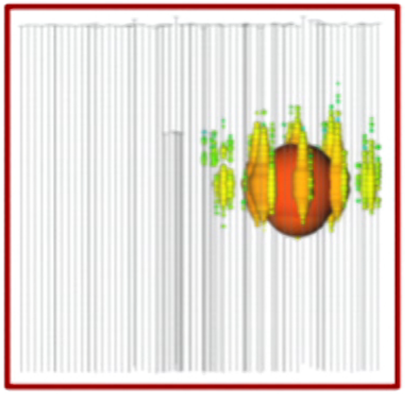
OBSERVABLES t^* AND E^*

$$\Delta t^* \equiv \Delta t \frac{D(1)}{D(z)} \qquad \Delta t^* = \eta_X \frac{E}{M_P} D(1) \pm \delta_X \frac{E}{M_P} D(1)$$

$$E^* \equiv E \frac{D(z)}{D(1)} \qquad \frac{\Delta t}{1+z} = \eta \frac{D(1)}{M_P} \frac{E^*}{1+z} \pm \delta \frac{D(1)}{M_P} \frac{E^*}{1+z}$$

EVENTS IN ICECUBE

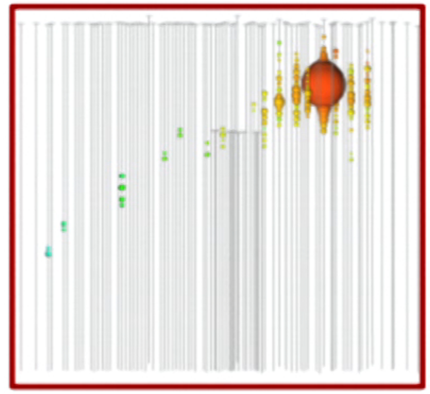
SHOWER EVENTS



GENERATED MOSTLY BY ν_e

- HIGHER ENERGY
- HIGHER SIGNIFICANCE
- WORST ANGULAR DISCRIMINATION

TRACK EVENTS



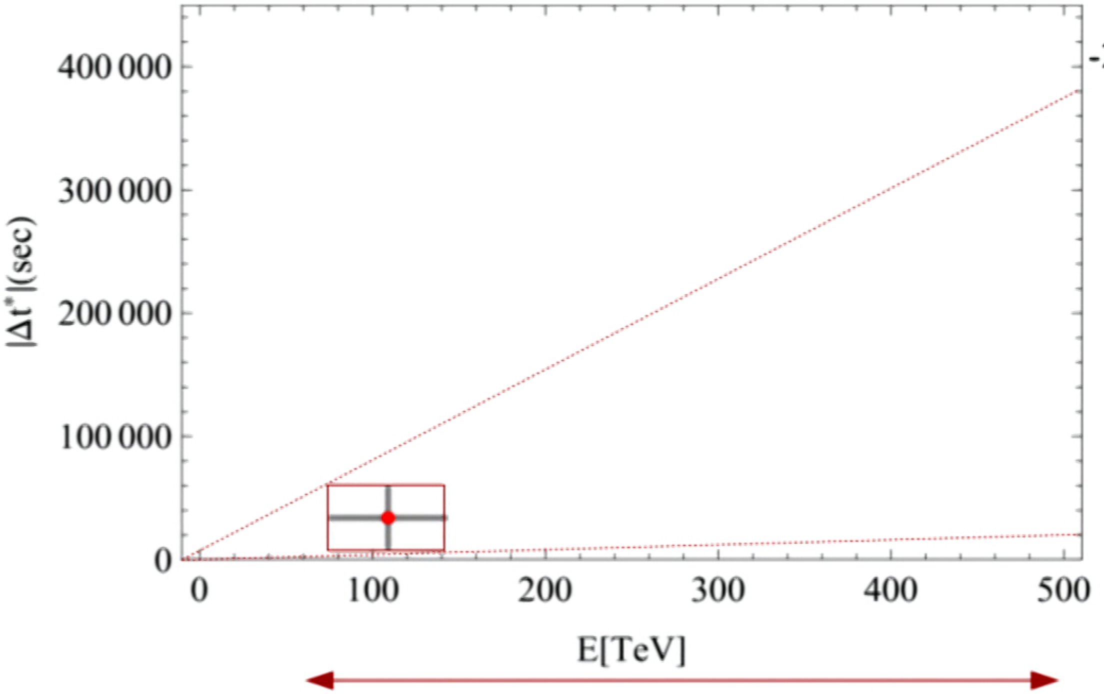
GENERATED BY ν_μ

- LOWER ENERGY
- LOW SIGNIFICANCE
- LOWER BOUND ON NEUTRINO ENERGY
- GOOD ANGULAR DISCRIMINATION

NO TRACKS, AT LEAST FOR NOW...

ENERGY AND TIME WINDOWS

WE USE THE 109 TeV NEUTRINO STUDIED IN [Amelino-camelia, Guetta, Piran arXiv:1303.1826] AS A PRIOR TO INSPIRE A CHOICE OF THE TEMPORAL WINDOW.

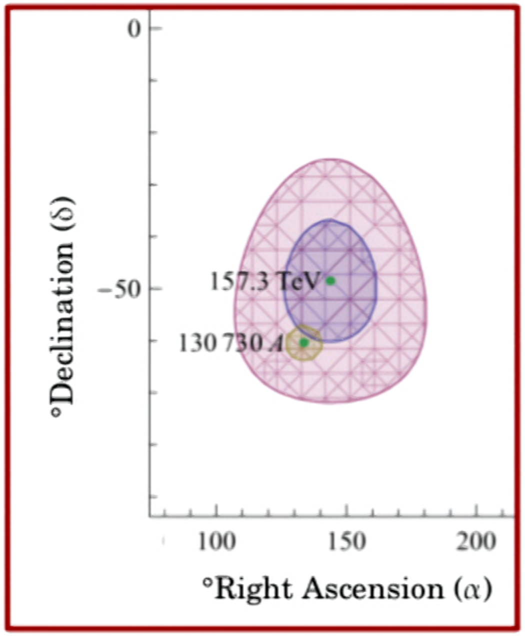


-3 days < Δt < +3 days

60 TeV< E < 500 TeV
PROBABLE ASTROPHYSICAL ORIGIN

PROBABILITY DENSITY FUNCTION

$$PDF(\nu, GRB) = \frac{1}{2\pi\sigma^2} e^{-\frac{\psi^2(\vec{x}_\nu, \vec{x}_{GRB})}{2\sigma^2}}$$



ANGULAR DISTANCE IN THE SKY

$$\psi^2(\vec{x}_\nu, \vec{x}_{GRB}) = \arccos\left(\cos(\delta_\nu)\cos(\delta_{GRB})\cos(\alpha_\nu - \alpha_{GRB}) + \sin(\delta_\nu)\sin(\delta_{GRB})\right)$$

ANGULAR UNCERTAINTY

$$\sigma = \sqrt{\sigma^2_{GRB} + \sigma^2_\nu}$$

OUR DATASET

- 4 YEARS OF OPERATION OF ICECUBE, FROM JUNE 2010 TO MAY 2014

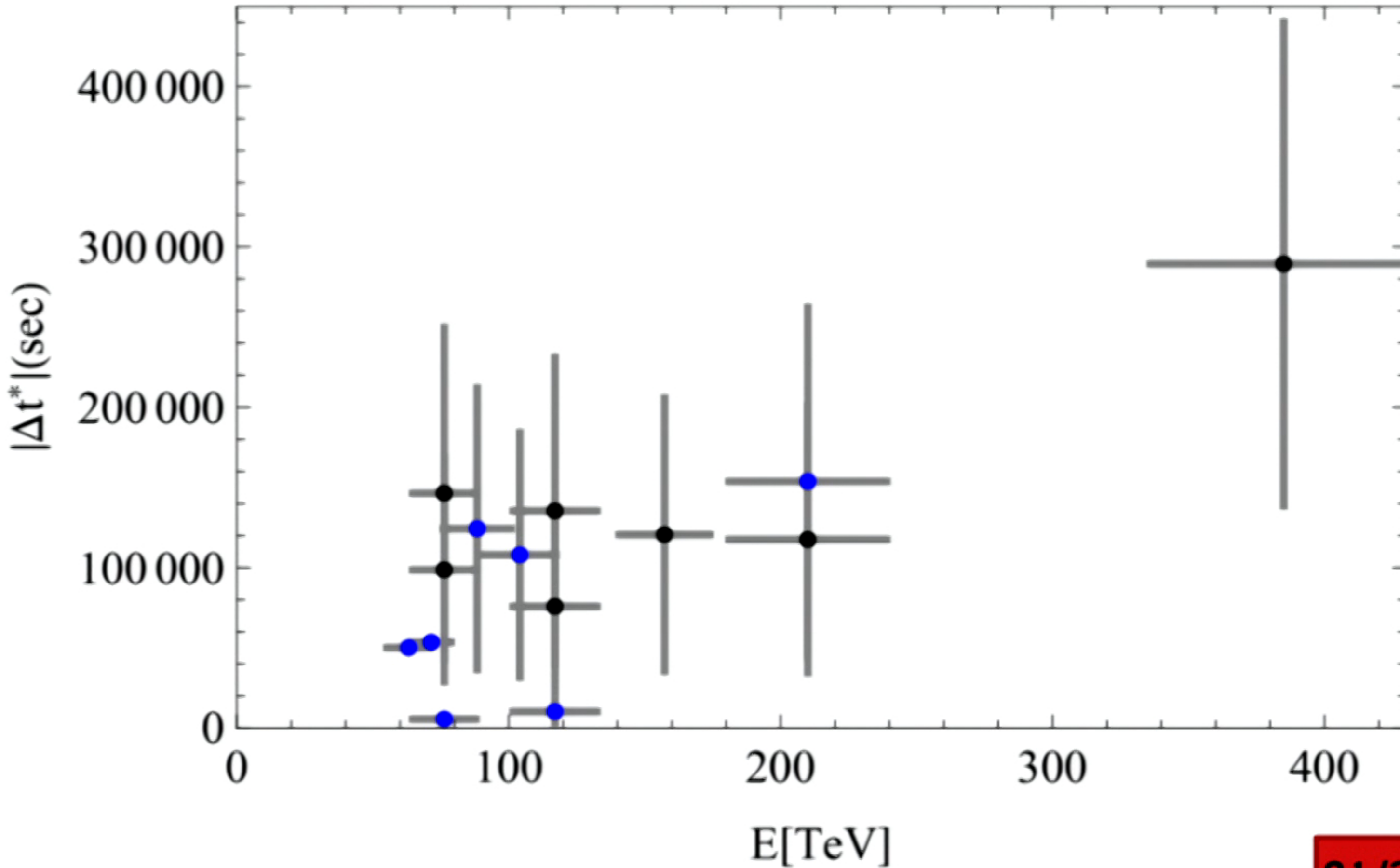
  21 "SHOWER" NEUTRINOS WITH ENERGIES BETWEEN 60 AND 500 TEV

- WHOLE COLLECTION OF OBSERVED GRBS, FROM JUNE 2010 TO MAY 2014

  1162 GRBS
  -1049 LONG GRBS
  -143 SHORT GRBS

	E[TeV]	GRB	z	Δt^* [s]	
IC9	63.2	110503A	1.613	50227	*
IC19	71.5	111229A	1.3805	53512	*
IC42	76.3	131117A	4.042	5620	
		131118A	1.497 *	-98694	*
		131119A	?	-146475	
IC11	88.4	110531A	1.497 *	124338	*
IC12	104.1	110625B	1.497 *	108061	*
IC2	117.0	100604A	?	10372	
		100605A	1.497 *	-75921	*
		100606A	?	-135456	
IC40	157.3	130730A	1.497 *	-120641	*
IC26	210.0	120219A	1.497 *	153815	*
		120224B	?	-117619	
IC33	384.7	121023A	0.6 *	-289371	*

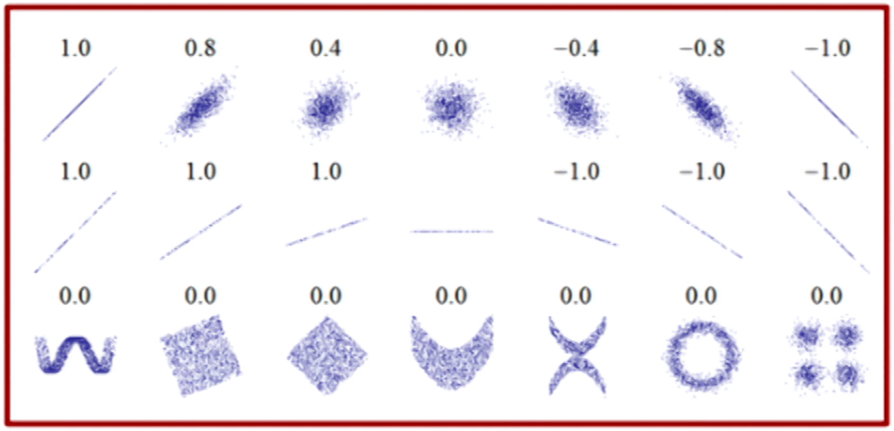
OUR DATASET



OUR CORRELATION TEST

OUR INDICATOR IS THE PEARSON-BRAVAIS CORRELATION COEFFICIENT: IT IS THE RATIO BETWEEN THE COVARIANCE OF THE TWO VARIABLES, DIVIDED BY THE PRODUCT OF THEIR STANDARD DEVIATIONS

$$\boxed{-1 \leq \rho_{xy} = \frac{\sigma_{xy}}{\sigma_x \sigma_y} = \frac{\sum_{i=1}^{n}(x_i - \mu_x)(y_i - \mu_y)}{\sqrt{\sum_{i=1}^{n}(x_i - \mu_x)^2}\sqrt{\sum_{i=1}^{n}(y_i - \mu_y)^2}} \leq +1}$$



NOW LETS DO IT 100.000 TIMES...

SOME RESULTS

	CORRELATION			FALSE ALARM PROBABILITY	

BEST CORRELATION SELECTION

	$z_{long} = \bar{z}$	$z_{long} = 2$
$z_{short} = 0.5$	0.958	0.953
$z_{short} = 0.6$	**0.951**	0.960
$z_{short} = 0.7$	0.941	0.964

	$z_{long} = \bar{z}$	$z_{long} = 2$
$z_{short} = 0.5$	0.03 %	0.04 %
$z_{short} = 0.6$	**0.03 %**	0.02 %
$z_{short} = 0.7$	0.04 %	0.01 %

MINIMIZATION OF ψ/σ

~ 0.86 ~ 0.12%

WORST CORRELATION SELECTION

	$z_{long} = \bar{z}$	$z_{long} = 2$
$z_{short} = 0.5$	0.844	0.869
$z_{short} = 0.6$	**0.803**	0.849
$z_{short} = 0.7$	0.751	0.822

	$z_{long} = \bar{z}$	$z_{long} = 2$
$z_{short} = 0.5$	0.7 %	0.6 %
$z_{short} = 0.6$	**1.0 %**	0.6 %
$z_{short} = 0.7$	1.5 %	0.8 %

OUR DATASET

- 4 YEARS OF OPERATION OF ICECUBE, FROM JUNE 2010 TO MAY 2014

  21 "SHOWER" NEUTRINOS WITH ENERGIES BETWEEN 60 AND 500 TEV

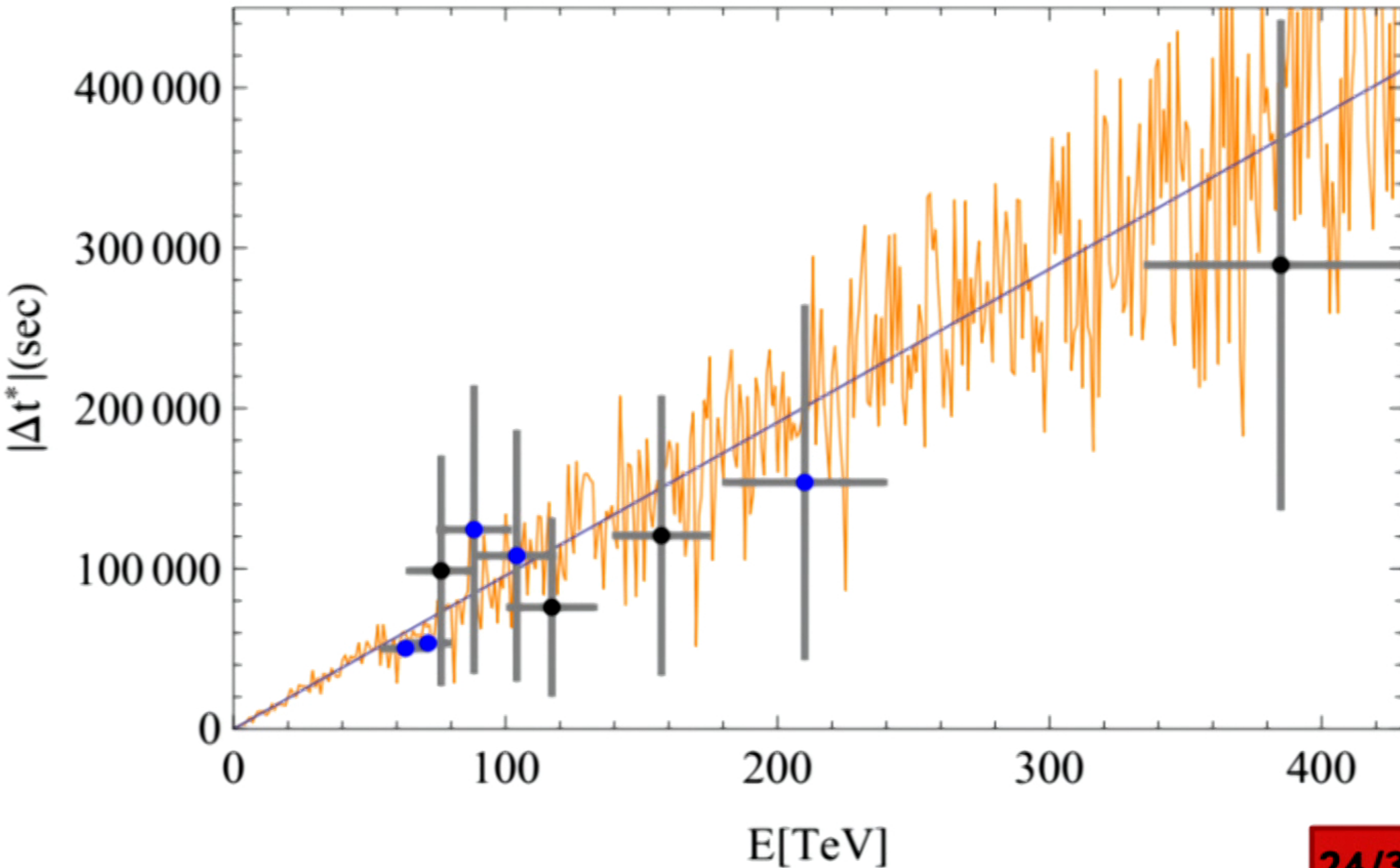
- WHOLE COLLECTION OF OBSERVED GRBS, FROM JUNE 2010 TO MAY 2014

  1162 GRBS
  -1049 LONG GRBS
  -143 SHORT GRBS

	E[TeV]	GRB	z	Δt^* [s]	
IC9	63.2	110503A	1.613	50227	*
IC19	71.5	111229A	1.3805	53512	*
IC42	76.3	131117A	4.042	5620	*
		131118A	1.497 *	-98694	
		131119A	?	-146475	
IC11	88.4	110531A	1.497 *	124338	*
IC12	104.1	110625B	1.497 *	108061	*
IC2	117.0	100604A	?	10372	*
		100605A	1.497 *	-75921	
		100606A	?	-135456	
IC40	157.3	130730A	1.497 *	-120641	*
IC26	210.0	120219A	1.497 *	153815	*
		120224B	?	-117619	
IC33	384.7	121023A	0.6 *	-289371	*

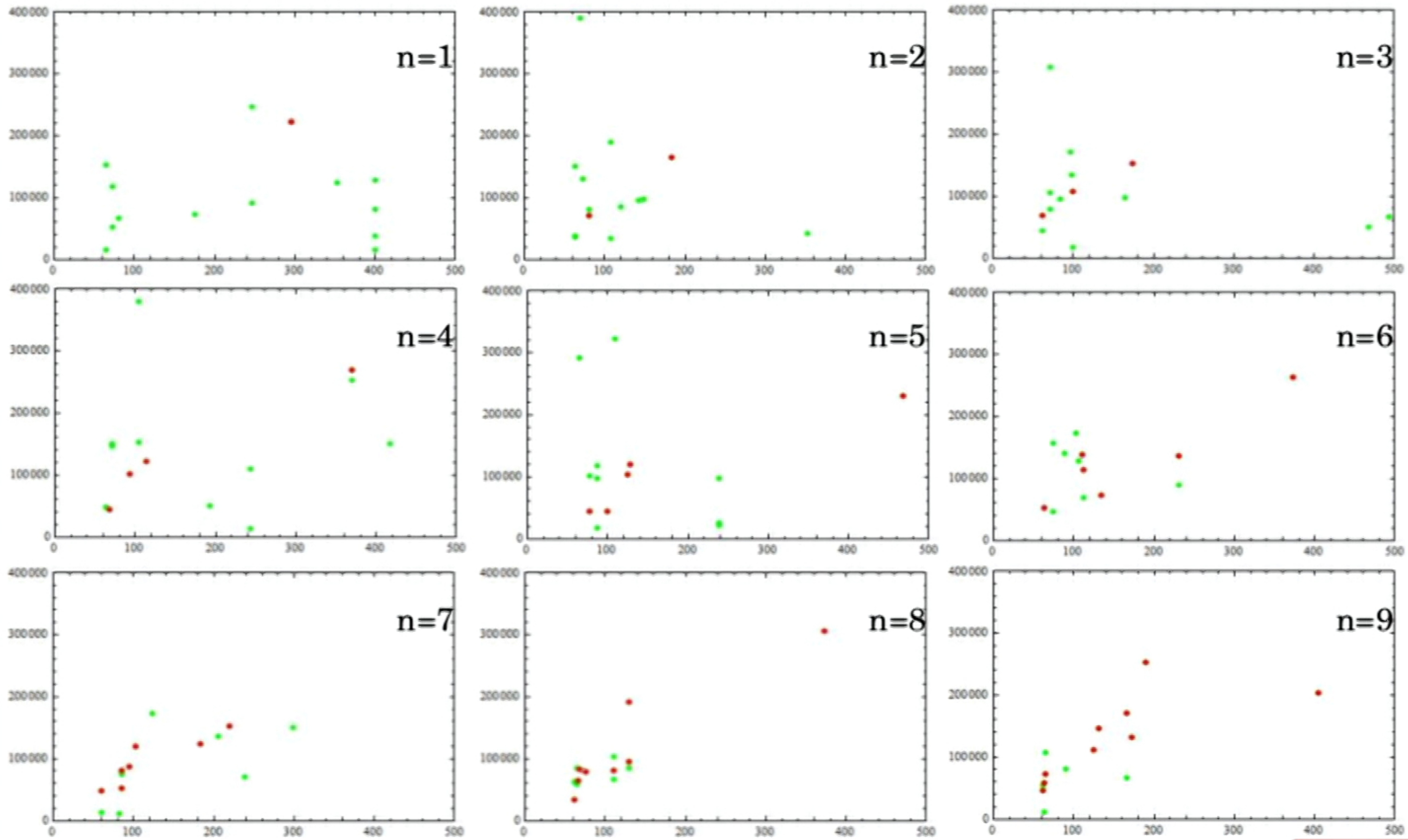
ESTIMATING THE MODEL'S PARAMETERS

$\eta_- = -\eta_+ \qquad \delta_- = \delta_+ \qquad \boxed{|\eta_+| = 23 \pm 2,\ \delta_+ = 4.7 \pm 1.5}$



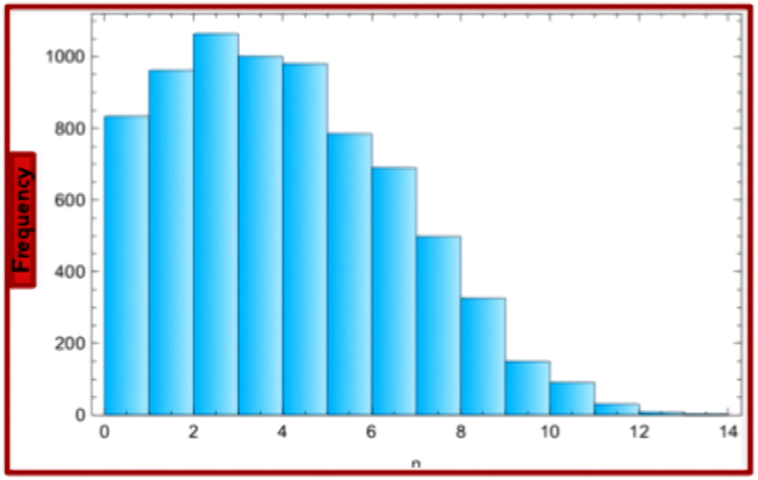
NOISE AND SIGNIFICANCE

n ⟶ MODEL 21-n ⟶ RANDOM



NOW LET'S DO IT 10.000 TIMES FOR EACH ONE

NOISE AND SIGNIFICANCE

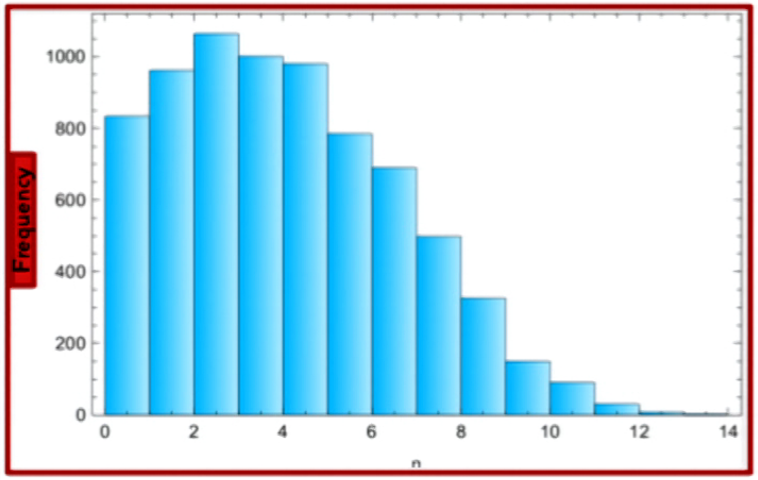


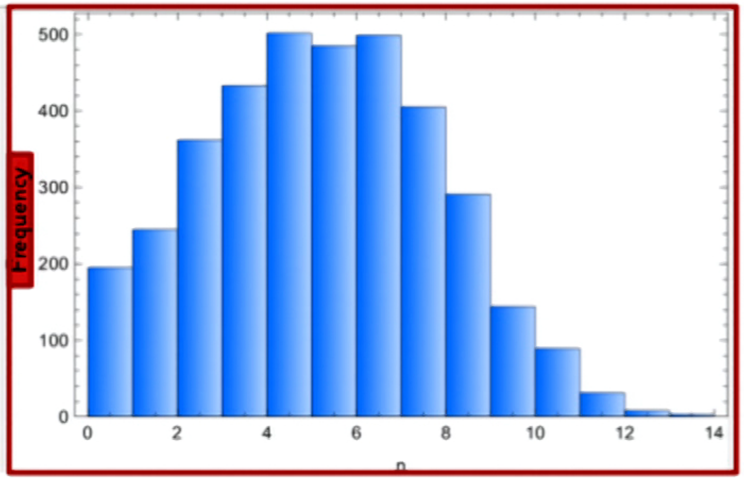
FREQUENCY OF A CONFIGURATION WITH
14 POINTS FROM 21 EVENTS, WITH

n POINTS FROM THE MODEL

N-n RANDOM NEUTRINO-GRB PAIR

NOISE AND SIGNIFICANCE





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N-n RANDOM NEUTRINO-GRB PAIR

WITH CORRELATION > 0.8

26/32

A CLOSER LOOK ON GRB PHOTONS

ENERGIES INVOLVED FOR GRB PHOTONS ARE IN THE RANGE OF 10 GeV

$$\longrightarrow \Delta t \propto \frac{E}{M_P} D(z) \sim 1\,s$$

$$\Delta t = \eta \frac{E}{M_P} D(z) \pm \delta \frac{E}{M_P} D(z)$$

IT IS SAFER FOR PHOTON ANALYSES TO FOCUS STRICTLY ON GRBS WITH MEASURED REDSHIFT AND WITH PHOTONS OF SUFFICIENTLY LARGE OBSERVED ENERGY

GRB	080916C	090510	090902B	090926A	100414A	130427A	160509A
redshift	4.35	0.903	1.822	2.106	1.368	0.34	1.17

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$$\boxed{\frac{\Delta t}{1+z} = \eta \frac{D(1)}{M_P} \frac{E^*}{1+z} \pm \delta \frac{D(1)}{M_P} \frac{E^*}{1+z} + t_{off}}$$

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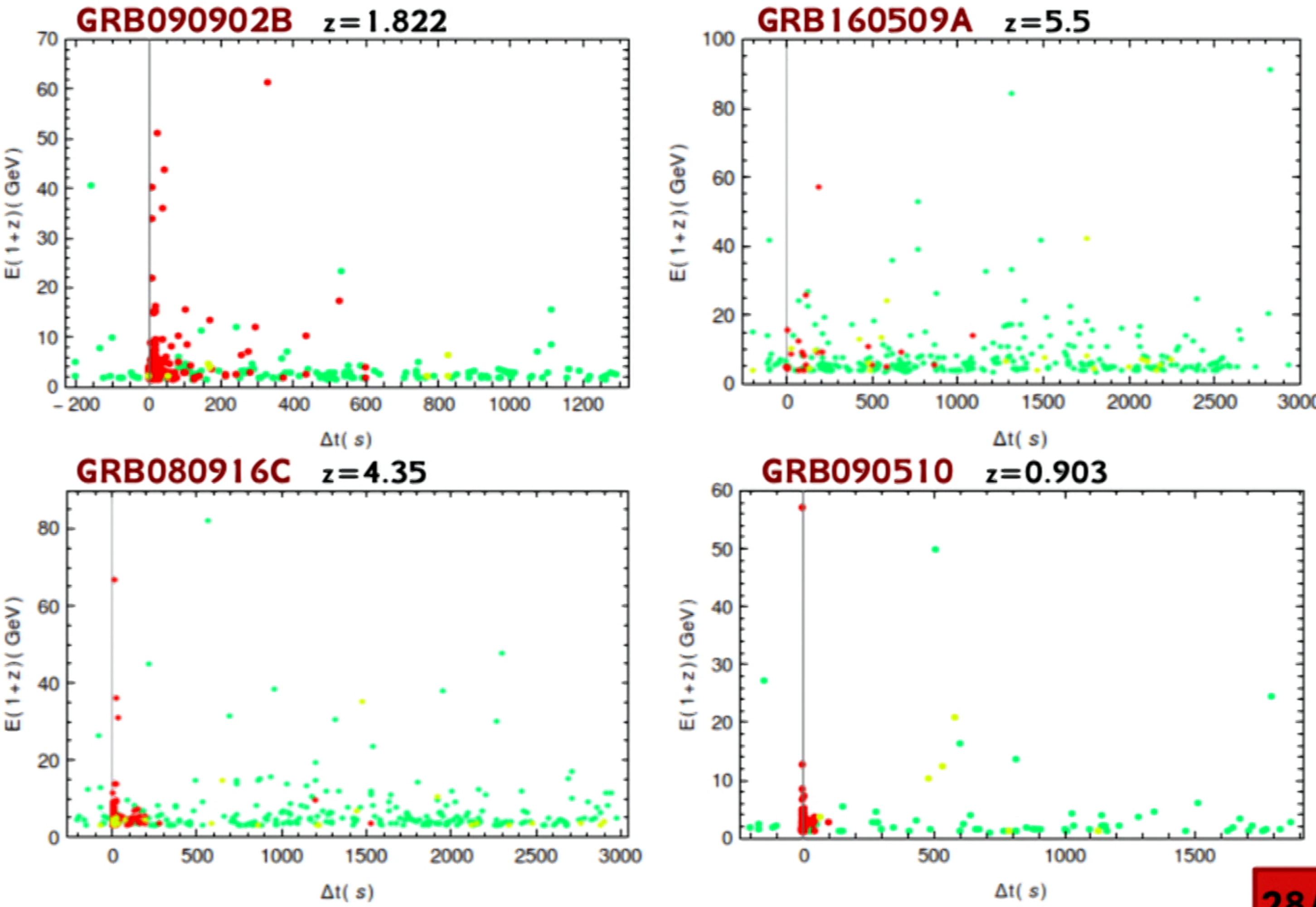
WHAT WE ARE DEALING WITH



28/32

ENERGY AND TIME SELECTION CRITERIA

WE FOCUS ON THE HIGHEST-ENERGY PHOTONS AMONG THOSE OBSERVED FOR GRBS BY THE FERMI TELESCOPE

$$\boxed{E_{em} = E_{obs}\,(1+z) > 40\,GeV}$$

WHEN EXPRESSED IN TERMS OF THE DIFFERENCE BETWEEN THE TIME OF OBSERVATION OF THE RELEVANT PHOTON AND THE TIME OF OBSERVATION OF THE FIRST GBM PEAK, OUR TIME SELECTION CRITERION TAKES THE FORM

$$\boxed{|\Delta t| \leq 10^{-16} D(z) + (1+z)\,20\,s}$$

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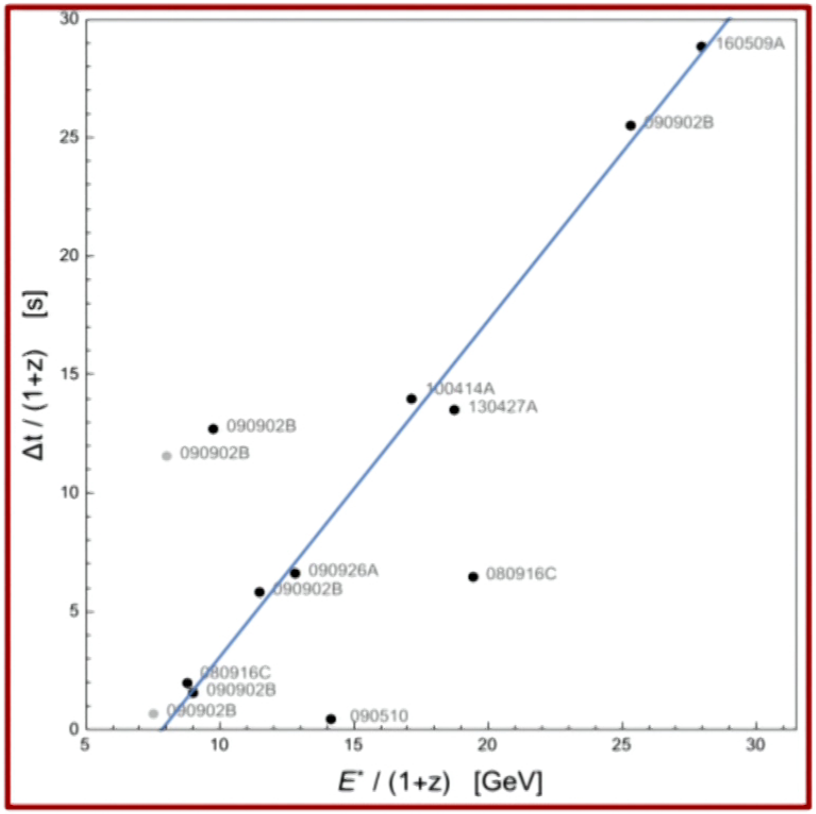
	$E_{\rm em}$[GeV]	$E_{\rm obs}$[GeV]	E^*[GeV]	Δt [s]	z	GRB
1	40.1	14.2	25.4	4.40	1.82	090902B
2	43.5	15.4	27.6	35.84	1.82	090902B
3	51.1	18.1	32.4	16.40	1.82	090902B
4	56.9	29.9	26.9	0.86	0.90	090510
5	60.5	19.5	40.0	20.51	2.11	090926A
6	66.5	12.4	47.1	10.56	4.35	080916C
7	70.6	29.8	40.7	33.08	1.37	100414A
8	103.3	77.1	25.2	18.10	0.34	130427A
9	112.5	39.9	71.5	71.98	1.82	090902B
10	112.6	51.9	60.7	62.59	1.17	160509A
11	146.7	27.4	104.1	34.53	4.35	080916C

29/32

RESULTS FOR GRB PHOTONS



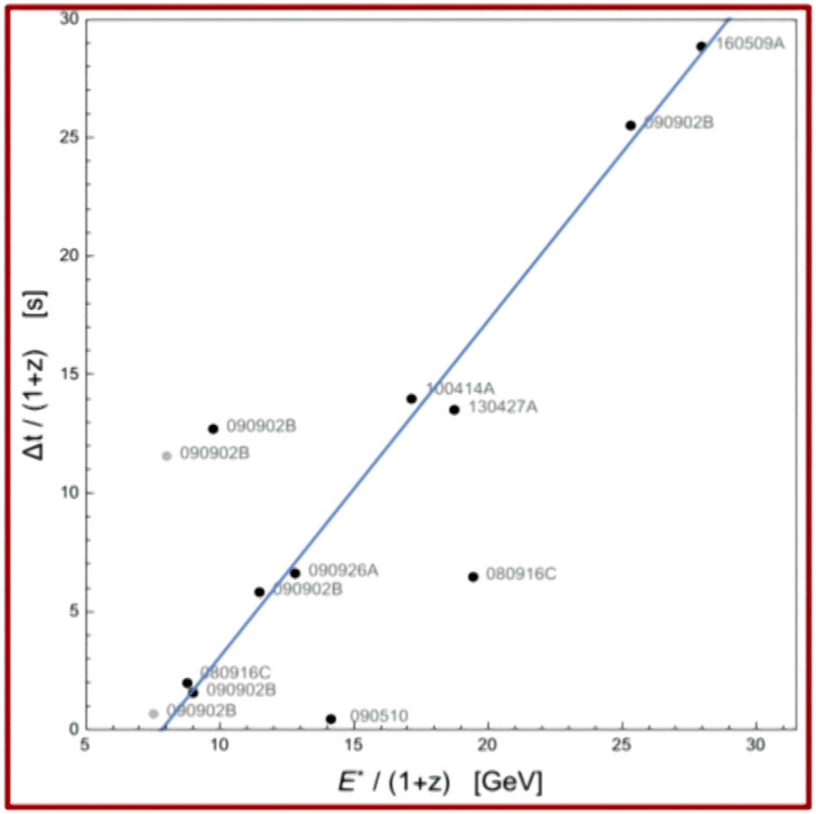
A RESULT SIMILAR TO THE ONE OF arXiv:1607.08043

$$\eta = 34 \pm 1 \qquad t_{off} = -11\,s \pm 1\,s$$

THE VALUE OF CORRELATION OBTAINED BY TAKING INTO ACCOUNT ALL 11 PHOTONS IS 0.845

30/32

RESULTS FOR GRB PHOTONS



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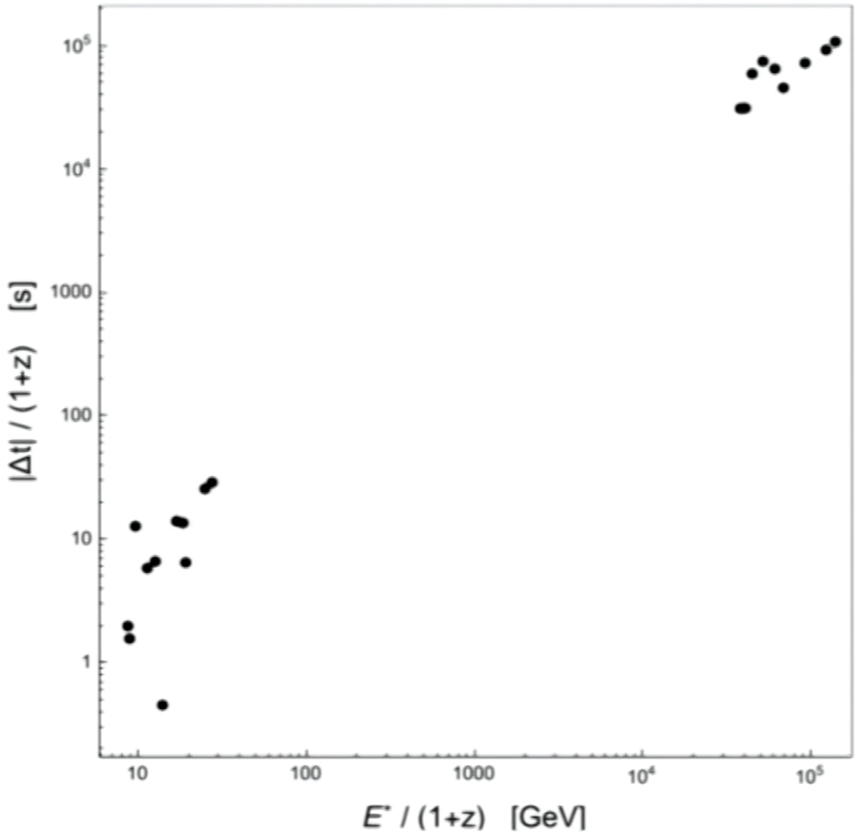
IF WE SHUFFLE 100.000 TIMES THE TIME DELAY OF EACH OF OUR 11 HIGH-ENERGY PHOTONS WITH RESPECT TO THE GBM PEAK OF THE RELEVANT GRB,
WE FIND THAT A VALUE OF CORRELATION FOR ALL 11 PHOTONS >0.845 IS OBTAINED ONLY IN 0.035% OF CASES

30/32

ICECUBE NEUTRINO AND GRB PHOTONS DATA



THIS COMPARISON SHOULD BE HANDLED WITH SOME CARE, SINCE SOME QUANTUM-SPACETIME MODELS PREDICT INDEPENDENT IN-VACUO DISPERSION PARAMETERS FOR DIFFERENT PARTICLES, AND ALSO A POSSIBLE DEPENDENCE OF THE EFFECTS ON POLARIZATION FOR PHOTONS AND ON HELICITY FOR NEUTRINOS

CONCLUSIONS

- **QUANTUM GRAVITY PHENOMENOLOGY, LIKE ANYTHING ELSE IN LIFE, SHOULD BE TAKEN *CUM GRANO SALIS***

- **DATA SELECTION: NO** tracks, **60TeV < E < 500TeV, ±3** days, **2σ** (not so selective this one...)

- **NEUTRINO FALSE ALARM PROBABILITY:** ~ **1%** for some **9** random points to reach our worst correlation ~ **0.8**

- **PARAMETERS OF THE MODEL:** compatible for photons and neutrini

- **NOISE** we payed our lage angular acceptance with some noise that we were able to quantify as ~ **1/3** of our dataset.

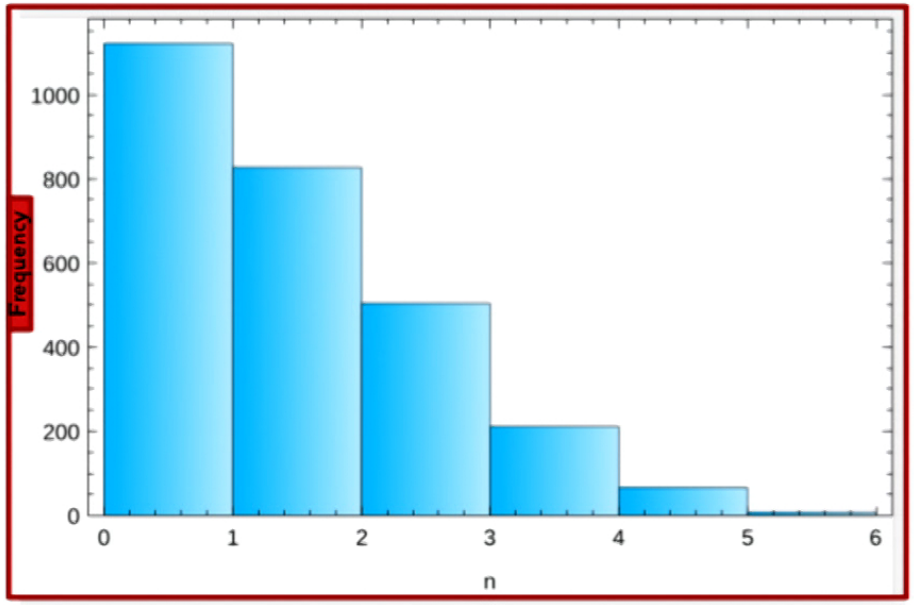
- It will be crucial to extend our analysis also to photons with emission energy below **40 GeV**

- **IT WILL BE ALSO CRUCIAL** a further understanding of quantum-spacetime models formalizing in-vacuo dispersion

WE NEED MORE DATA

ICECUBE DATA UPDATE?

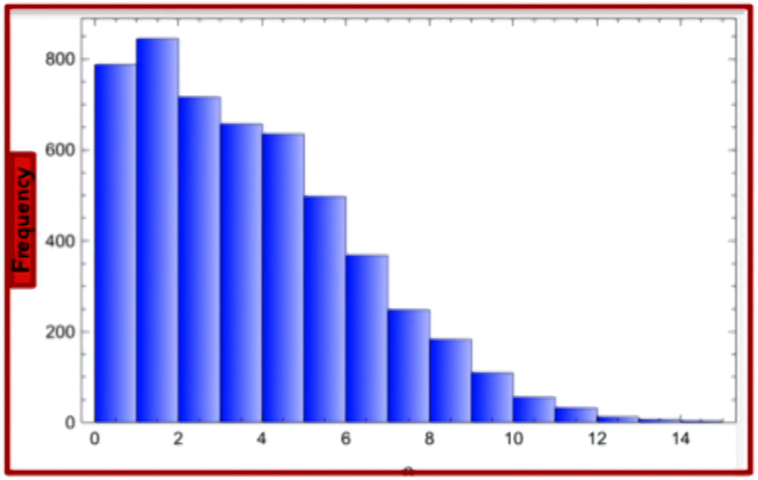
WE EXPECT TO HAVE 5 MORE POINTS OUT OF A 13 CANDIDATES DATASET

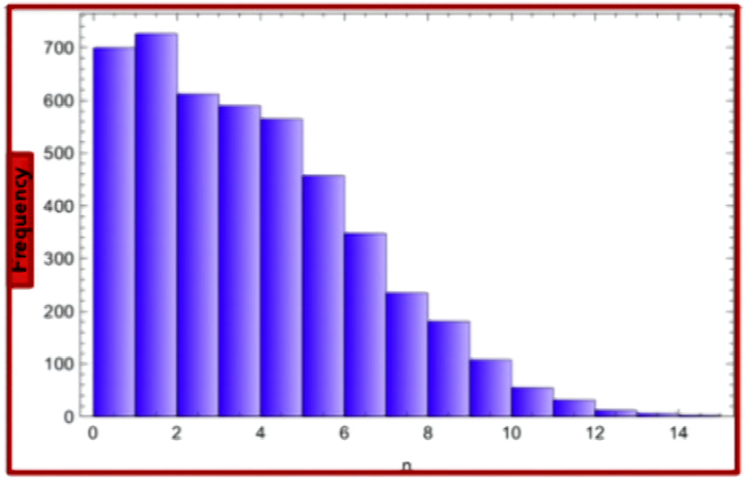


MOREOVER IN arXiv:1707.05168 A STUDY BETWEEN 40-200 TeV SHOWS THE POSSIBILITY OF A NON-ASTROPHYSICAL COMPONENT IN THE NEUTRINO FLUX POWER-LAW UNDER 150 TeV.
PROBABLY ONLY 3-4 OF OUR HIGH ENERGY NEUTRINI WERE ORIGINATED FROM AN ASTROPHYSICAL SOURCE

1/4

UPDATE: NOISE AND SIGNIFICANCE





FREQUENCY OF A CONFIGURATION WITH
19 POINTS FROM 34 EVENTS, WITH

n POINTS FROM THE MODEL

N-n RANDOM NEUTRINO-GRB PAIR

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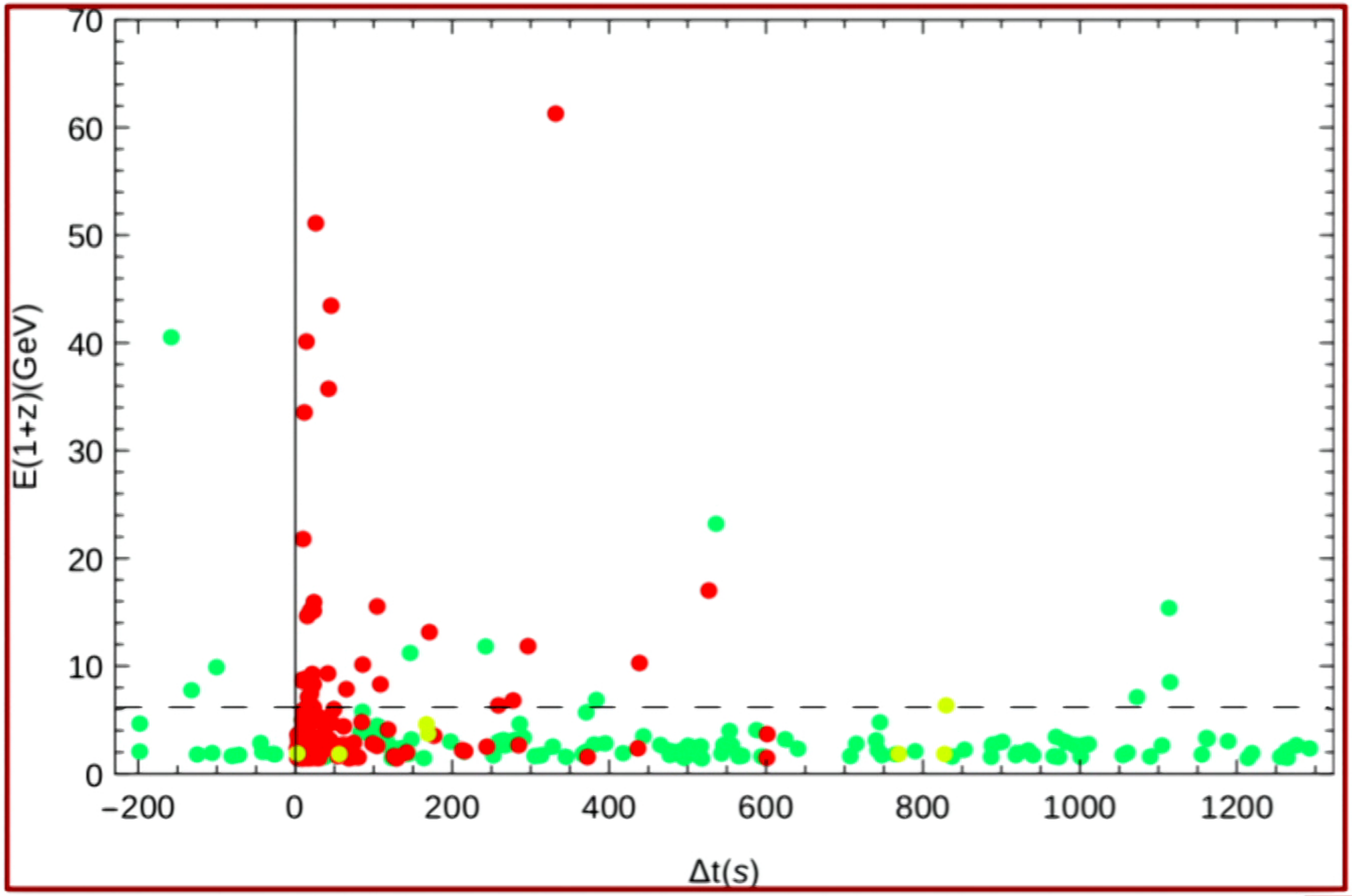
WITH CORRELATION > 0.4

2/4

NEW ANALYSIS ON GRB PHOTONS



GRB090902B

3/4

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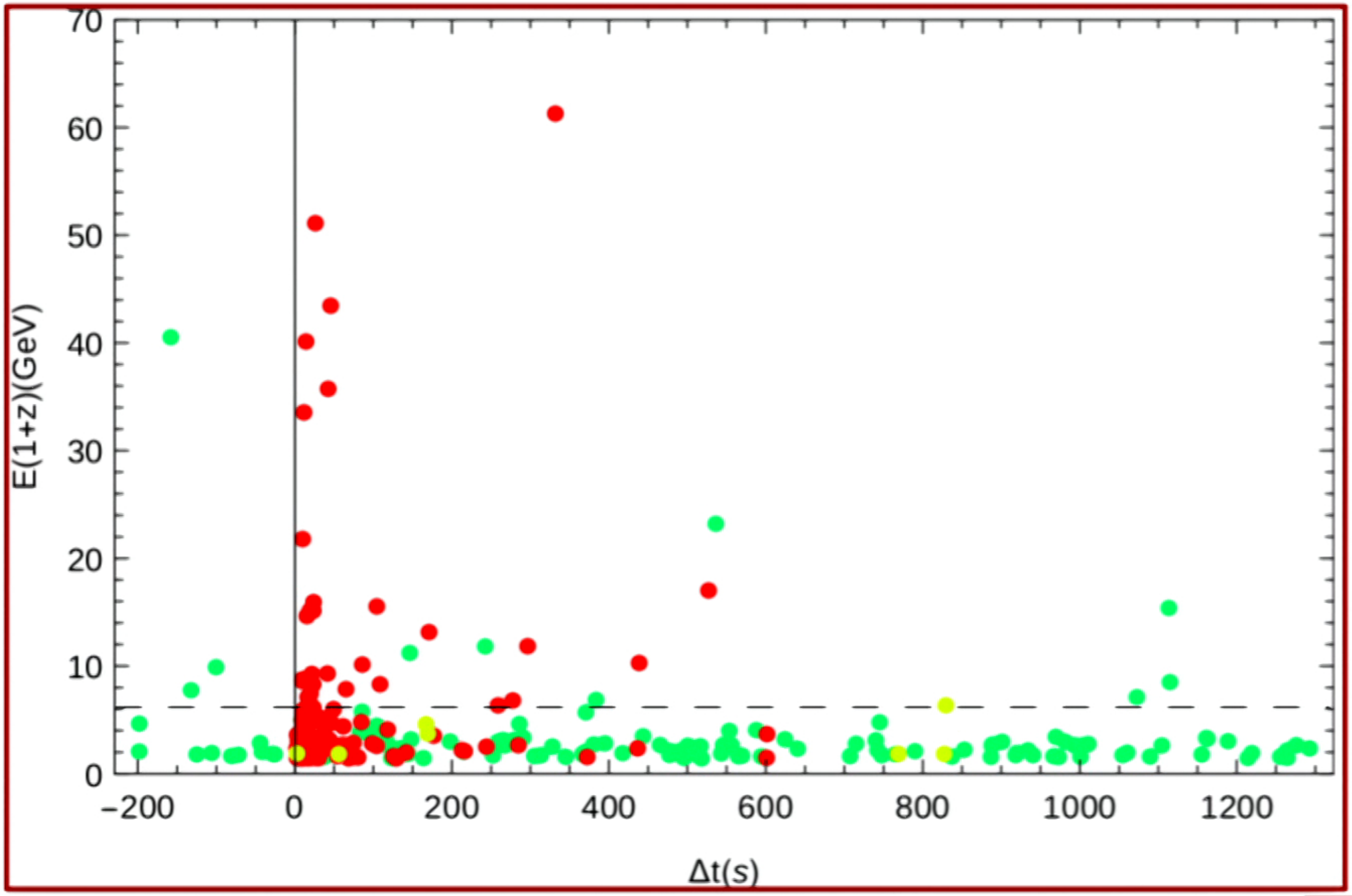

GRB090902B

3/4

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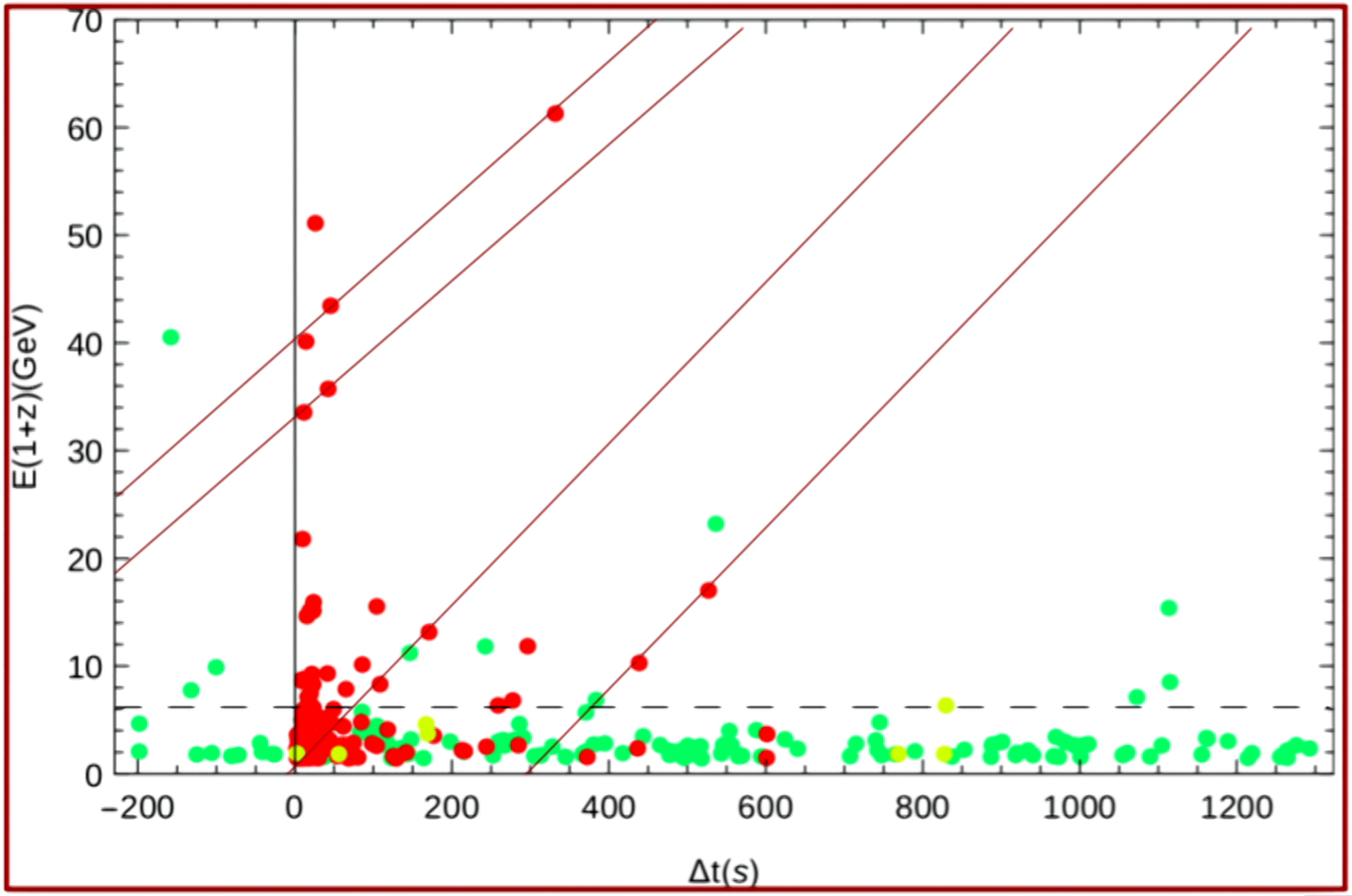

GRB090902B

3/4

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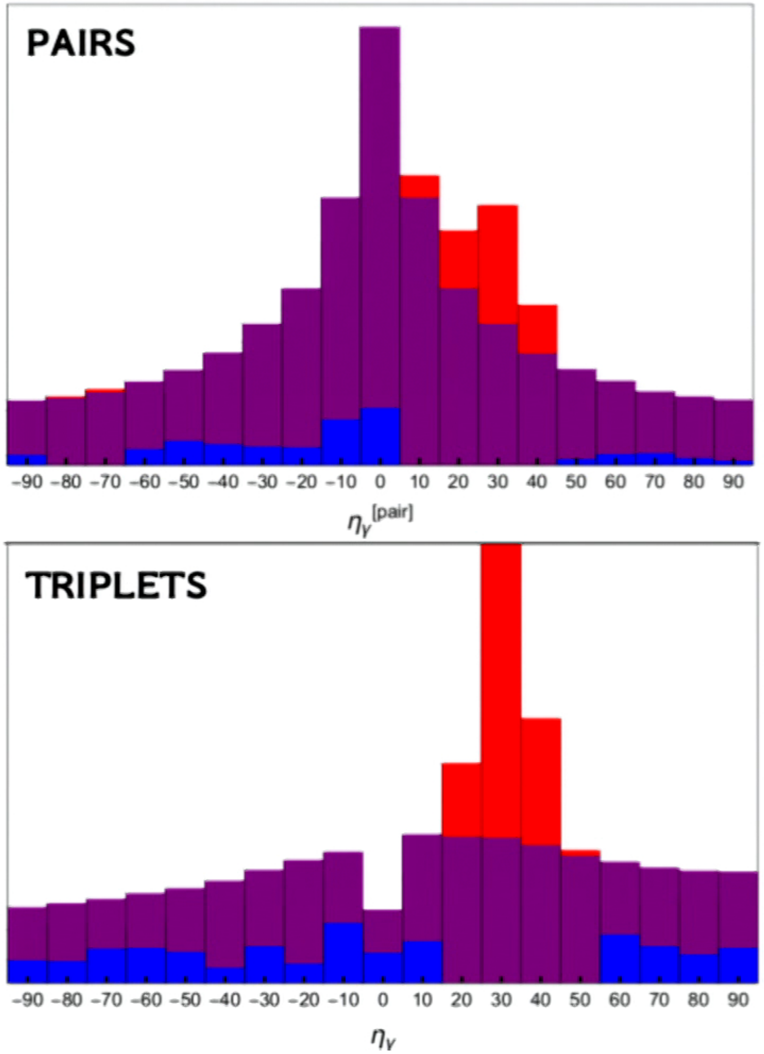

SEE arXiv:1707.02413

4/4

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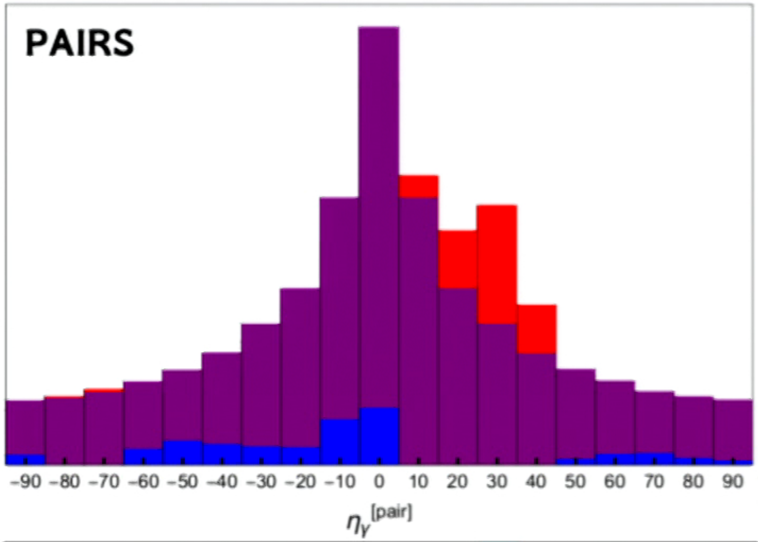
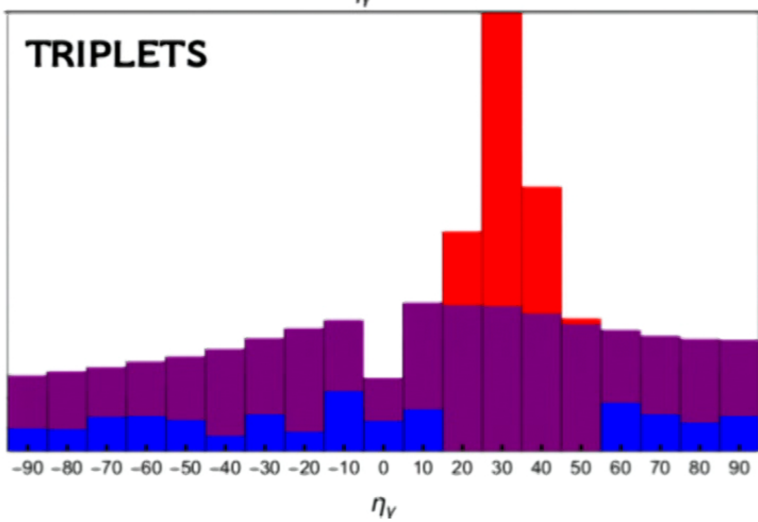
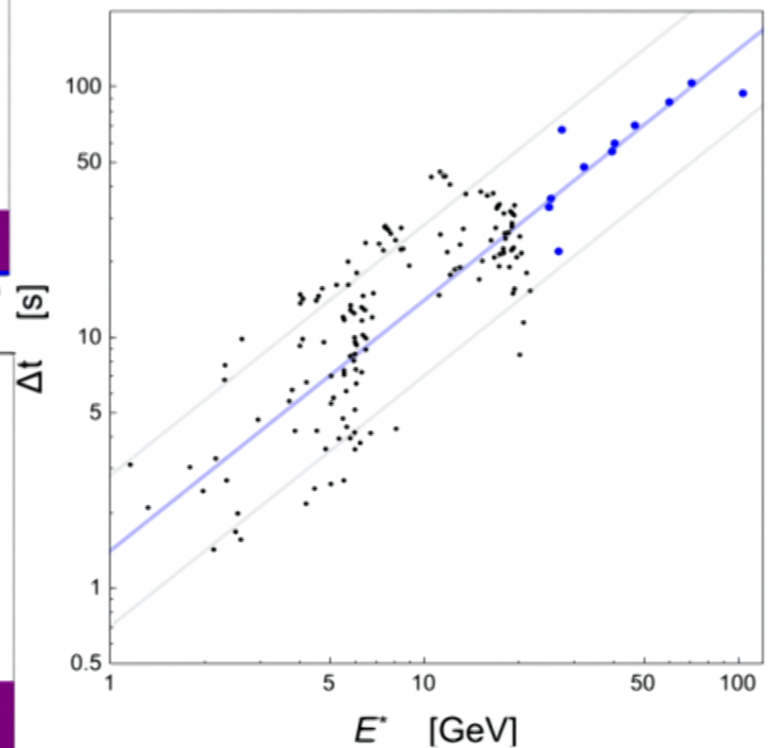




$$\Delta t_{pair} = \eta_\gamma^{[pair]} \frac{D(1)}{M_P} \Delta E^*_{pair}$$



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4/4

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32/32