# Spectral properties and HE behaviour of few bright and young Fermi PSRs

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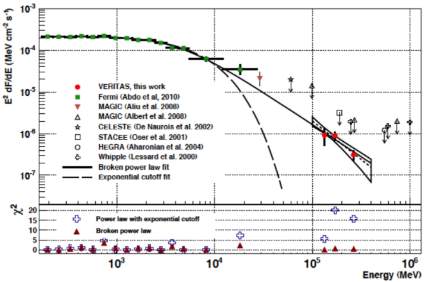
# Section 1

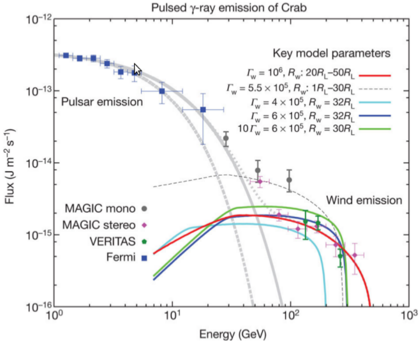
# Introdution

# Pulsed emission beyond TeV already observed for the Crab PSR

Pulsed emission has been observed by the MAGIC and VERITAS collaborations.

2 Hypotheses:




The VERITAS collaboration, Detection of Pulsed Gamma Rays Above 100 GeV from the Crab Pulsar(2011)

A.Aharonian, S.V.Bogovalov & D.Khangulian Abrupt acceleration of a 'cold' ultrarelativistic wind from the Crab pulsar(2012)

# List of brightest Fermi pulsars

| PSR | Assoc | Type[†] | Energy Flux[‡] ($10^{-11}$ erg cm$^{-2}$ s$^{-1}$) | $\dot{E}_{rot}/d^2$ ($10^{36}$ erg kpc$^{-2}$ s$^{-1}$) | $\Gamma$ | $E_{cutoff}$ (GeV) |
|---|---|---|---|---|---|---|
| J0835−4510 | Vela | r | 879.4 ± 5.4 | 85 | 1.57 ± 0.01 | 3.2 ± 0.1 |
| J0633+1746 | Geminga | g | 338.1 ± 3.5 | 1.3 | 1.08 ± 0.02 | 1.9 ± 0.05 |
| J0534+2200 | Crab | r | 130.6 ± 3.4 | 120 | 1.97 ± 0.02 | 5.8 ± 0.5 |
| J1709−4429 | B1706-44 | r | 124 ± 2.6 | 1 | 1.70 ± 0.04 | 4.9 ± 0.4 |
| J1809−2332 | Taz | g | 41.3 ± 1.6 | 0.13 | 1.52 ± 0.07 | 2.9 ± 0.3 |
| J1826−1256 | | g | 33.4 ± 1.8 | * | 1.49 ± 0.11 | 2.4 ± 0.3 |
| J1907+06 | Milagro[a] | g | 27.5 ± 1.6 | 0.31 | 1.84 ± 0.10 | 4.6 ± 1.0 |
| J1057−5226 | | r | 27.2 ± 0.98 | 0.013 | 1.06 ± 0.10 | 1.3 ± 0.1 |
| J1732−31 | | g | 24.2 ± 1.4 | * | 1.27 ± 0.14 | 2.2 ± 0.3 |
| J1418−6058 | Kooka | g | 23.5 ± 3.8 | * | 1.32 ± 0.24 | 1.9 ± 0.4 |
| J1741−2054 | | r(g) | 20.3 ± 2.0 | 0.15 | 12.8 ± 0.8 | 1.39 ± 0.17 |
| J1028−5819 | | r | 17.7 ± 1.4 | 0.11 | 1.25 ± 0.20 | 1.9 ± 0.5 |
| J1048−5832 | | r | 17.2 ± 1.3 | 0.23 | 1.31 ± 0.18 | 2.0 ± 0.4 |
| J1813−1246 | | g | 16.9 ± 1.3 | * | 1.83 ± 0.14 | 2.9 ± 0.8 |
| J1420−6048 | Kooka | r | 15.8 ± 3.5 | 0.18 | 1.73 ± 0.24 | 2.7 ± 1.0 |
| J1747−2958 | | r | 13.1 ± 1.7 | 0.4 | 1.11 ± 0.34 | 1.0 ± 0.2 |
| J1459−60 | | g | 10.56 ± 1.2 | * | 1.83 ± 0.24 | 2.7 ± 1.1 |
| J1833−1034 | G21.5−0.9 | r | 10.1 ± 1.4 | 1.8 | 2.24 ± 0.18 | 7.7 ± 4.8 |

Abdo, A. A. et al. 2010, ApJS, 187, Issue 2, 460-494

# Methodology

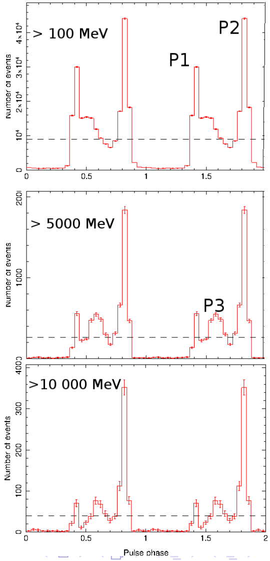
## Methodology

- Fermi data analysis of bright pulsars (6 are discussed here)
- Phase averaged + Phase-resolved spectra
- Test of different spectral shapes (PLEC, sub-PLEC, broken power-law)
- Choose the most likely shapes
- Use CTA (config E) sensitivity curves to evaluate expected signals

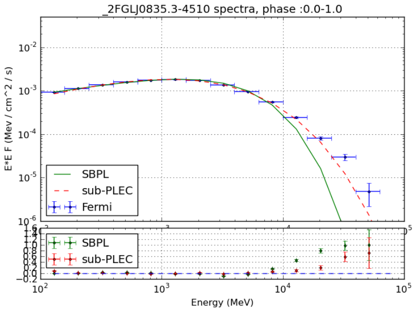
Ephemerides : Lucas Guillemot (Max Planck Bonn), Ryan Shanon ( ATNF) & David Smith (CENBG Bordeaux).

# Vela PSR

Vela



# Phase averaged spectrum of Vela




$$F(E) = \phi_0 \left(\frac{E}{E_0}\right)^a exp\left(-\left(\frac{E}{E_c}\right)^b\right)$$

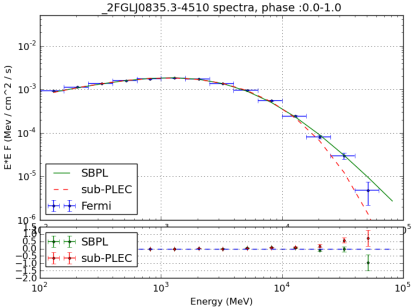
**best PLEC fit**

$\phi_0 =$ (2.41 +/- 0.11) $.10^{-9}$ $MeV.cm^{-2}.s^{-1}$
$a =$1.53 +/- 0.04
$E_0 =$ 1000 MeV
$E_c =$ 2934 +/- 26 MeV
$b = 1$

**best sub-PLEC fit**

$\phi_0 =$ (7.2 +/- 1.1) $.10^{-9}$ $MeV.cm^{-2}.s^{-1}$
$a =$1.16 +/- 0.04
$E_0 =$ 1000 MeV
$E_c =$ 521 +/- 124 MeV
$b =$ 0.54 +/- 0.02

# Phase averaged spectrum of Vela: SBPL fit

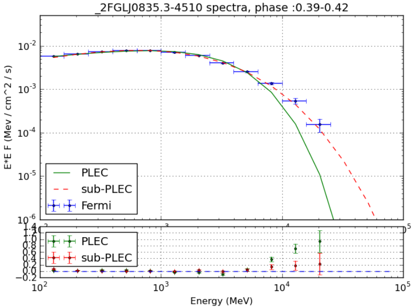



$$F(E) = \phi_0 \frac{E}{E_0}^{\gamma_1} \left(1 + \frac{E}{E_b}^{\frac{\gamma_1 - \gamma_2}{\beta}}\right)^{-\beta}$$

## best SBPL fit

$\phi_0 =$ (7.68 +/- 0.03) $.10^{-8}$ $MeV.cm^{-2}.s^{-1}$
$\gamma_1$ =-1.398 +/- 0.09
$E_0 = 100$
$\gamma_2$ = - 5.00 +/- 0.0001
$E_b$ =5514 +/- 62
$\beta$ =3.52 +/- 0.05

# Phase Resolved spectrum of Vela : P1



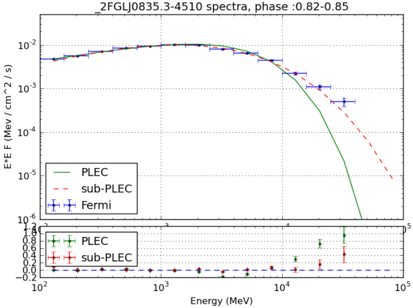

$$F(E) = \phi_0 \left(\frac{E}{E_0}\right)^a exp\left(-\left(\frac{E}{E_c}\right)^b\right)$$

## best sub-PLEC fit

$\phi_0 =$ (1.77 +/- 0.08) $.10^{-11}$ $MeV.cm^{-2}.s^{-1}$
$a =$01.20 +/- 0.01
$E_0 =$ 1000 MeV
$E_c =$ 206 +/- 13 MeV
$b =$ 0.47 +/- 0.01

Rejection Coefficient for the PLEC shape : $> 10\sigma$

# Phase Resolved spectrum of Vela : P2




$$F(E) = \phi_0 \left(\frac{E}{E_0}\right)^a exp\left(-\left(\frac{E}{E_c}\right)^b\right)$$

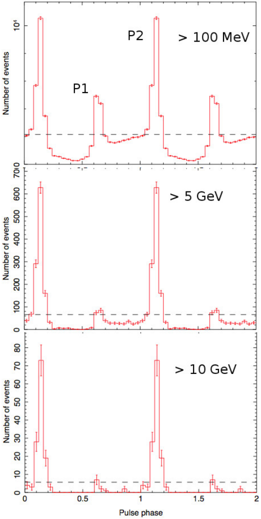
## best sub-PLEC fit

$\phi_0$ = (1.69 +/- 0.07) $.10^{-11}$ $MeV.cm^{-2}.s^{-1}$
$a$ =1.07 +/- 0.01
$E_0$ = 1000 MeV
$E_c$ = 275 +/- 18 MeV
$b$ = 0.456 +/- 0.005

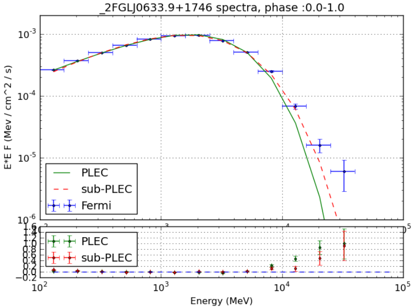
Rejection Coefficient for the PLEC shape : $> 10\sigma$

# Geminga

Geminga



# Phase averaged spectrum of Geminga




$$F(E) = \phi_0 \left(\frac{E}{E_0}\right)^a exp\left(-\left(\frac{E}{E_c}\right)^b\right)$$

**best PLEC fit**

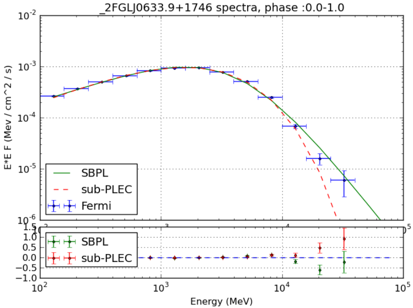
$\phi_0 = (1.36 \text{ +/- } 0.01)\ .10^{-9}\ MeV.cm^{-2}.s^{-1}$
$a = 1.204 \text{ +/- } 0.007$
$E_0 = 1000$ MeV
$E_c = 2117 \text{ +/- } 26$ MeV
$b = 1$

**best sub-PLEC fit**

$\phi_0 = (2.285 \text{ +/- } 0.003)\ .10^{-9}\ MeV.cm^{-2}.s^{-1}$
$a = 1.002 \text{ +/- } 0.001$
$E_0 = 1000$ MeV
$E_c = 1035 \text{ +/- } 1$ MeV
$b = 0.741 \text{ +/- } 0.001$

Rejection Coefficient for the PLEC shape : $\sim 5\sigma$

# Phase averaged spectrum of Geminga : SBPL fit



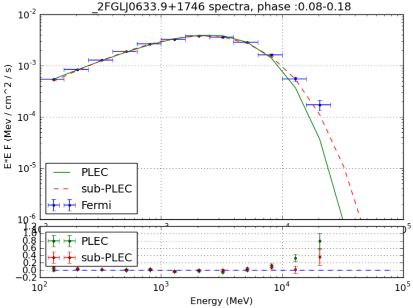

$$F(E) = \phi_0 \frac{E}{E_0}^{\gamma_1} \left(1 + \frac{E}{E_b}^{\frac{\gamma_1 - \gamma_2}{\beta}}\right)^{-\beta}$$

**best SBPL fit**

$\phi_0 =$ (1.23 +/- 0.05) $.10^{-9}$
$\gamma_1$ =-1.23 +/- 0.02
$E_0 = 1000$
$\gamma_2$ = - 5.05 +/- 0.1
$E_b$ =3969 +/- 94
$\beta$ =2.63 +/- 0.08

Rejection Coefficient for the SBPL shape : $\sim 4.2\sigma$

# Phase resolved spectra : P2




$$F(E) = \phi_0 \left(\frac{E}{E_0}\right)^a exp\left(-\left(\frac{E}{E_c}\right)^b\right)$$

## best PLEC fit

$\phi_0 =$ (0.4290 +/- 0.005) $.10^{-9}$ $MeV.cm^{-2}.s^{-1}$
$a =$1.01 +/- 0.01
$E_0 =$ 1000 MeV
$E_c =$ 2420+/- 46 MeV
$b = 1$

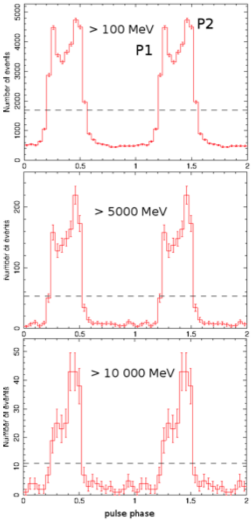
## best sub-PLEC fit

$\phi_0 =$ (0.8 +/- 0.1) $.10^{-9}$ $MeV.cm^{-2}.s^{-1}$
$a =$ 0.73 +/- 0.05
$E_0 =$ 1000 MeV
$E_c =$ 925 +/- 205 MeV
$b =$ 0.69 +/- 0.04

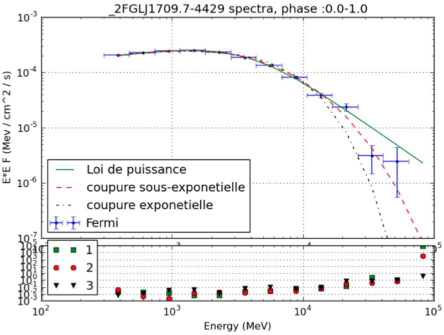
Rejection Coefficient for the PLEC shape : $\sim 5\sigma$

# B1706-44 (PSRJ1709-4429)

B1706-44 (PSRJ1709-4429)



# Phase averaged spectrum of B1706-44




$$F(E) = \phi_0 \left(\frac{E}{E_0}\right)^a exp\left(-\left(\frac{E}{E_c}\right)^b\right)$$

**best PLEC fit**

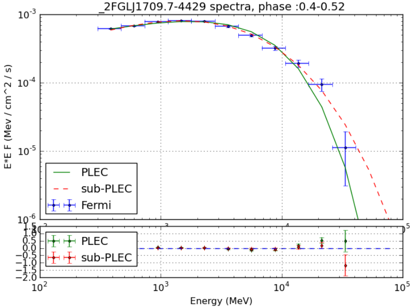
$\phi_0 =$ (3.86+/- 0.2) $.10^{-9}$ $MeV.cm^{-2}.s^{-1}$
$a =$-1.71 +/- 0.01
$E_0 =$ 218.5 +/- 6 MeV
$E_c =$ 4499 +/- 156 MeV
$b = 1$

**best sub-PLEC fit**

$\phi_0 =$ (1.0 +/- 0.2) $.10^{-9}$ $MeV.cm^{-2}.s^{-1}$
$a =$1.18 +/- 0.02
$E_0 =$ 1000 MeV
$E_c =$ 452 +/- 11 MeV
$b =$ 0.50 +/- 0.004

Rejection Coefficient for the PLEC shape : $\sim 3\sigma$

# Phase Resolved spectrum of B1706-44 : P2




$$F(E) = \phi_0 \left(\frac{E}{E_0}\right)^a exp\left(-\left(\frac{E}{E_c}\right)^b\right)$$

**best PLEC fit**

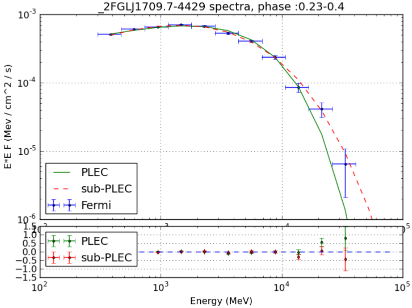
$\phi_0 = (1.37$+/- $0.02)\ .10^{-10}\ MeV.cm^{-2}.s^{-1}$
$a =$1.59 +/- 0.02
$E_0 = 1000$ MeV
$E_c = 3921$+/- 183 MeV
$b = 1$

**best sub-PLEC fit**

$\phi_0 = (4.9$ +/- $3)\ .10^{-10}\ MeV.cm^{-2}.s^{-1}$
$a =$1.1 +/- 0.2
$E_0 = 1000$ MeV
$E_c = 456$ +/- 27 MeV
$b = 0.52$ +/- 0.09

Rejection Coefficient for the PLEC shape : $\sim 3\sigma$

# Phase Resolved spectrum of B1706-44 : shoulder




$$F(E) = \phi_0 \left(\frac{E}{E_0}\right)^a exp\left(-\left(\frac{E}{E_c}\right)^b\right)$$

**best PLEC fit**

$\phi_0 =$ (1.06+/- 0.02) $.10^{-10}$ $MeV.cm^{-2}.s^{-1}$
$a =$1.65 +/- 0.02
$E_0 =$ 1000 MeV
$E_c =$ 4831 +/- 265 MeV
$b = 1$

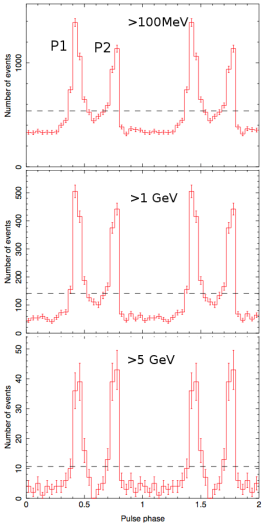
**best sub-PLEC fit**

$\phi_0 =$ (3.9 +/- 2.6) $.10^{-10}$ $MeV.cm^{-2}.s^{-1}$
$a =$1.1+/- 0.1
$E_0 =$ 1000 MeV
$E_c =$ 452 +/- 477 MeV
$b =$ 0.49 +/- 0.08

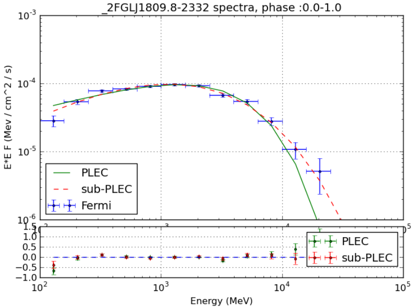
Rejection Coefficient for the PLEC shape : $\sim 3\sigma$

# TAZ (PSRJ1809-2332)

TAZ (PSRJ1809-2332)



# Phase averaged spectrum of TAZ




$$F(E) = \phi_0 \left(\frac{E}{E_0}\right)^a exp\left(-\left(\frac{E}{E_c}\right)^b\right)$$

## best PLEC fit

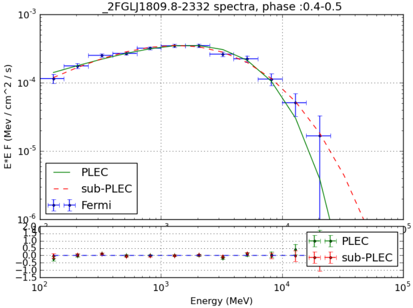
$\phi_0 =$ (1.2 +/- 0.01) $.10^{-10}$ $MeV.cm^{-2}.s^{-1}$
$a =$1.52 +/- 0.03
$E_0 =$ 1000 MeV
$E_c =$ 2874 +/- 196 MeV
$b = 1$

## best sub-PLEC fit

$\phi_0 =$ (12.73 +/- 0.05) $.10^{-10}$ $MeV.cm^{-2}.s^{-1}$
$a =$0.816 +/- 0.004
$E_0 =$ 1000 MeV
$E_c =$ 107 +/- 0.3 MeV
$b =$ 0.43191 +/- 0.0004

Rejection Coefficient for the PLEC shape : $\sim 3\sigma$

# Phase Resolved spectrum of TAZ : P1




$$F(E) = \phi_0 \left(\frac{E}{E_0}\right)^a exp\left(-\left(\frac{E}{E_c}\right)^b\right)$$

**best PLEC fit**

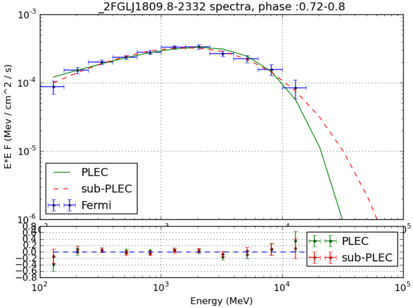
$\phi_0 = (4.4+/- 0.2)\ .10^{-11}\ MeV.cm^{-2}.s^{-1}$
$a =$1.44 +/- 0.04
$E_0 =$ 1000 MeV
$E_c =$ 2926 +/- 282 MeV
$b = 1$

**best sub-PLEC fit**

$\phi_0 = (4.6\ +/-\ 0.1)\ .10^{-10}\ MeV.cm^{-2}.s^{-1}$
$a =$0.7 +/- 0.07
$E_0 =$ 1000 MeV
$E_c =$ 102 +/- 27 MeV
$b =$ 0.42 +/- 0.01

Rejection Coefficient for the PLEC shape :
$\sim 2.3\sigma$

# Phase Resolved spectrum of TAZ : P2




$$F(E) = \phi_0 \left(\frac{E}{E_0}\right)^a exp\left(-\left(\frac{E}{E_c}\right)^b\right)$$

**best PLEC fit**

$\phi_0 =$ (3.0+/- 0.1) $.10^{-11}$ $MeV.cm^{-2}.s^{-1}$
$a =$1.45 +/- 0.05
$E_0 =$ 1000 MeV
$E_c =$ 3696 +/- 408 MeV
$b = 1$

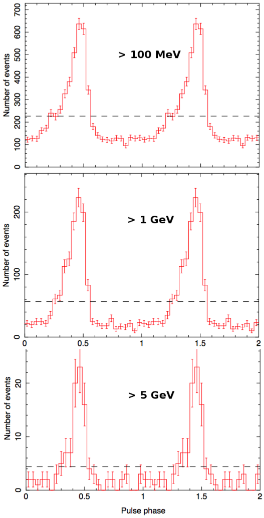
**best sub-PLEC fit**

$\phi_0 =$ (2.8 +/- 0.7) $.10^{-10}$ $MeV.cm^{-2}.s^{-1}$
$a =$0.76 +/- 0.08
$E_0 =$ 1000 MeV
$E_c =$ 108 +/- 35 MeV
$b =$ 0.41 +/- 0.02

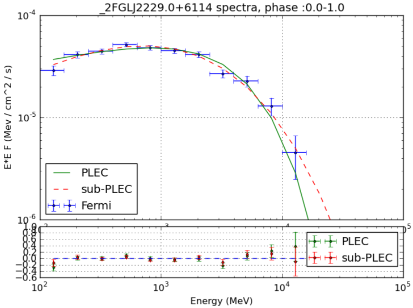
Rejection Coefficient for the PLEC shape : $\sim 1.7\sigma$

# PSRJ2229+6114

PSRJ2229+6114



# Phase averaged spectrum of PSRJ2229+6114




$$F(E) = \phi_0 \left(\frac{E}{E_0}\right)^a exp\left(-\left(\frac{E}{E_c}\right)^b\right)$$

## best PLEC fit

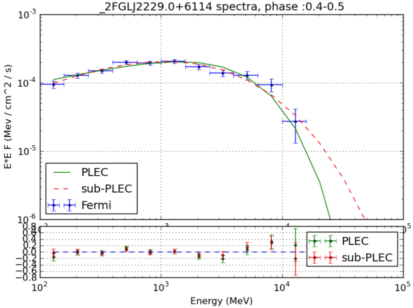
$\phi_0$ = (6.2 +/- 0.3) $.10^{-11}$ $MeV.cm^{-2}.s^{-1}$
$a$ =1.7 +/- 0.04
$E_0$ = 1000 MeV
$E_c$ = 3218 +/- 353 MeV
$b = 1$

## best sub-PLEC fit

$\phi_0$ = (58.6+/- 0.5) $.10^{-11}$ $MeV.cm^{-2}.s^{-1}$
$a$ =1.112 +/- 0.007
$E_0$ = 1000 MeV
$E_c$ = 102 +/- 0.7 MeV
$b$ = 0.408 +/- 0.001

Rejection Coefficient for the PLEC shape : $\sim 3\sigma$

# Phase resolved spectrum of J2229+6114




$$F(E) = \phi_0 \left(\frac{E}{E_0}\right)^a exp\left(-\left(\frac{E}{E_c}\right)^b\right)$$

## best PLEC fit

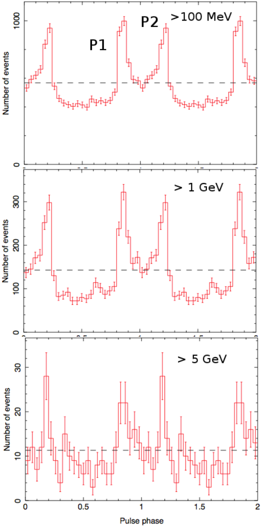
$\phi_0 =$ (2.5 +/- 0.1) $.10^{-11}$ $MeV.cm^{-2}.s^{-1}$
$a =$1.6 +/- 0.05
$E_0 =$ 1000 MeV
$E_c =$ 3435 +/- 440 MeV
$b = 1$

## best sub-PLEC fit

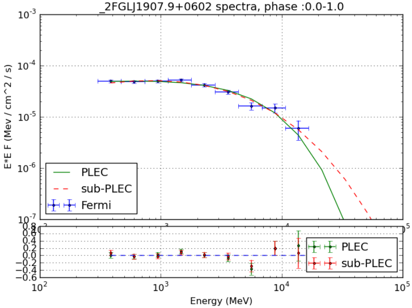
$\phi_0 =$ (24+/- 5) $.10^{-11}$ $MeV.cm^{-2}.s^{-1}$
$a =$0.95 +/- 0.03
$E_0 =$ 1000 MeV
$E_c =$ 100 +/- 36 MeV
$b =$ 0.40 +/- 0.02

Rejection Coefficient for the PLEC shape : $\sim 2\sigma$

# PSRJ1907+0602



# Phase averaged spectrum of PSRJ1907+0602




$$F(E) = \phi_0 \left(\frac{E}{E_0}\right)^a exp\left(-\left(\frac{E}{E_c}\right)^b\right)$$

**best PLEC fit**

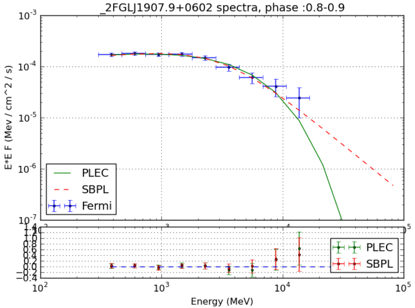
$\phi_0 = $ (5.8 +/- 0.2) $.10^{-11}$ $MeV.cm^{-2}.s^{-1}$
$a =$1.86 +/- 0.06
$E_0 =$ 1000 MeV
$E_c =$ 4347 +/- 540 MeV
$b = 1$

**best sub-PLEC fit**

$\phi_0 = $ (58 +/- 6) $.10^{-11}$ $MeV.cm^{-2}.s^{-1}$
$a =$1.06 +/- 0.08
$E_0 =$ 1000 MeV
$E_c =$ 105 +/- 11 MeV
$b =$ 0.41 +/- 0.01

Hypotheses are compatible

# Phase resolved spectrum of PSRJ1907+0602




**best PLEC fit**

$\phi_0$ = (2.2 +/- 0.2) $.10^{-11}$ $MeV.cm^{-2}.s^{-1}$
$a$ =1.86 +/- 0.3
$E_0$ = 1000 MeV
$E_c$ = 3357 +/- 735 MeV
$b = 1$

**best SBPL fit**

$\phi_0$ = (1.23 +/- 0.05) $.10^{-10}$
$\gamma_1$ =-1.8 +/- 0.3
$E_0$ = 1000
$\gamma_2$ = -3.6 +/- 0.3
$E_b$ =2499 +/- 15
$\beta$ =0.6 +/- 0.8

Hypotheses are compatible

## Best Sub-PLEC fits

| PSR | $\phi_0$ $(MeV.cm^{-2}.s^{-1})$ | $a$ | $E_0$ (MeV) | $E_c$ (MeV) | $b$ | Flux > 30 GeV $(cm^{-2}s^{-1})$ | % of CrbPSR >30 GeV | Flux > 100 GeV $(cm^{-2}s^{-1})$ |
|---|---|---|---|---|---|---|---|---|
| Vela | $7.2.10^{-9}$ | -1.16 | 1000 | 521 | 0.54 | 1.02e-10 | 73 | 1.60e-15 |
| Geminga | $2.3.10^{-9}$ | -1.0 | 1000 | 1035 | 0.74 | 5.11e-17 | 3.6e-5 | 1.12e-23 |
| B1706-44 | $1.0.10^{-9}$ | -1.2 | 1000 | 452 | 0.5 | 2.30e-11 | 16 | 1.04e-14 |
| TAZ | $1.2.10^{-9}$ | -0.8 | 1000 | 107 | 0.43 | 4.48e-14 | 0.03 | 1.12e-16 |
| PSRJ2229+6114 | $5.8.10^{-10}$ | -1.2 | 1000 | 102 | 0.40 | 1.93e-13 | 0.1 | 1.47e-15 |
| PSRJ1907+0602 | $5.8.10^{-10}$ | -1.1 | 1000 | 102 | 0.41 | 1.25e-13 | 0.09 | 6.95e-16 |

## Best SBPL fits

| | $\phi_0$ $(MeV.cm^{-2}.s^{-1})$ | $\gamma_1$ | $E_0$ (MeV) | $\gamma_2$ (MeV) | $E_b$ | $\beta$ $(cm^{-2}s^{-1})$ | Flux > 30 GeV >30 GeV | % of CrbPSR $(cm^{-2}s^{-1})$ | Flux > 100 GeV |
|---|---|---|---|---|---|---|---|---|---|
| Vela | $7.7.10^{-8}$ | -1.4 | 100 | -5.0 | 5514 | 3.52 | 2.81e-10 | 200 | 3.11e-12 |
| Geminga | $1.23.10^{-9}$ | -1.23 | 1000 | -5.0 | 3969 | 2.63 | 5.56e-11 | 40 | 3.20e-13 |
| B1706-44 | $6.9.10-9$ | -1.73 | 104.8 | -3.65 | 3550 | 1 | 7.86e-11 | 56 | 2.14e-12 |

# Prospects of detection with CTA (Config E)

## Vela

SBPL : $< 1h$
Sub-PLEC : $\sim 3h$

## geminga

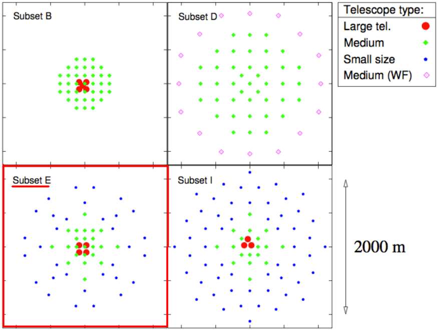
SBPL : $\sim 2h$
Sub-PLEC : No detection

## B1706-44

SBPL : $\sim 2h$
Sub-PLEC : $\sim 20h$

## PSRJ1907+0602

SBPL : $\sim 30h$
Sub-PLEC : no detection



# Section 3

## A closer look on the sub-exponential cutoff shape

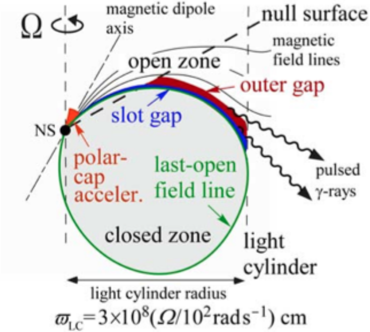
# A closer look on the sub-exponential cutoff shape

## Problem?

Presently favored models, were the HE emission is from curvature radiation of particles inside the magnetosphere (slot & outer Gap ) predict a spectral shape with an exponential Cut-off.

*We observe harder spectrum for the young and bright PSR presented in this work*

b<1 significantly!



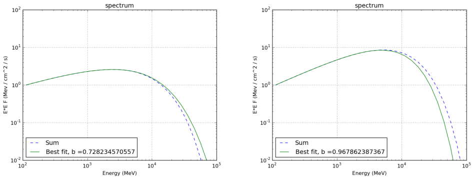
# A closer look on the sub-exponential cutoff shape

## usually evoked hypothesis (for Phase averaged spectra)

The sub-exponential shape is the result of a sum of multiple power laws each with a simple exponential cut-off but different $E_{cut}$.

## But...

- The spectrum derived for a very short phase interval shows still a sub-exponential shape, sometimes even harder than the phase averaged spectrum.
- Summing multiple power laws with simple exponential cut-off and different $E_{cut}$ leads indeed to a sub-exponential cut-off, but softer than the observed pulsar spectra (b >0.7).




1st sum :

$$\sum_{E_c=0}^{10000} \left(\frac{E}{E_0}\right)^{1.7} exp\left(-\left(\frac{E}{E_c}\right)\right)$$

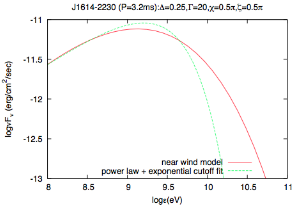
2nd sum :

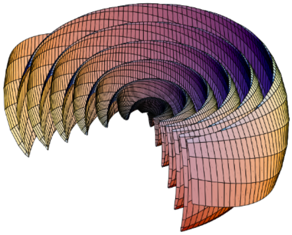
$$\sum_{E_c=0}^{10000} \left(\frac{E}{E_0}\right)^{rand[-1,-2]} exp\left(-\left(\frac{E}{E_c}\right)\right)$$

# A closer look on the sub-exponential cutoff shape

## Other possible explanations

- Peculiar particle energy distributions
- More than 1 component (IC, secondary particles)
- Others models
  - The Striped Wind model, where the emission region is outside the light cylinder (e.g the work of Jérôme Pétri)
  - I. Arka & G.Dubus predict for the near wind emission a power law with a sub-exponential cut-off (b = 0.35)
    (Pulsed high energy $\gamma$rays from thermal populations in the current sheets of pulsar winds A&A 2012 )
- ...



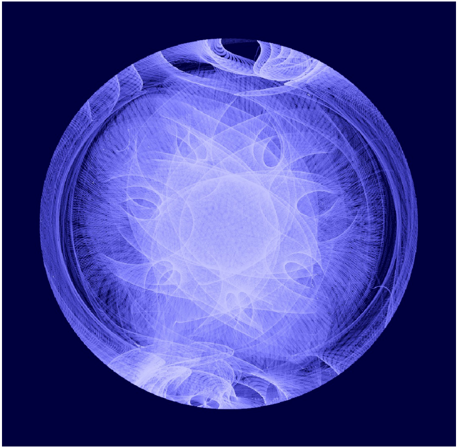



# Conclusions

- All investigated PSRs seem to exhibit a sub-exponential cutoff shape, both for phase averaged and resolved spectra
- Prospects for ground detection of pulsars are not exiting if the sub-exponential shape is really at play.
  - 2 only detectable PSRs
    - Vela
    - B1706-44
- Things get better if there are broken power laws instead
  - Few detectable PRS
    - Vela
    - Geminga
    - B1706-44
    - PSRJ1907+0602

## Perspectives

- 4 out of 6 pulsars were investigated using only 2 years of data : more statistics could help clarifying the spectra shapes.
- HESS II is online since july 2012 : southern hemisphere PSRs will be investigated soon.
- An improved analysis will be made using phase resolved spectra and H-test for signal predictions.



Thank you

# annex

| PSR | $\phi_0$ ($MeV.cm^{-2}.s^{-1}$) | $a$ | $E_0$ (MeV) | $E_c$ (MeV) | $b$ |
|---|---|---|---|---|---|
| Vela | $2.41.10^{-9}$ | -1.53 | 1000 | 2934 | 1 |
| Y | 3 | 4 | 5 | 6 | s |
| Z | 5 | 6 | 7 | 8 | s |