

# Direct observation of interfacial exchange coupling in a magnetic tunnel junction through spin-polarized quasiparticle interference

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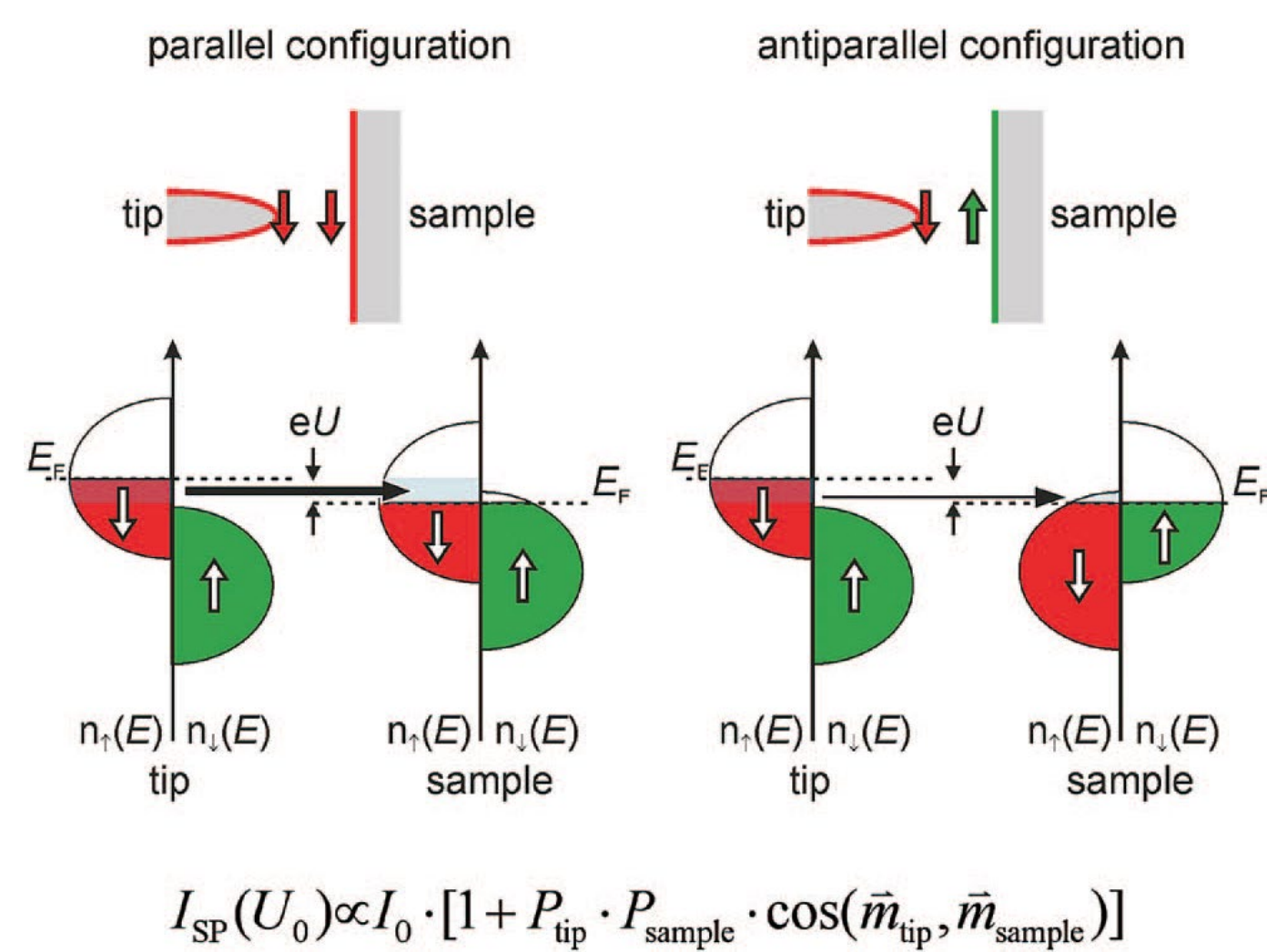
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## 1. Introduction

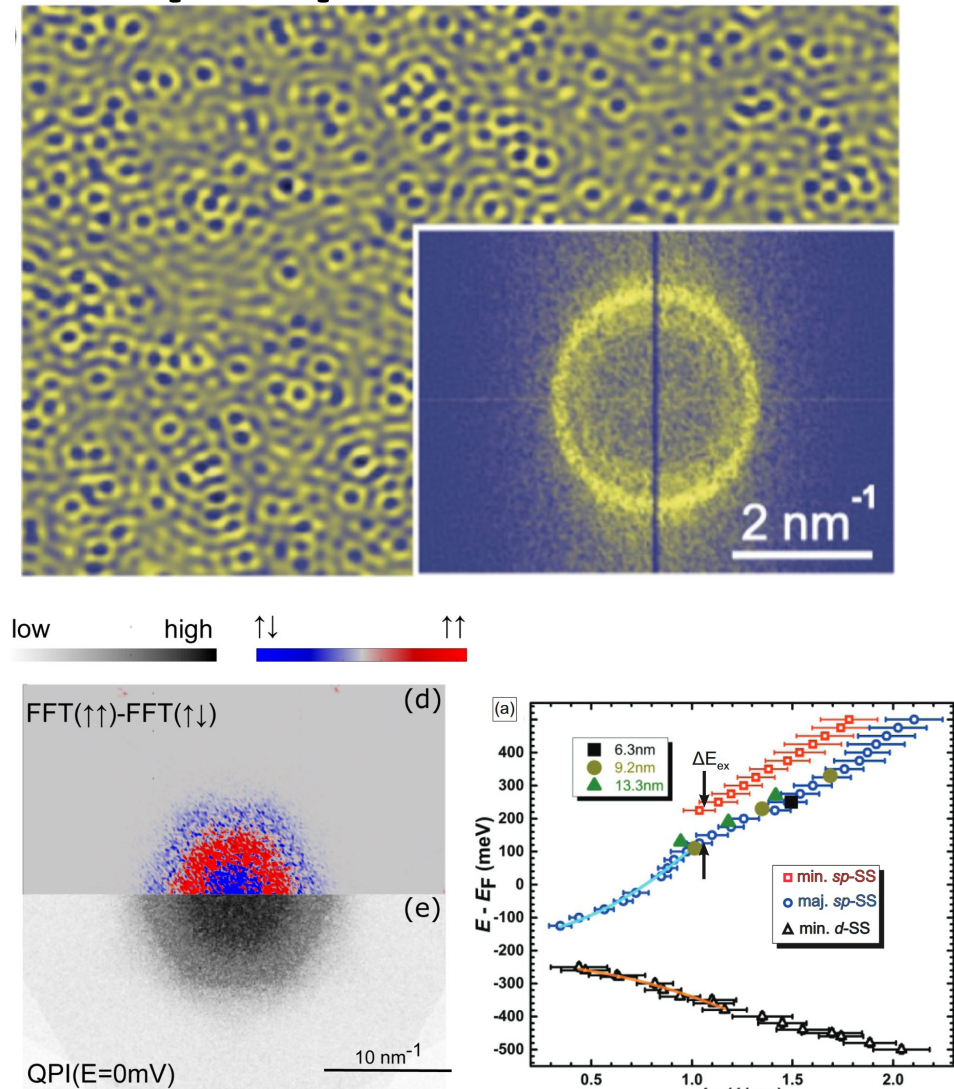
### Spin-polarized STM



$$I_{SP}(U_0) \propto I_0 \cdot [1 + P_{tip} \cdot P_{sample} \cdot \cos(\vec{m}_{tip} \cdot \vec{m}_{sample})]$$

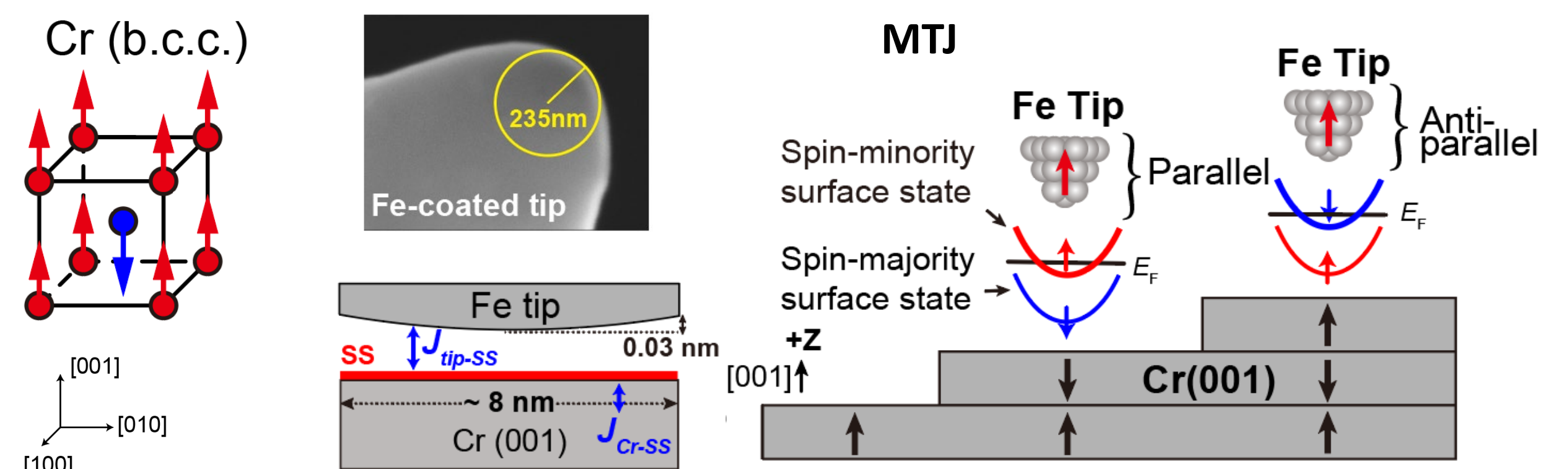
Rev. Mod. Phys. 81, 4 (2009).

### Spin-polarized QPI



Phys. Rev. B 106, L081405 (2022). Phys. Rev. B 89, 155413 (2014).

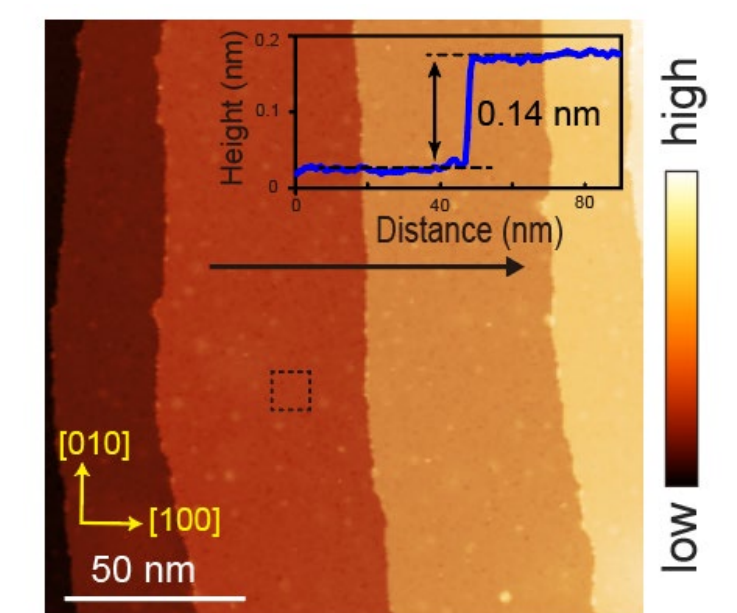
### Magnetic and electronic structure of Cr(001) surface



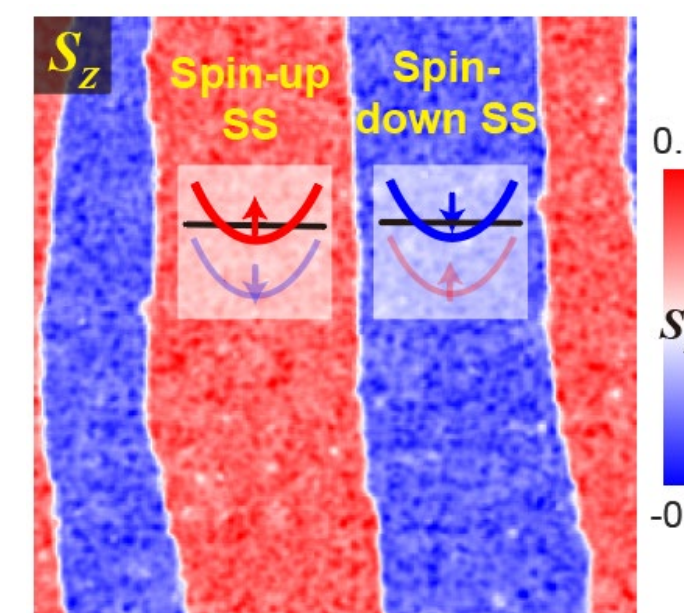
- Exchange splitting creates minority (near  $E_F$ ) and majority ( $\sim -1$  eV) spin states.
- Magnetic Tunnel Junction (MTJ) between the magnetic tip and sample surface via vacuum.
- Interfacial exchange coupling in MTJ

## 2. SP-STM characterization on Cr(001) surface

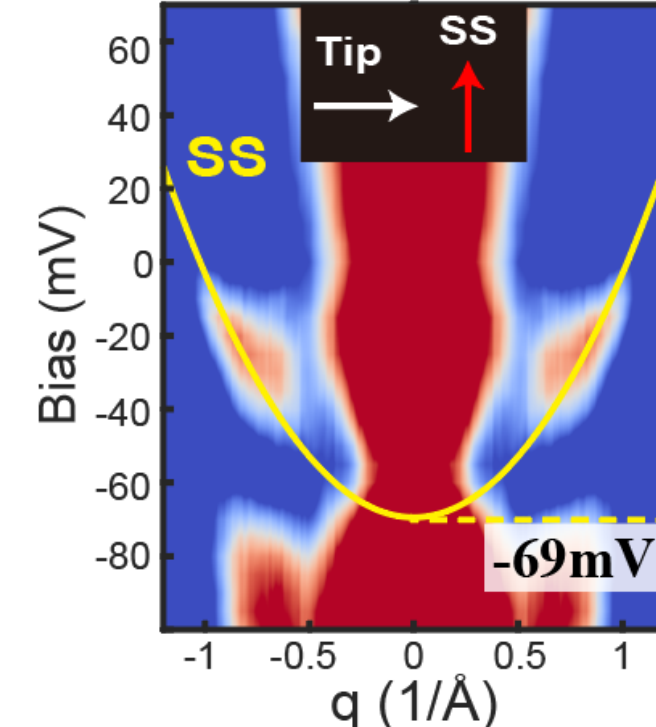
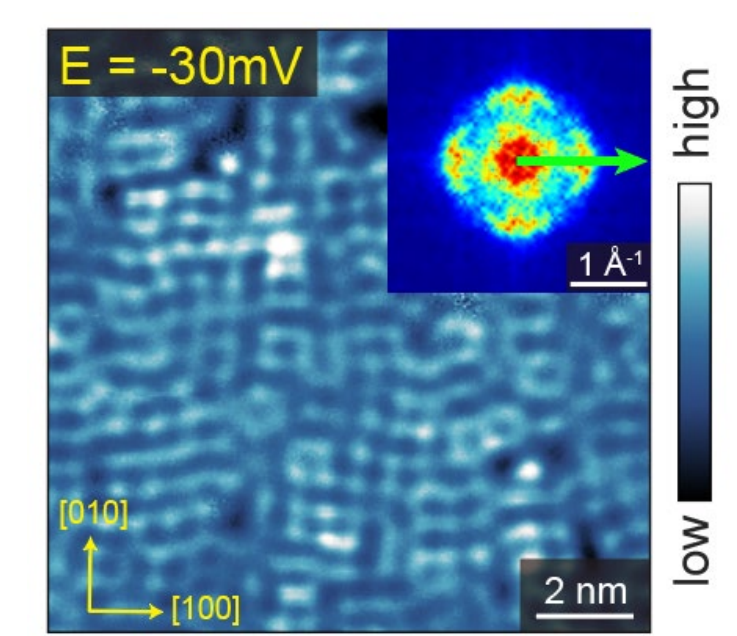
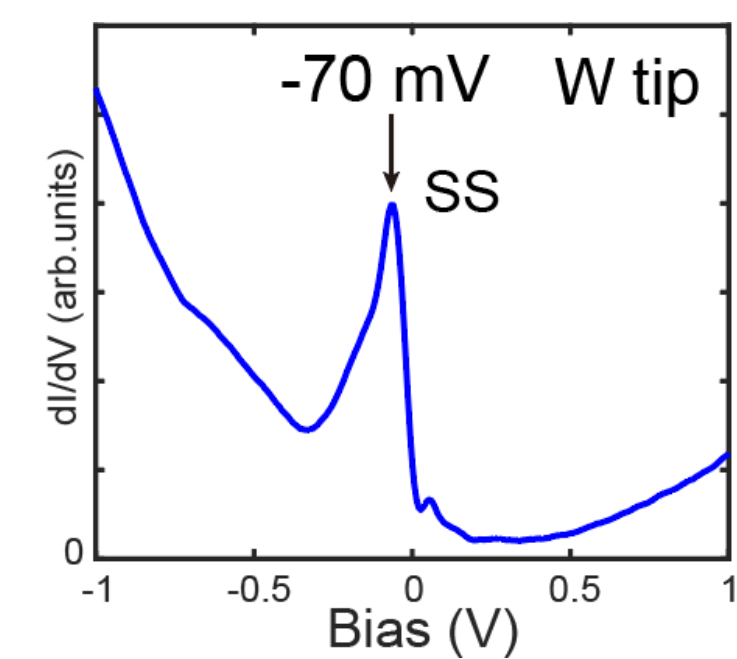
### Topography on Cr(001)



### $S_z$ -sensitive DOS map



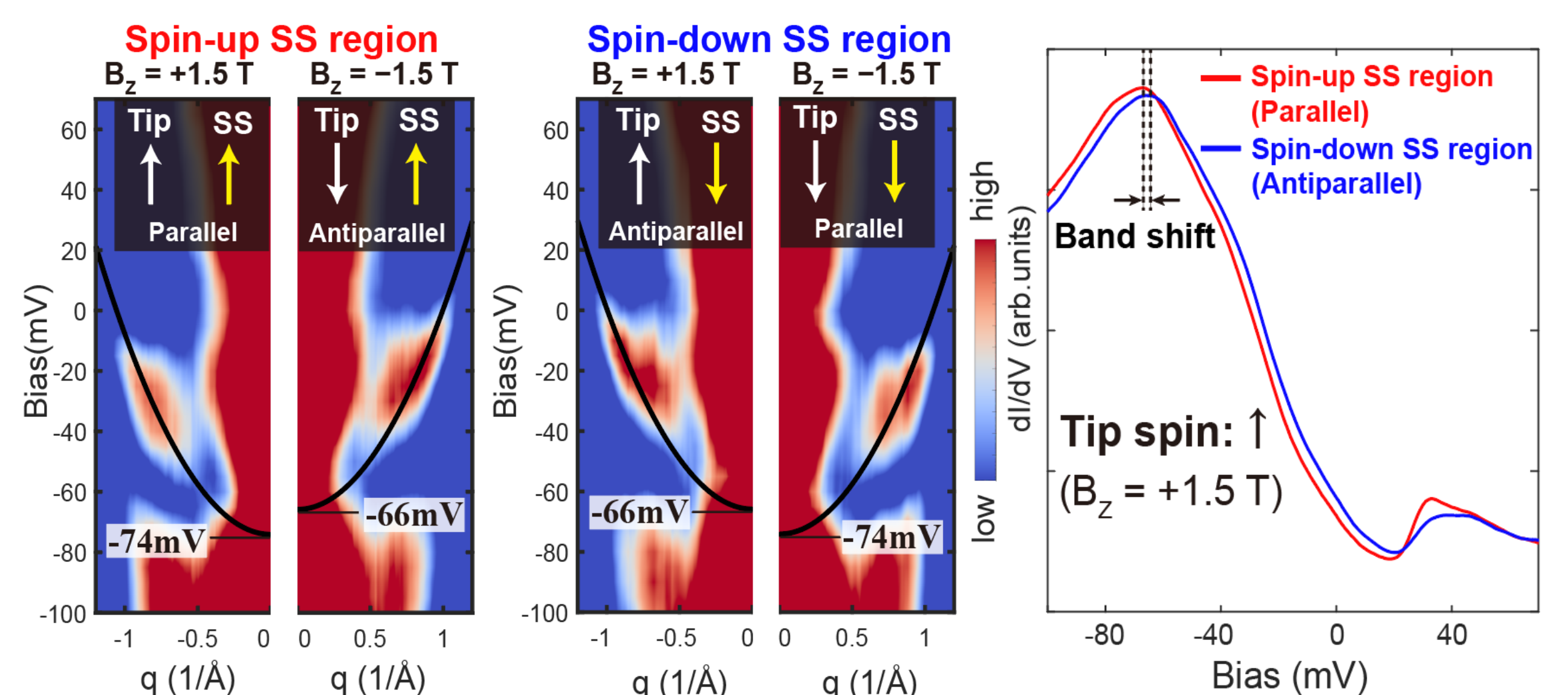
### dI/dV spectrum



- Interlayer antiferromagnetism
- Clear QPI pattern
- Surface state dispersion

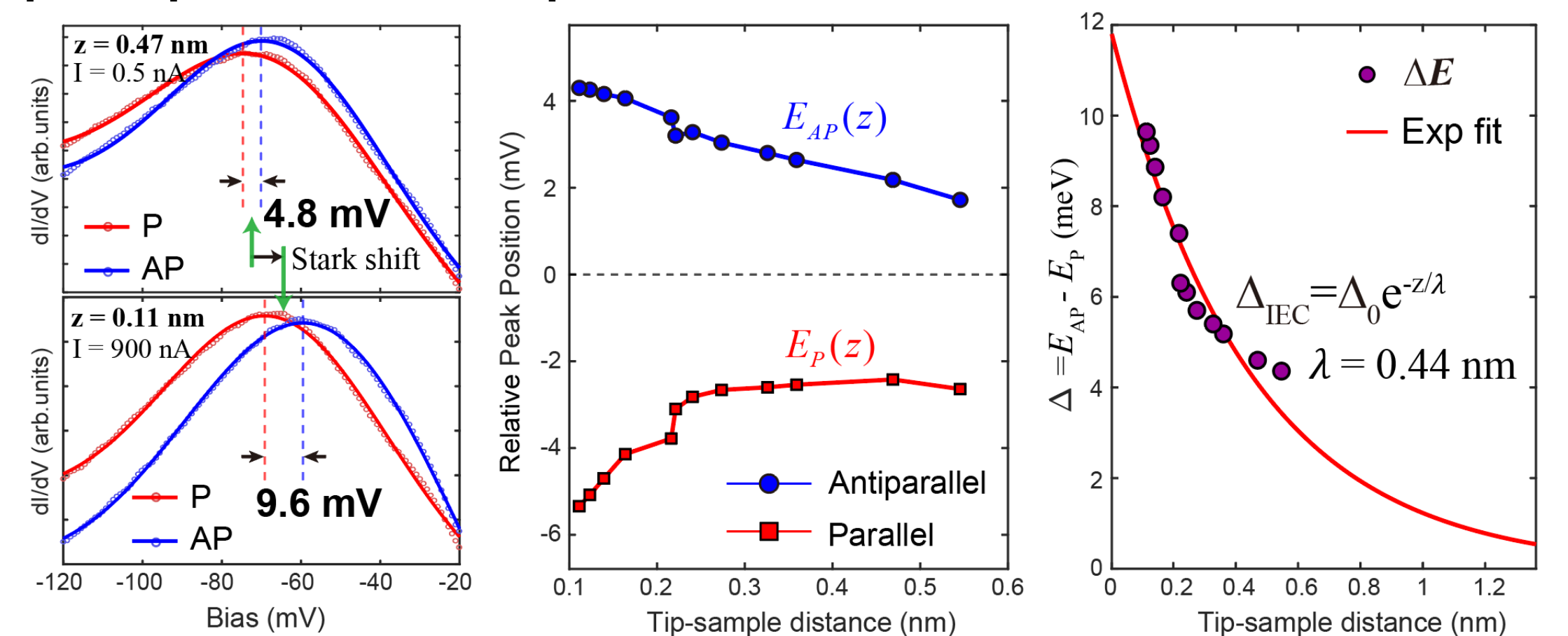
## 3. Exchange coupling within the MTJ

- QPI dispersion and dI/dV peak shift under different tip/SS spin alignments



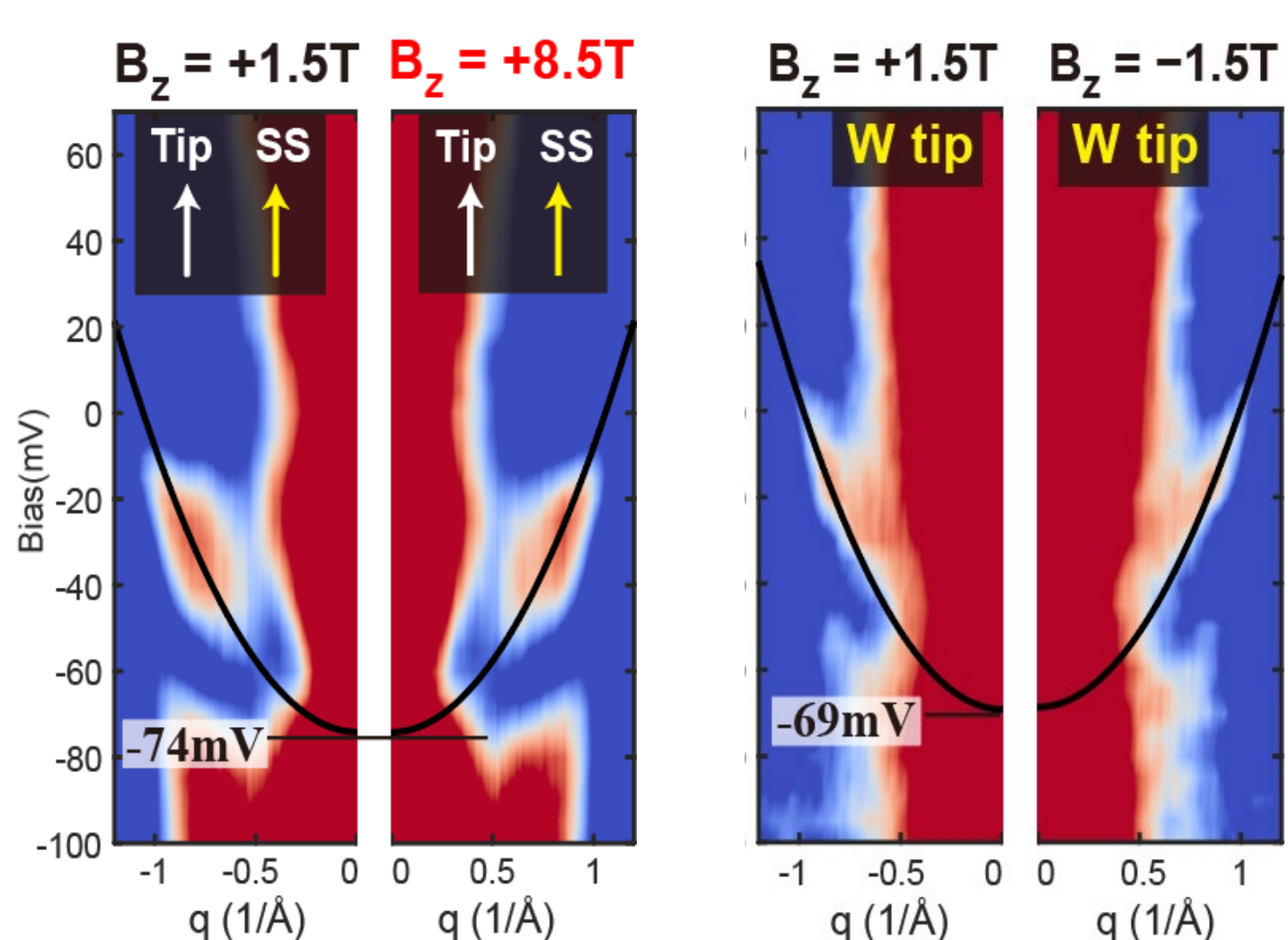
- Parallel alignment shifts the SS band downward while an antiparallel alignment shifts it upward

- Tip-samples distance dependence of surface state



- Energy shift of SP-SS increases as tip-surface distance decreases

## 4. Dependence on relative spin alignment



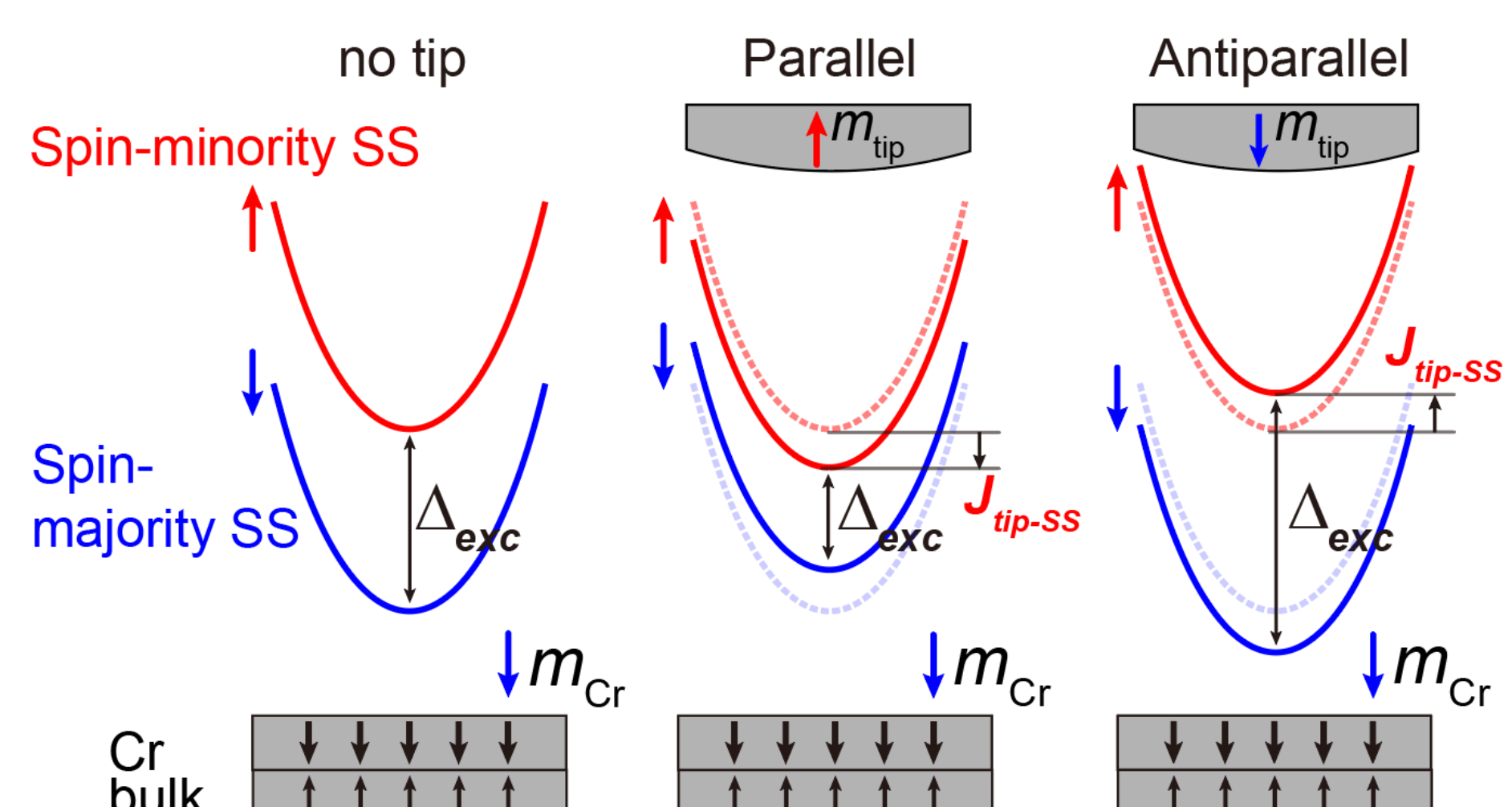
- Insensitive to external field strength
- No band shift by W tip
- Exclude Zeeman effect origin

## 6. Conclusion

Direct observation of **Interfacial exchange coupling** in a **magnetic tunnel junction** formed by an Fe-coated tip and a Cr(001) surface

- Ferromagnetic tip induces significant **energy shift** in the **spin-polarized surface state** of Cr.
- Energy shift is sensitive to the **tip-surface distance** and the **spin-alignment** between Fe tip and Cr surface, which can be **switched** by external magnetic field.

## 5. Illustration of interfacial exchange coupling



- Parallel: Fe tip weakens  $\Delta_{exc}$  and shifts the spin-minority band downward
- Antiparallel: Fe tip enhances  $\Delta_{exc}$  and shifts the spin-minority band upward