Preliminary
Planck Results on Dark Matter Annihilation

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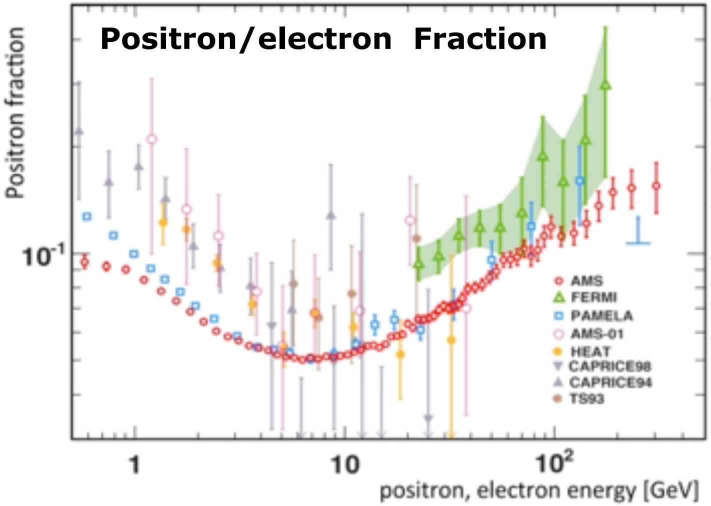
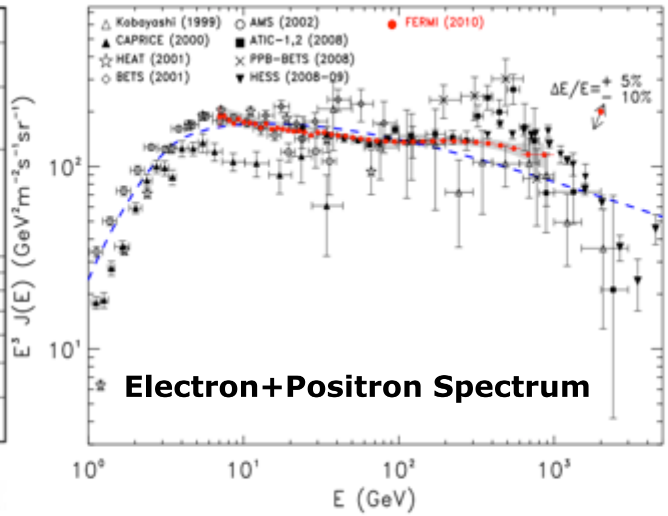
on behalf of the Planck Collaboration

Dark Matter Searches

- **Collider searches**: LHC.
- **Direct detection:** CoGeNT, DAMA/LIBRA, CRESST-II, CDMSII, XENON, LUX, PICASSO, COUPP ….
- **Indirect detection**
  - High energy photons: Fermi-LAT, HESS….
  - Electrons/positrons: PAMELA,AMS02, ATIC, Fermi-LAT, HESS...
  - Antiprotons: PAMELA, AMS02...
  - Neutrinos: ANTARES, IceCube...
  - CMB, 21 cm, BBN etc..

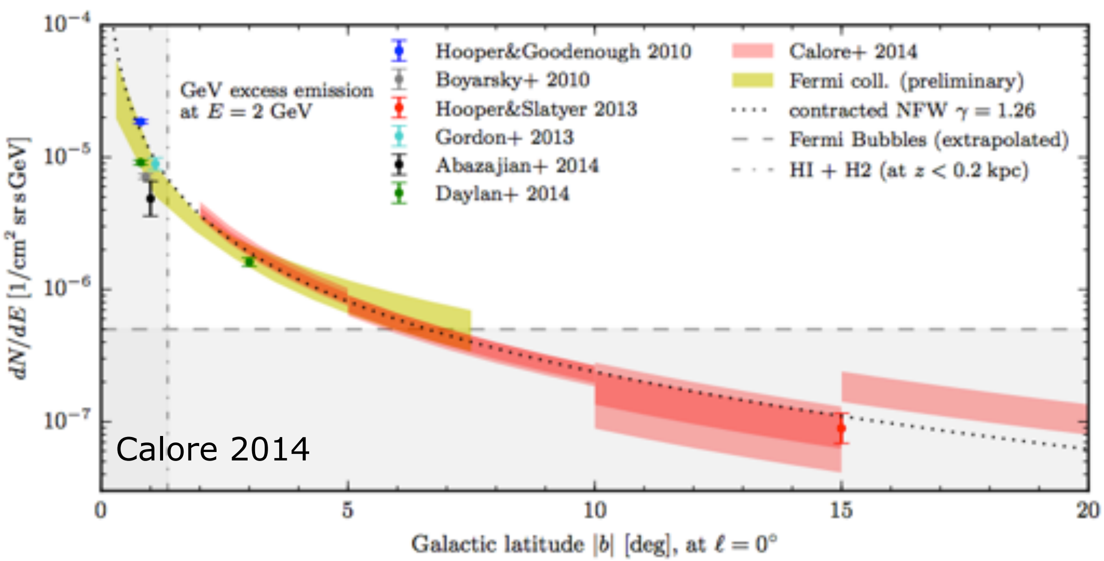
Recent anomalies





Cosmic rays excesses in PAMELA/FERMI/AMS-02

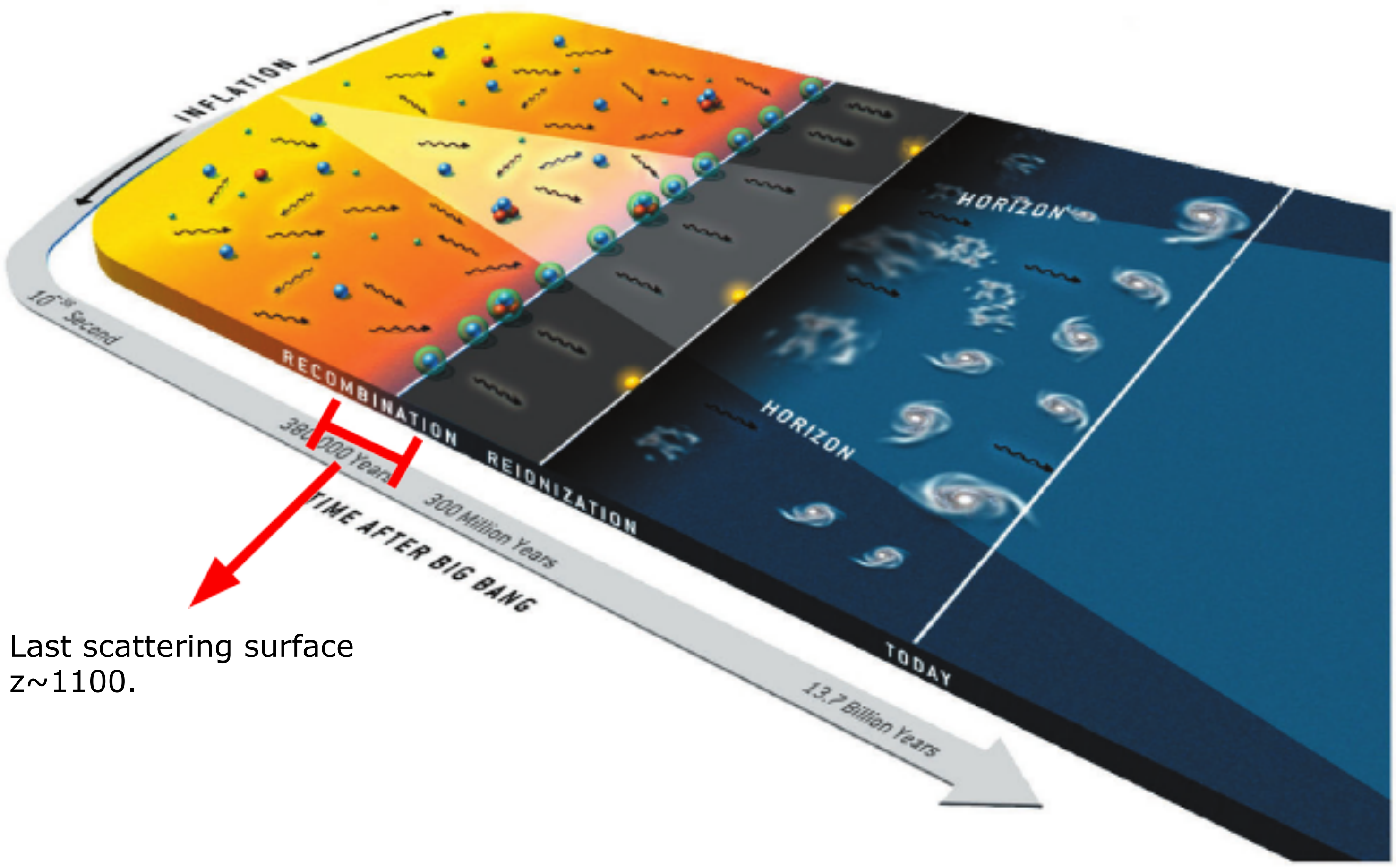
- Leptonic ann.chan.,
- Mass~ TeV,
- Large cross-section required (~10^{-23}cm^3/s).
- Need broken power law in electrons.



Fermi Galactic Center excess

- Many ann.chan. allowed.
- Mass ~few tens GeV,
- ~Thermal relic cross section (~10^{-26}cm^3/s)

The CMB as a probe of DM annihilation



Last scattering surface
z~1100.

Hu & White (2004); artist: B. Christie/SciAm; available at http://background.uchicago.edu

DM annihilation at the epoch of recombination

$$\frac{dE}{dt} = \rho_c^2 c^2 \Omega_{DM}^2 (1+z)^6 f(z) \frac{<\sigma v>}{m_\chi}$$

Chen & Kamionkowski 2004,Padmanabhan & Finkbeiner 2005

DM annihilation at the epoch of recombination

p_{ann}

$$\frac{dE}{dt} = \rho_c^2 c^2 \Omega_{DM}^2 (1+z)^6 f(z) \frac{<\sigma v>}{m_\chi}$$

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f(z) is the fraction of overall annihilation energy absorbed by the medium.

In the following, we will assume f(z) constant with redshift, f(z)~f_{eff}.

(Galli 2009,2011, Slatyer 2009,Finkbeiner2012)

DM annihilation at the epoch of recombination

$$\frac{dE}{dt} = \rho_c^2 c^2 \Omega_{DM}^2 (1+z)^6 \underbrace{f_{eff} \frac{<\sigma v>}{m_\chi}}_{p_{ann}}$$

p_{ann}

$$\chi_i \frac{dE}{dt} \qquad \chi_\alpha \frac{dE}{dt} \qquad \chi_h \frac{dE}{dt}$$

IONIZATIONS LYMAN-α HEATING

χ are the fractions of absorbed energy going into heating, ionization and excitation of the medium.

Shull and Van Steenberg 1989,
Chen & Kamionkowski 2004
Valdes 2009, Galli 2014

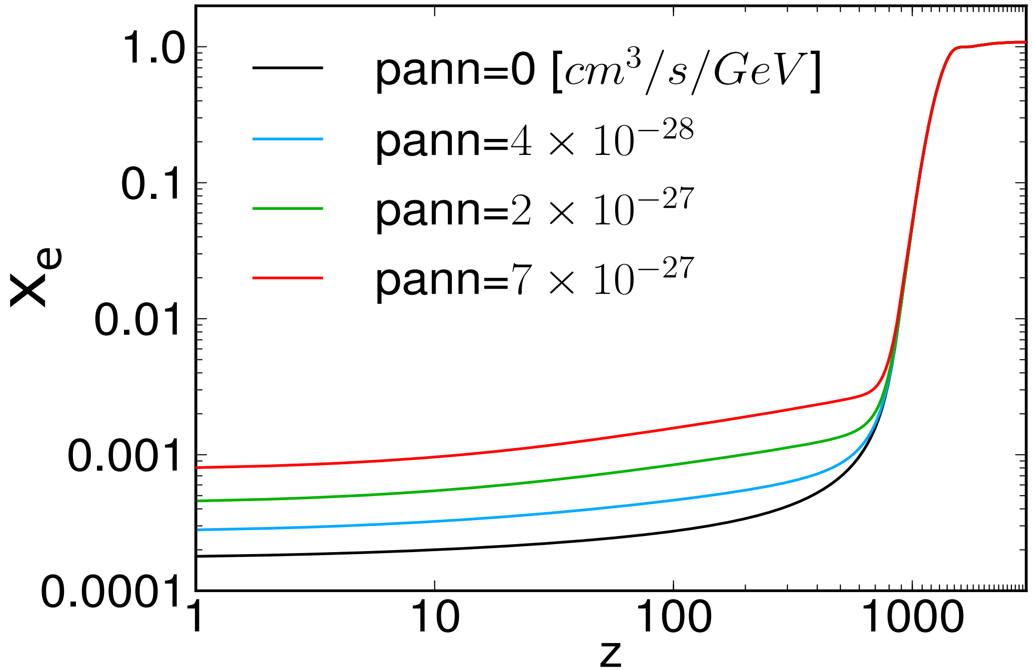
f(z) is the fraction of overall annihilation energy absorbed by the medium.

In the following, we will assume f(z) constant with redshift, $f(z) \sim f_{eff}$.

(Galli 2009,2011, Slatyer 2009,Finkbeiner2012)

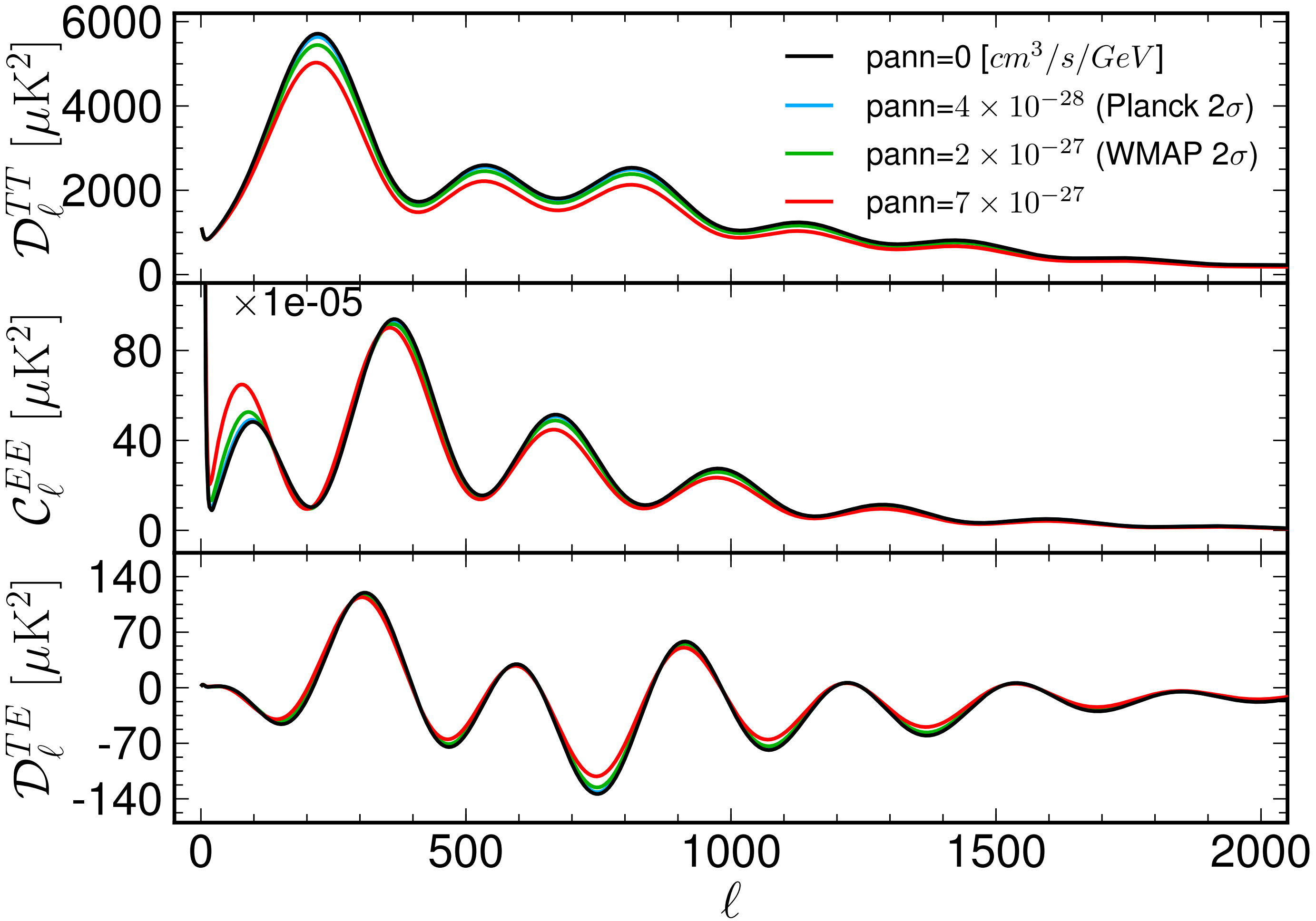
DM annihilation at the epoch of recombination

$$\frac{dE}{dt} = \rho_c^2 c^2 \Omega_{DM}^2 (1+z)^6 \underbrace{f_{eff} \frac{<\sigma v>}{m_\chi}}_{p_{ann}}$$



The injected energy ionizes, excites and heats the medium. This affects the evolution of the free electron fraction.

DM annihilation and CMB power spectra



DM annihilation:

- Suppresses amplitude (very degenerate with other parameters).
- Enhances polarization at large scales (l<~300).

$$p_{ann} = f_{eff}\frac{<\sigma v>}{m_\chi}$$

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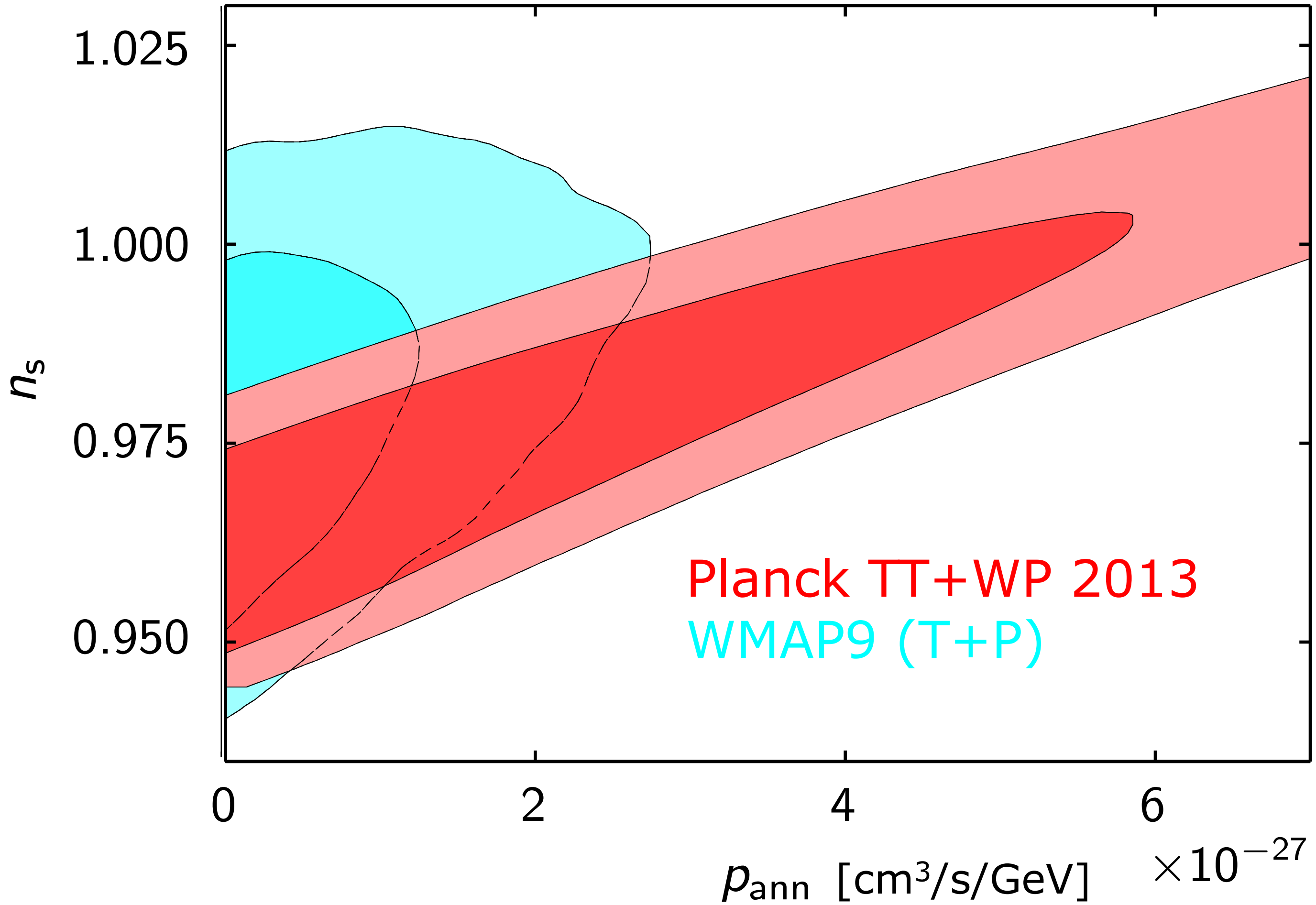
Previous Constraints

- Chen & Kamionkowski 2004 (decay)
- Padmanabhan & Finkbeiner 2005;
- Zhang et al. 2006 (WMAP3+others, constant f)
- Galli et al. 2009 (WMAP5+others, constant f)
- Kim & Naselsky (WMAP5+others, constant f)
- Galli et al 2011 (Future constraints, constant f)
- Galli et al. 2011 (WMAP7+ACT, const. f, f(z) for ee, mm chann.)
- Huetsi et al. 2011 (WMAP7, empirical parametrization of f)
- Natarajan 2012 (WMAP7+SPT+other, f for bbar)
- Finkbeiner, SG, et al. (Principal components approach for f)
- Giesen et al. 2012 (WMAP7+SPT, f constant and variable)
- Lopez-Honorez, L. et al 2013 (WMAP9+ACT2013/SPT2013.)
- Planck collaboration 2013 (Planck data)
- Madhavacheril 2013 (WMAP+Planck data)
- Diamanti et al. 2014 (Planck, WMAP9, SPT and ACT, as well as Lyman−α, p-wave/ decay)

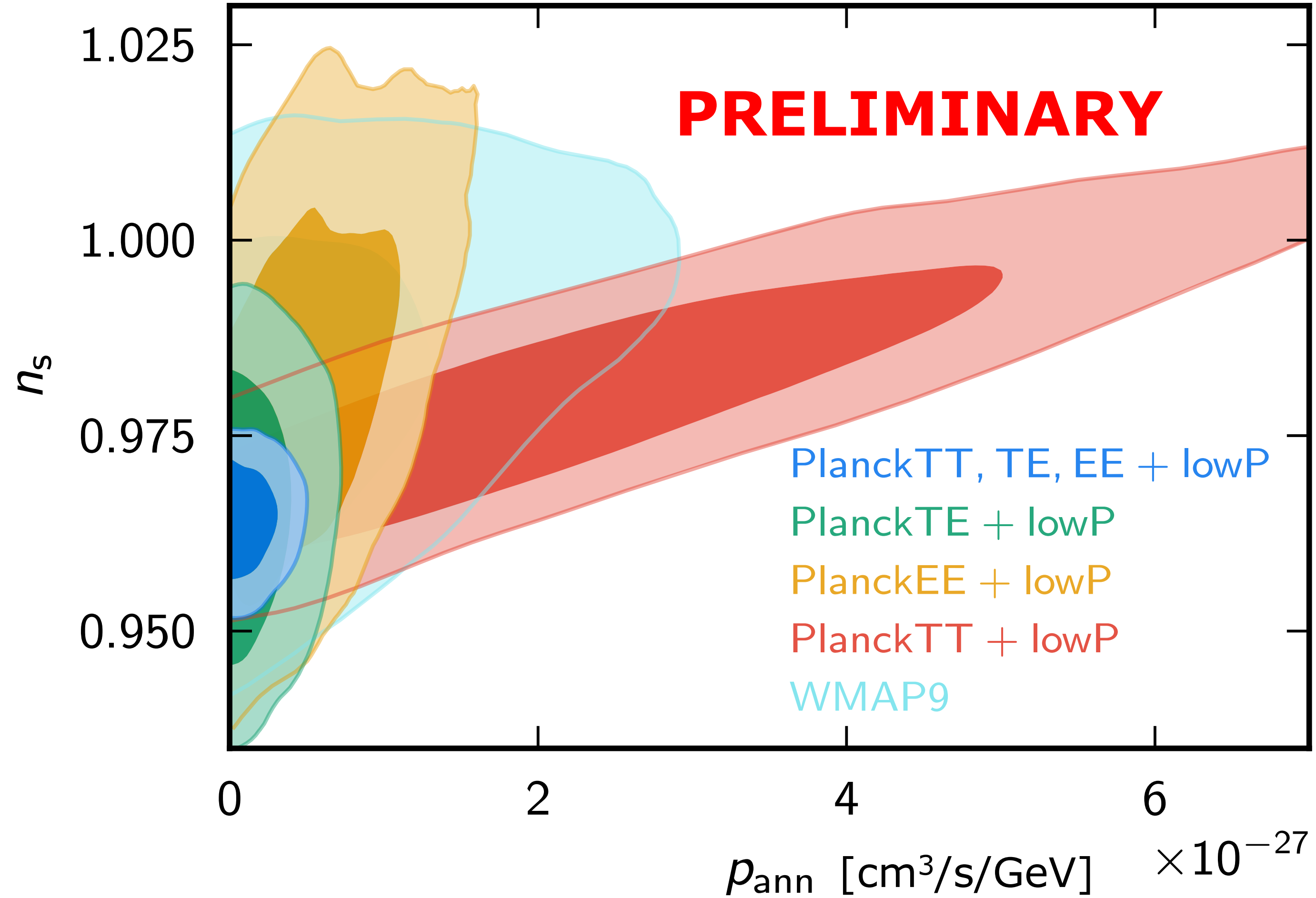
Previous Constraints



Large degeneracies in TT only data.

$$p_{ann} = f_{eff} \frac{<\sigma v>}{m_\chi}$$

Planck 2014 Constraints

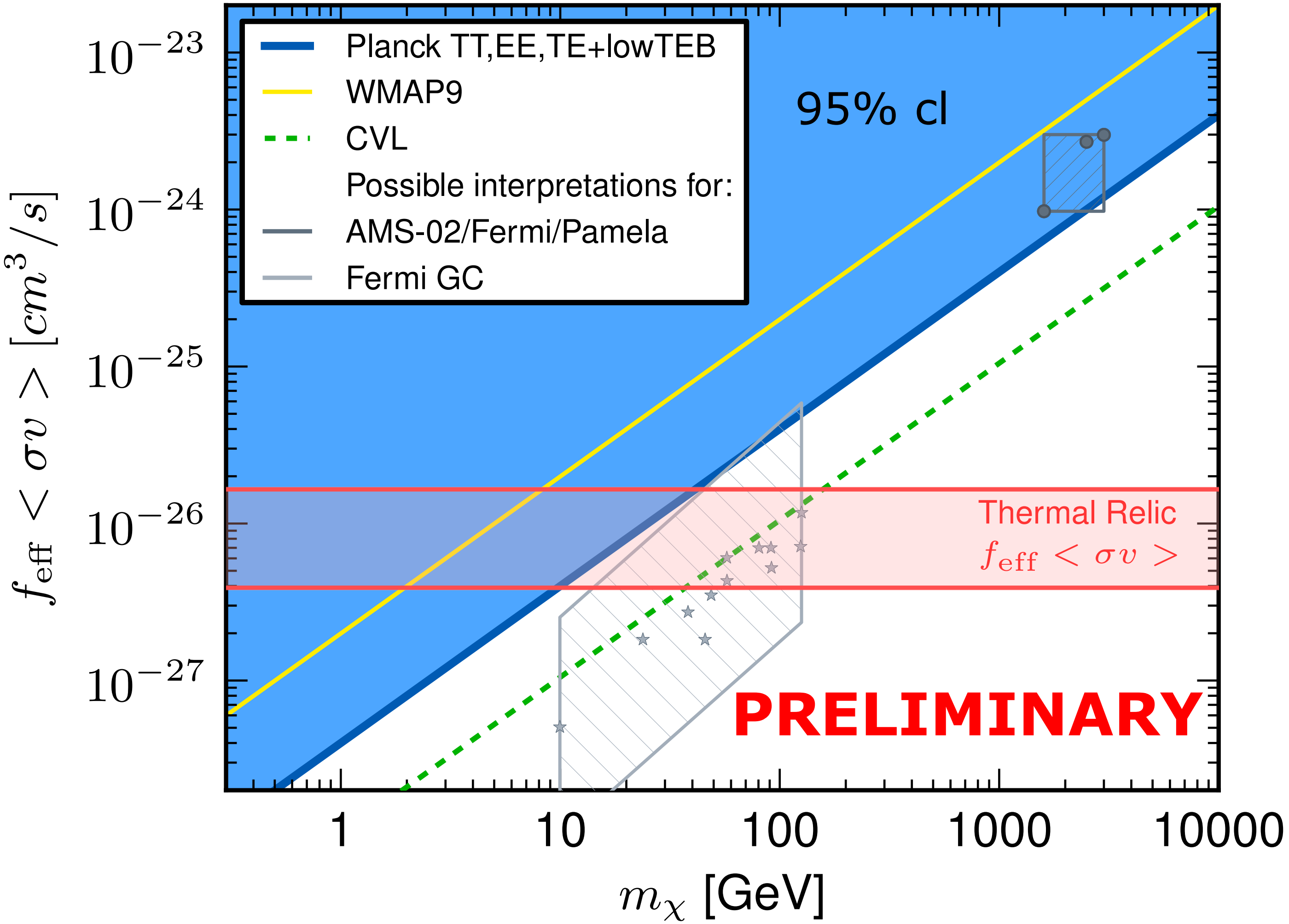


Polarization breaks degeneracies!

Planck TT,TE,EE set a constraint 5 times stronger than WMAP9, 4 times stronger than WMAP9+SPT

$$p_{ann} = f_{eff} \frac{<\sigma v>}{m_\chi}$$

Planck 2014 Constraints



$$p_{ann} = f_{eff} \frac{<\sigma v>}{m_\chi}$$

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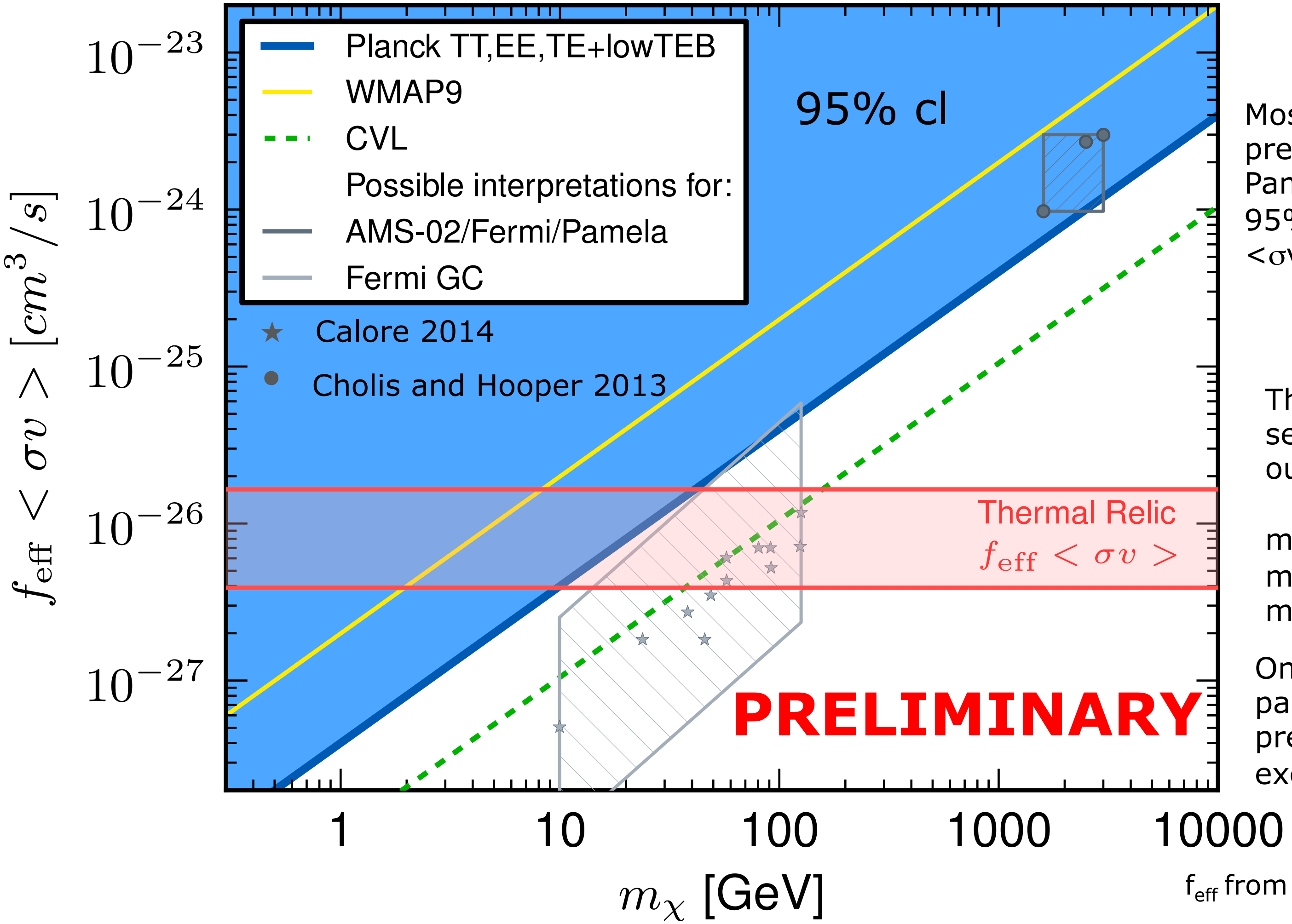
Planck 2014 Constraints



Most of parameter space preferred by AMS-02/ Pamela/Fermi ruled out at 95%, under the assumption <σv>(z=100)=<σv>(z=0)

Thermal Relic cross sections at z~1000 ruled out for:

m~<40GeV (e^-e^+)
m~<20GeV ($\mu^+\mu^-$)
m~<10 GeV ($\tau^+\tau^-$).

Only a small part of the parameter space preferred by Fermi GC is excluded

f_{eff} from T. Slatyer (Madhavacheril 2013)

Conclusions

1. Planck Polarization is a powerful probe of Dark matter annihilation.
2. We do not detect dark matter annihilation in the data.
3. The constraints exclude a thermal relic cross-section for particles of mass~<40 GeV annihilating in e^+e^-, 20 GeV in $\mu^+\mu^-$, 10 GeV in $\tau^+\tau^-$. The constraints are consistent with forecasts.
4. Planck can exclude only a very small part of the parameter space preferred by the Fermi GC excess.
5. Planck excludes most of the parameter space region preferred by the Pamela/AMS-02/Fermi cosmic-ray excess under the assumption $<\sigma v>(z=100)=<\sigma v>(z=0)$.

PRELIMINARY

The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 100 scientific institutes in Europe, the USA and Canada.

Planck is a project of the European Space Agency, with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.